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## F 900  REHABILITATION DESIGN

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**APPENDIX A**  FORMULAE AND SAMPLE CALCULATIONS  "

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F 900 INTRODUCTION & PURPOSE OF REHABILITATION

F 901 INTRODUCTION

A significant part of the Clean Water Program funding is for construction projects that improve the hydraulic capacity and the structural integrity of the existing, deteriorated sewer system. This includes the evaluation and reduction of extraneous flows into the sewer system. This section provides guidelines and procedures that will assist in the investigation and design of sewer system rehabilitation.

F 902 PURPOSE

This section provides technical guidance for the planning and design of a rehabilitation program. It includes a description of materials and techniques used, and describes the applicability and advantages of each. Also, it outlines factors in selecting appropriate materials and techniques to solve specific problems.

This section does not attempt to cover all possible design conditions. Designing a rehabilitation project can seldom be done "by the book" because unusual conditions are the rule and not the exception. Emerging technologies are constantly being developed and should be considered when evaluating rehabilitation alternatives. The engineer should consult the Bureau's Approved Product List of established materials found at http://boe.lacity.org/apm/

The City has a sewer system, constructed from a wide variety of materials. This variability in age and type of materials rules out a formula approach to design of rehabilitation projects. Each project should be planned and designed considering the characteristics of the existing materials and the overall system it serves.
F 903 GLOSSARY OF TERMS


Bypass: A temporary arrangement of pipes and valves to route flow around a hydraulic structure or appurtenance by mechanical means (pump system).

Cracks: Crack lines visible along the pipe barrel length and/or circumference.

Debris: Soil, rock, sand, grease, roots, tiles, bricks, etc. in a sewer line excluding items mechanically attached to the line, such as protruding service connections, protruding pipe, joint materials, etc.

Defects: Insert CCTV inspection manual types of defects - insert hyperlink to CCTV manual (PDF)

Diversion: Rerouting of sewage flows within an existing structure in the system through use of stop logs or sluice gates.

Exfiltration: Leakage of flow from a sewer into surrounding ground.

Flow Control: A method whereby normal sewer flows or a portion thereof are blocked, retarded, diverted, or bypassed within certain areas of the sewer collection system.

Greenbook: This is in reference to the Standard Specification for Public Works Construction - APWA/AGC

Infiltration: The water entering a sewer system through defective pipes, pipe joints, connections, or maintenance hole walls.
Inflow: The water discharged into a sewer system, including service connections, from such sources as roof drains, cellar, yard, and area drains, foundation drains, cooling water discharges, drains from springs and swamp areas, maintenance hole covers, cross connections from storm sewers, combined sewers, catch basins, surface run-off, street washwaters, or drainage.

MSDS: The Manufacturers Safety Data Sheet (MSDS) provides information for safe and proper use of their materials.

Point (Spot) Repair: Repairing damaged pipe at specific or isolated locations.

Primary Sewers: Sewers in size 16 inches diameter or larger. Sewers with the most significant consequences in the event of failure (see F 922.4).

Rehabilitation: All aspects of upgrading the performance of existing sewer systems. Structural rehabilitation includes point (spot) repair and renewal. Hydraulic rehabilitation covers replacement, reinforcement, and flow reduction.

Renewal: Construction of a new sewer, on or off the line of an existing sewer. The basic function and capacity of the new sewer being similar to those of the old.

Secondary Sewers: Sewers in size less than 16 inches in diameter.

Replacement: Construction of a new sewer, on or off the line of an existing sewer. The function of the new sewer will incorporate that of the old, but may also include increased capacity.

Risk Score: A value assigned to a project based on a ranking system used for the purpose of project prioritization. See F960.
F 904 REHABILITATION POLICY

Rehabilitation of sewers is to be encouraged rather than replacement whenever possible. However, the following policies shall be adhered to at all times:

A. Rehabilitation shall always consider and allow replacement as an alternative except for those instances where reconstruction is impossible due to existing physical conditions or other constraint.

B. When included on the plans or in the specifications, at least two different rehabilitation processes, not including replacement, shall be listed.

C. Pipelines to be rehabilitated shall be structurally sound. Pipes with minor longitudinal cracks and/or voids shall not be considered for rehabilitation. Circumferential cracks, leaking joints and abraded and/or corroded pipe can be rehabilitated. RCP that has been abraded or corroded to the extent that reinforcing steel is exposed can be rehabilitated, provided the steel is still present and can be treated, and concrete, mortar or slurry can be used to replace the missing concrete. Pipes having steel that is extensively corroded or absent are not to be rehabilitated, but localized point repairs may be considered. In all cases the Structural Engineering Division and the Bureau of Sanitation Wastewater Collection Division shall be consulted in arriving at any decisions.
F 905 PROPRIETARY REHABILITATION METHODS

Several of the rehabilitation methods described in this chapter are proprietary. These methods are often patented and are sometimes available from a single franchise contractor or vendor only. In most cases, this precludes the existence of any competition, creating sole source products or technologies. If there is no alternate for a "sole source" item, or even if two or three alternatives are specified, bids are invariably increased by the sole source bidder.

While it is preferable to specify methods that are not sole source in order to allow for competition, allowing sole source methods will be necessary. Therefore, sole source methods may be specified when the particular method is suitable, but only if sufficient alternates are also specified.
F 910  SEWER SYSTEM INVESTIGATION

F 911  INTRODUCTION

The Bureau of Sanitation (BOS) is responsible for the operation and maintenance of the City of Los Angeles’s collection and treatment plant systems. BOS is also responsible for authorizing and funding projects to make repairs or improvements to these systems. The Wastewater Engineering Systems Division (WESD) of BOS continually evaluates the collection systems and performs advance planning. Based on their planning, studies, and inspection, WESD will issue sewer reconstruction and rehabilitation projects to the Bureau of Engineering (BOE) to design and construct the rehabilitation project. In doing so, the project enters the Wastewater Capitol Improvement Program (WCIP). The project request received by BOE is typically a Technical Memorandum, summarizing the project objective, basic information about the sewer, schedule and budget, flow data, CCTV inspection (if existing), and maps and plans. BOE is responsible for preparing a Preliminary Design Report which provides a review of the sewer, its current condition to the extent possible, associated issues related to performing the work, proposals with cost and schedule, and recommendations. For collection system related projects, they are assigned to BOE's Wastewater Conveyance Engineering Division (WCED) to determine the design approach and eventually deliver a complete project.

While the project's introduction into the WCIP was based on BOS' initial inspection, research, and study efforts, BOE-WCED may expand this initial effort as part of its Pre-design work or as a necessary element to better identify the level of rehabilitation required and/or to establish a more detailed knowledge of the financial impact of the project onto the WCIP. Where a certain sewer system is consistently showing evidence of distress and degradation, BOS-WESD may elect to by-pass the typical inspection in order to initiate/expedite the effort, and have BOE perform the inspection under its purview.

This section outlines a methodology for performing a detailed sewer investigation when deemed necessary by WCED. The specific methods employed for evaluation are discussed in Section F 920. The cursory and detailed investigation procedures are described for each activity.
F 912  IDENTIFYING AND INVESTIGATING PRIMARY SEWERS

When required, conduct a detailed investigation on each sewer identified as a qualifying primary sewer. A primary sewer is one where failure would have impact on performance elsewhere in the system or where failure would have serious economic impact on the City. Primary sewers are prioritized for a detailed investigation because these failures are difficult to deal with and tend to result in significant disruption and inconvenience to the City.

If the primary sewer is not hydraulically overloaded, the structural condition of the sewer shall then be investigated. If the structural condition of the sewer requires rehabilitation then hydraulic modeling and a detailed investigation may be required. Ultimately, a wide range of rehabilitation alternates should be considered before making final recommendations.

There are some instances where a detailed investigation is not feasible. In those instances a cursory investigation shall be made. In a cursory investigation, information is obtained from review of available data and whatever is easily accessible, without expending time or resources to develop additional data. Cursory investigations are appropriate for low priority elements of the system. However, this approach is also taken to obtain essential information as a temporary measure until the time and resources are available to do a thorough investigation. A cursory investigation shall not be substituted for a detailed investigation on a qualifying primary sewer.

A cursory investigation shall be performed when any of the following criteria are met:

A. The sewers have adequate capacity meeting performance standards,

B. There is no history of capacity deficiencies in the primary sewers now or with further area development, as presented by WESD,

C. It is expected that any needed rehabilitation method will not reduce needed capacity in the primary sewers.

D. The sewers are not categorized as primary sewers.
F 913 IDENTIFYING SYSTEMS WITH PRIMARY SEWERS

Identification of primary sewers should be done at the start of a detailed investigation. Projects not containing a primary sewer may be identified as minor/secondary -- assuming no major issues have been observed -- and shall be categorized for cursory investigation. For large projects containing more than one primary sewer, each sewer may have to be investigated on its own to better manage the investigation and model the system. In many instances, it will be obvious how to subdivide the inspection effort at the outset. However, in some instances, it is better to see their combined effect and therefore, model the total system. As such, investigate them simultaneously until the limits of the hydraulic investigation are determined.

F 914 OUTLINE OF DETAILED INVESTIGATION

A detailed investigation involves four distinct phases and it is intended to provide key information that can be incorporated into a Pre-Design Report. These are shown in Figure F 911A and are described in the subsequent subsections.

F 914.1 PLANNING AN INVESTIGATION (PHASE I)

Phase I is work pertaining to establishing an overall understanding of the sewer line(s) current performance and the significance it has toward the overall sewer system / branch it is connected.

Review Line Records: Determine if it is a primary sewer.

A. Categorize Project: Categorize the project’s sewer(s) relative to their importance to the overall system operation. This assessment shall consider what impact on the system or potential liability to the City would result if failure occurred. Detailed criteria for categorizing are given in this section.

B. Identify Project's Primary Sewers: Primary sewers are those where failure, emergency repairs, crisis response or spillage will be most expensive or disruptive, and where hydraulic failure will have serious consequence to the public or existing structures.

C. Document Performance: The collective records of stoppages, collapses, spills, crisis responses, and damages provide a reasonable picture of the a sewer’s overall performance. Typically, this information is collected and studied in detail by the
Bureau of Sanitation and tends to form the basis identifying a sewer that is potentially in need of rehabilitation. A designer may find it useful to obtain this information in order to get a more complete picture of the sewer(s) being addressed under a particular project. The extent, location, and frequency of these problems should be noted. In particular, detailed reviews of spills and collapses may point to evidence of the potential problems. In some instances, this will provide sufficient information for initiating an immediate rehabilitation and/or replacement plan through an emergency contract.

D. Detailed Investigation: A Detailed Investigation is justified whenever the primary sewers are, or are suspected to be, hydraulically overloaded or where corrosion or structural problems are possible, and where rehabilitation is constrained by insufficient capacity. Where these conditions are known not to exist, the Cursory Investigation may be selected.

E. Prioritize Detailed Investigations: The Detailed Investigation requires resources which are normally limited. To best utilize available resources prioritize the issues known and addressing the most critical problems first.

F. Provide Updated Records to BOS: Existing system maps and records should be updated where necessary to provide more accurate information to BOS on a sewer's condition for their use in future hydraulic, corrosion and structural investigations. Share the information as soon as it becomes available.

**F 914.2 CONDUCTING A DETAILED INVESTIGATION (PHASE II)**

A Detailed Investigation requires an assessment of I/I, structural condition and system hydraulics. The initial activity for assessing a sewer’s condition is closed circuit television (CCTV) viewing and/or persons inspection and survey work as discussed under hydraulics. This information should have been provided to WCED by BOS as part of their Technical Memorandum. If this information is missing, discuss with BOS if a pre-design assessment is necessary using BOS resources or through those available to WCED.
F 914.2.1 ASSESS INFILTRATION/INFLOW CONDITIONS (PHASE II-A)

Phase II-A assessment involves evaluating extraneous flows other than normal flow into the sewer system. These extraneous flows are classified as infiltration from groundwater levels and/or rainfall, and inflow from storm drainage sources, which enter the system through cracks, joints, porous walls, breaks, and voids.

A. Infiltration/Inflow Condition: The CCTV video and/or person inspection will provide information that is beneficial for determining points of extraneous flow (e.g. displaced joints, cracks, voids, and leaking, broken or illegal service connections, etc) and identify mainline and service connection problems.

B. Flow Monitoring: Records of existing measuring devices in the system may be reviewed and correlated to determine dry and wet weather flows. Where no data is available, but there exists some evidence that extraneous flows are occurring, a flow monitoring program shall be initiated. This will entail locating measuring devices at selected locations.

C. Quantifying Extraneous Flows: An analysis shall be performed to determine normal system flow. The total flows after a rainfall event include groundwater infiltration (GWI), storm water inflow (SWI) and rainfall dependent infiltration (RDI). These sources shall be quantified and subtracted from the measured flow to determine the base sanitary sewage system flow.

F 914.2.2 ASSESS STRUCTURAL CONDITION (PHASE II-B)

Phase II-B assessment involves inspection of the primary sewers and identification of needs for rehabilitation, replacement and/or future condition monitoring requirements.

A. Structural Condition: The CCTV video and/or person inspection will provide information for locating structural problems, e.g. cracks, breaks, displaced joints, missing pipe pieces, clay liners, roots, sags, corrosion, etc.

B. Evaluate Corrosion Condition: The corrosion or deterioration of a cementitious or corroducible material will continue until there is a failure. Thus, corrosion shall be identified and an assessment made of its progression, so remedial action can be taken
before failure occurs. As deemed necessary, employ the services of subject matter
experts including those of the Structural Engineering Division, Geotechnical
Engineering Division, and/or specialized consultant.

C. Quantify Problem Areas: Establish a rating system to identify the structural or
corrosion failure state, magnitude, condition and progress. (See Section F 920.)

F 914.2.3 ASSESS HYDRAULICS (PHASE II-C)

Phase II-C assessment involves the investigation of the hydraulic performance of the primary
sewer line in general and the particular areas of concern in detail, to establish their actual
performance and any needs for improvement.

A. Hydraulics: The actual flow rates the line is experiencing shall be determined.

B. Develop a Hydraulic Model: When appropriate, a hydraulic model of the line should be
developed upon which the particular sewer’s performance and needed improvements
can be based. Detailed information on selecting and verifying a hydraulic model is
readily available (EPA Models, etc.) and is not covered in this Section. Selection,
calibration, and verification of an appropriate model should be done by an engineer
experienced in this specialty. While an analytical model is primarily in mind, a scaled
physical model may be required for more complex configurations and/or flows.
Coordinate with the Bureau’s Hydraulic Lab for any modeling plans.

C. Confirm Field Conditions: The mapping and "as-built" construction drawings are
necessary input, however, invert elevations and pipe diameters should be verified in
the field to the extent possible.

D. Assess Hydraulic Performance: The model is run with a range of flow conditions to
access its hydraulic capacity.

E. Locate Areas of Performance Deficiencies: Portions of the sewer which fail to meet the
minimum required hydraulic performance criteria shall be identified, and the
deficiencies noted.

F. Assemble Data: Information obtained in the Infiltration/Inflow, Structural and
Hydraulics assessments should be incorporated into the model.
G. Identify Portions Needing Rehabilitation/Replacement: This work may entail point repair, rehabilitation, relief or parallel sewers and/or replacement.

**F 914.3 DEVELOP THE PRE-DESIGN REPORT (PHASE III)**

Phase III involves producing a set of recommendations to accomplish an over-all improvement of the sewer in question in the most cost effective way. Reflect these recommendations in the project’s Pre-Design Report (See F 970)

A. Set Priorities for each Problem: This plan allows the project to tackle the most pressing issues within funding constraints. Priorities shall be established for each specific problem based on available funding.

B. Consider Rehabilitation Options and/or Replacement: Consideration of all possible solutions to the problems shall be identified, taking into account scheduling and coordinating the work.

C. Develop Consistent Solutions to Problems: To expedite the design and construction work, a format for developing consistent solutions to the problems shall be utilized.

D. Identify Cost Effective Solutions: The objective is to identify the most cost effective combination of solutions on which the project can be based.

E. Establish System Usage Plan: When the proposed of the project has been identified, an implementation schedule shall then be prepared consistent with past similar work to serve as templates.

**F 914.4 IMPLEMENTATION: FROM PRE-DESIGN TO DESIGN (PHASE IV)**

Phase IV consists of implementing the recommendations of the pre-design report onto the design phase of the project and monitor its development to ensure the scope is appropriate or is modified as necessary.

A. Design and Construct Rehabilitation/Replacement Projects: This involves taking the individual prioritized recommendations in the pre-design report, together with the established design criteria, and developing these through detailed design and construction. The timing of this shall be coordinated with other project work in the system, updated as necessary by subsequent findings and scheduled to be
accomplished within available funds.
B. Monitor Conditions of Primary Sewers: The Infiltration/Inflow reduction and the structural condition of the primary sewers should be monitored regularly, whenever possible, to ensure that the assessed needs and priorities are being attained and continue to be adequate.

C. Adjust Hydraulic Model as Needed: The hydraulic model shall be kept updated during the design phase so it continues to represent the targeted improvements & conditions in the line. This is necessary so that the model can be used reliably in design work and to assess unforeseen changes during construction.

D. Review Pre-design Report as Needed: Updating the sewer information and records is an ongoing requirement as more is acquired during the design phase. Events or circumstances may change which may impact the planning of future projects. Such changes shall be noted on the project documents, and appropriate modifications made to the project file and contract documents.

**F 915 OUTLINE OF CURSORY INVESTIGATION**

The Cursory Investigation involves the same four phases and has similar steps as the Detailed Investigation, however, at a reduced level. These steps, shown in Figure F 911B, have generally been described in the detailed investigation.
F 920 EVALUATION METHODS AND PROCEDURES

F 921 INTRODUCTION

A complete evaluation of the sewer and related collection system facilities is necessary to understand the system and develop correct conclusions and recommendations for sewer system rehabilitation and/or improvements. The framework for carrying out a sewer investigation has been discussed in Section F 910. The approach and methods for evaluating the condition of a sewer and related collection system will be discussed in this Section as outlined below.

EVALUATION METHODS

A. Preliminary Analysis:
   1. Analysis approach
   2. Location maps and plans
   3. Sewer Basins and Sub-Basins
   4. Categorize sewers
   5. Review and evaluate existing records
   6. Flow Gauging
   7. Geotechnical Information
   8. Survey Data
   9. Environmental Clearances
  10. Street Paving
  11. Project Reservation System

B. Inspection Program:
   1. Field Inspection
   2. Physical Inspection
   3. Closed circuit television (CCTV)
   4. Laser and sonar inspection
   5. Manholes and lamping
   6. Ground surface condition
   7. Pumping stations and other structures
   8. Smoke testing
   9. Dye-water testing
  10. Infrared thermography
  11. Ground penetrating radar
  12. Groundwater monitoring
C. Flow monitoring:
   1. Design Flow
   2. System Hydraulics
   3. Sewer Flow gauging

D. Data Evaluation and Summary:
   1. Review Data
   2. Conclusions
   3. Recommendation

**F 922 PRELIMINARY ANALYSIS**

The sewer and related collection system are to be evaluated for capacity, physical condition, alignment, maintenance issues, interferences, illegal connections, reports, permits, and future development. The steps for evaluating the sewer and related collection system to determine condition are discussed in this Section. In addition to evaluating the system, the Engineer should identify and evaluate known system problems for prioritization.

**F 922.1 ANALYSIS APPROACH**

The analysis approach is to identify, locate, and review all the available data on the sewer and related collection system, such as:

A. Sewer and related collection system (Navigate LA)
B. Collection system plans and maps
C. Related plans and maps
D. Bureau of Engineering and LASAN reports and studies
E. Bureau of Sanitation (LASAN) plant and collection system records
F. Bureau of Contract Administration (BCA) construction records
G. Alignment interferences
H. Sewer flow gauging
I. Geotechnical reports and information
J. Survey data
K. Environmental clearance
L. BSS street paving schedule
The evaluation and review of a sewer and related collection system should identify system carrying capacity, flows in excess of the sewer’s capacity, condition of the pipes and related structures, and assess the severity and consequences of structural failure. The evaluation should also identify opportunities for rehabilitation or replacement of a damaged or failing facility based on the structural conditions, consequence of failure, and opportunities for capacity improvement.

**F 922.2 LOCATION MAPS AND PLANS**

The BOE NavigateLA intranet/internet application provides a good general resource with access to a wide range of City data, records, reports, and information through the use of layers, pull down menus, and interactive databases, including, but not limited to:

- Public improvements; such as: Public Right of Way, property lines, easements, street improvements, sewer and collection system (i.e. mainlines, structures, wyes, laterals, etc.), and storm water facilities (mainline, laterals, and catch basins).
- Sewer location and networks, sewer information, such as: the name of a sewer, sewer pipe sizes, sewer depth, flow direction, lateral information, stationing, node numbering, plan numbers, etc.
- Links to the BOE Vault to view and download existing indexed plans.
- Wye Maps, Substructure Maps, sewer permits.
- In Navigate LA, BSS has identified each street segment with a unique identifier, these are important with regard to street paving moratoriums and a project’s street reservations.
- Geotechnical boring locations, with links to geotechnical reports.
- Survey datum, with links to log books.
- Project and program construction holds on street, including Traffic Counts and Pavement Reports.
- City Department and Bureau records, permits, and reports.
- Access to other Department/Bureau records.

As-Built Plans (i.e Record Drawings)
- As-Built plans from the Vault, reflecting the “as-constructed” sewer.
- Recent plans will reflect Plan and Profile on the same sheet.
- Data on As-Built plans may vary from data in Navigate LA and reference obsolete Standard Plans.
- Older plans reflect the Plan and Profile on separate sheets and may not be stamped “As-Built”
- Very old plans were drawn as a roll plan, which was cut up to fit into approximate D-size sections for microfilming for the Vault and stamped “As-Built”, verify elevations, datum change in 1927; download both the Plan and Profile of the existing sewer.

BOE District Maps provide information on Public Right of Way limits, property lines, property addresses, easements, and plans for sewers, streets, and storm water facilities. Check for older historic water system pipes, such as the “Zanja Madre”, the original wood and brick water system for Los Angeles.

Sewer Wye Maps provide information on sewers; such as: design/construction plan number, pipe size and material, slope of sewer, date of construction, sewer depth at laterals, sewer depths, lateral depths, property addresses and lot numbering, Right of Way limits, property lines, easements, MH and sewer node stationing, MH rim and MH base information, MH Drop Structure information, sewer slope along the alignment, sewer information, etc. The elevations indicated on the Wye Maps are typically based on the NGVD 1929 datum with adjustments made up to 1985. However, there is the possibility that newer sewers shown on the Wye Maps
may list invert and lid elevations at MHs based on the newer NAVD 1988 datum. Keep in mind that there is no direct correlation between the two vertical datums. As such, when performing any sewer design, one needs to obtain survey information using the most current NAVD 1988 adjusted datum.

Street and Storm Drain plans include information such as: sewer depths, crossing locations, embedment of a sewer in a structure, clearances, and encasement.

CalTrans, LA County, Metro, and plans from adjacent Cities may include information about City sewers and sewer relocations performed as part of project construction work.

BCA should be contacted for construction records, such as actual wye connection locations, changes during construction, and details sometimes not included in the As-Built plans.

For recently constructed projects, the contractor can sometimes supply information and details not included in the As-Builts plans.

**F 922.3 SEWER BASINS AND SUB-BASINS**

LASAN has classified and identified the City’s collection systems by Basins and Sub-Basins, which are utilized in the project requests and Technical Memoranda. Similar to "Zip Codes" zones, the entire City of Los Angeles is broken down into geographical areas, or basins, to aid in grouping associated sewer systems for design or maintenance purposes. Basins can be further divided in to sub-basins for use in similar purpose as basins.

**F 922.4 CATEGORIZE SEWERS**

Sewer pipes are categorized as Primary and Minor (Secondary), reference Section F-910.

Primary sewers:

A. Trunk
B. Interceptor
C. Relief
D. Outfall
E. Force Main (18 inches and larger)

Minor/Secondary sewers:
A. Collector (18 inches and smaller)
B. Relief (18 inches and smaller)
C. Force Main (18 inches and smaller)
D. Local (Typically 8 inch)

F 922.5 REPORTS, RECORDS, AND STUDIES

A. Identify, locate, and review previous existing relevant BOE and LASAN program and project reports and studies.

B. LASAN, WCSD (Operations) maintains records or maintenance and operation of the collection system facilities, such as: cleaning and maintenance, flow complaints, odor complaints, blockages, bucketing, rodding, hydro-flushing, heavy roots, sand in a line, emergency sewer repair requests, capacity issues, attorney requests for information, lawsuits and other related data. It is noted that sand recovered during bucketing or hydro-flushing, or a rod becoming stuck during a cleaning operation typically is the result of an open pipe joint.

C. LASAN, WESD (Engineering and Planning), evaluates sewer flow, choke points in a collection system, prepares studies and reports related to deficiencies in the collection system and proposes projects.

D. LASAN, WESD, maintains numerous continual sewer flow gauging stations throughout the City and maintains a database.

E. BCA Project Daily Reports and Wye Sheets from the project(s) that constructed the sewer/facility (as available).

F. It is important to coordinate with the other Bureaus and Agencies with information requests and provide sufficient time for them to assist with your request.
G. Information is useful in the field investigation prioritization work.

**F 922.6 FLOW GAUGING**

LASAN maintains sewer flow gauging stations throughout the City, typically on the larger sewers, to capture flow data. LASAN also has historic flow records for sewers throughout the City. In the Technical Memorandum, sewer flow gaugings relevant to the project work are typically included. If additional flow gauging data is required, temporary flow gaugings may be requested, please refer to Section F-924.3 Sewer Flow Gauging, of this Specification.

**F 922.7 GEOTECHNICAL INFORMATION**

NavigateLA has links to some existing geotechnical data for specific locations. The Geotechnical Engineering Division (GED) has a wide range of existing geotechnical data for locations throughout the City. A request can be made to GED for existing data and reports for the project area. If excavation and shoring will part of the project work or if there is the potential for contaminated soil, it is recommended that a Geotechnical Data Report be requested. The request to GED should be made early in the project design process as it takes time to research and prepare. Review the project budget and determine the allowable budget for Geotechnical Services.

**F 922.8 SURVEY DATA**

A project survey should be requested for all projects. Although there is existing survey data available, it is not specific to a project and may not be correct. The survey will provide a basis for plan development and construction work. Survey will accurately locate Right of Way, property lines, improvements, street furniture, easements, sewer structures, MH depths and rim elevations. Forms for ordering Survey are located in the Survey’s intranet site at https://eng.insidela.org/divisions/survey/. Survey should be ordered early in the design process as it will take time and the base survey is needed for plan preparation. Review the project budget and determine the allowable budget for Survey. Coordinate with Survey on the survey datum being used; horizontal and vertical datums have been abandoned and established and adjusted throughout the years. Such is the case for NGVD29 and NAVD88 both are vertical datums that
are unrelated because they have different origins and definitions of heights and also measurements. For this reason, there is no direct relationship between the two systems. Therefore it is necessary to coordinate with Survey in determining which datum to use based on the type of sewer project. Survey benchmarks are routinely set into sewer MH frames to protect them from damage during street work, if they are on the alignment of the sewer, coordinate with Survey during construction to install offset benchmarks. After receiving the survey, review it and go to the field and verify the accuracy of the data; if questions, meet with Survey and go over the material.

When a rehabilitation project includes designing and constructing a new sewer as part of its scope, a survey request must be submitted in order to obtain existing MH invert & lid elevations along with surface improvement elevations along and/or near the alignment using the latest NAVD 1988 survey datum with the 2000 adjustment -- unless a newer datum or adjustment has been adopted. This information must then be used throughout the contract documents for both the new and existing sewers shown to ensure consistency. The goal is to void presenting survey data based on an old datum or data based on different datums.

**F 922.9 ENVIRONMENTAL CLEARANCES**

All projects require an environmental clearance. Wastewater projects require an environmental clearance on a project by project basis. The Engineer should meet with the Environmental Management Group (EMG) early in the project. EMG will provide a form to request the Environmental Clearance. It is recommended that the environmental review be requested early in the design process as it takes time to conduct.

**F 922.10 STREET PAVING**

It is necessary to coordinate the construction of a project in a public street with either the paving or slurry coating of the street in order to not be required to pay Street Damage Restoration Fees. There is a one year construction moratorium for streets that have been slurry sealed, and a five year construction moratorium for reconstructed streets. The Bureau of Street Services (BSS) in Navigate LA will list planned street paving work by block segments. Coordination should be
made with BSS regarding street paving work. Engineers are referred to the BOE TCTMC contact for coordination with the Bureau of Street Services. Please refer to Standard Plan S-477.

**F 922.11 ♦ PROJECT RESERVATION SYSTEM**

In Navigate LA, Bureau of Engineering tab, it is important that a project reservation be entered to minimize construction conflicts. The project limits are identified, project name, W.O. number and Engineer contact information. Engineers are recommended to coordinate with the Bureau of Street Services to have their project additionally listed.
F 923    INSPECTION PROGRAM

From the preliminary data review, analysis, and subsequent investigation, locations in the field should be identified for inspection/investigation for inflow, infiltration, corrosion and structural problems. Many of the field investigation methods do not provide complete information for making a decision on sewer system rehabilitation/replacement. There are many methods and procedures, and it is necessary to consider their limitations in selecting the most appropriate one from among them. The combination of two or more methods usually provides sufficient information for making a cost effective evaluation.

F 923.1    ENGINEER’S FIELD INSPECTION

A field inspection of the complete project alignment is required for all projects. During design, it is recommended that multiple field inspections be performed. Beyond the records, plans, studies, and data, a field inspection puts the information into reference. It is helpful to coordinate with LASAN and have a maintenance crew assist with opening MH structures and traffic control. Engineers going to the field must wear the appropriate personal protection equipment (PPE) for the location they are visiting, including proper footwear, safety vest, and possibly a hard hat. Engineers should always bring their City ID and business cards for identification. For field inspections or field work, it is preferable to go out in pairs -- avoid going to the field alone to the extent possible. During the field inspection, take notes, make notations on the plans, and take photos. A tape measure and measuring wheel should be brought for measuring distances and offsets; although a survey will be prepared, personal measurements are necessary. With the plan view of the sewer system as a guide, walk the complete alignment. To the extent possible, locate the MH structures, adjacent City and private improvements (i.e.: storm drain MH, cable TV boxes, DWP facilities), check for improvements such as buildings, trees, or street improvements that may interfere with work on the sewer. The area adjacent to the sewer may have developed subsequent to the design and construction of the sewer. Check for overhead obstructions which may interfere with construction such as: power poles, overhead wires, and bridges. Open the MH and verify sewer flows, note depth of sewer flow (¼, ½, ¾, overtopping the MH shelf (note: MH shelf is located at the soffit, top, of the pipe), or no flow. Note the interior bottom diameter and condition of the interior of the MH and if there are any obstructions. If there are Drop MHs in the sewer alignment, note the drop connection and if it has separated from
the wall of the MH; a common occurrence. Open storm drain MH adjacent to the sewer and review the condition. Upon request, LASAN will inspect the collection system structures and prepare a report. Note the condition of the street, traffic conditions, freeways, bus stops, rail lines, street furniture (trees, gas and water meters, bus stops, valves, etc.), condition of adjacent curbs and gutter, decorative crosswalks. Review the alignment of the sewer, the old sewer trenchline may be observable in the pavement due to settlement, look for depressions along the alignment and around MH, which may indicate a breakage in the pipe and soil washing away and possibly creating a void which can result in a collapse. Note schools, businesses, and residences which may be impacted during construction.

F923.2 PHYSICAL INSPECTION OF FACILITIES

It is necessary to inspect the interior of the sewer pipe and collection system structures and facilities to determine general condition, specific details of the constructed facility, identify issues, identify possible areas for remodeling, and identify areas requiring reconstruction. Inspection in a facility, pipe or structure, can be performed by either a physical inspection by personnel or the use of a CCTV. In addition to the basics of physical space available for inspection, health and safety concerns are present, such as air quality, high sewer flows, and personal safety due to a failing structure. Generally, such entries are considered Confined Space Entry. As such, CalOSHA Permitted Confined Space Entry regulations must be followed.

For a physical inspection by personnel entry, the pipe size or internal dimensions that permit in-pipe physical inspection/observation are as follows:

   A. For 39 inch and larger -- personnel entry inspection and CCTV
   B. For 32 inch to 39 inch -- possibly personnel entry inspection (crawler) and CCTV
   C. For 32 inch and smaller -- CCTV and lamping (mirror)

It is usually more cost effective to simply clean and pull a CCTV camera through the pipeline or a structure. There are times, however, when a physical inspection is necessary to supplement CCTV for identifying suspected problems. Sewers and collection system facilities may contain deadly gases which can harm and kill. Prior to the actual entering of a structure, the construction drawing, operations, and maintenance records for the facility are to be reviewed. LASAN, and
BCA, is to be notified prior to entering a wastewater collection system facility. LASAN personnel experienced in internal pipe inspection are available to provide direct, on the spot, interpretation of the problems. During construction, the contractor may provide specific safety training in advance of the actual inspection. During construction, the BCA Project Inspector will be working closely with the contractor’s team. Logging and photo work can be accomplished with much more reliability by experienced personnel. Inspection of a facility may require special clothing, air sampling, blowers, tethers, and escape plan. All persons entering a confined space are to have completed “Confined Space Training”. Sampling of the environment in a sewer and structure is to be made prior to the inspection and during the inspection. Site specific safety measures are to be developed and plan of operations prepared for all to review and follow. The inspection may require the Fire Department to be on site. In preparation for persons entering a collection system facility, the facility is to be cleaned and properly ventilated. The degree of cleaning needed depends on the extent of physical movement required. Proper ventilation, including gas monitoring, is a required safety precaution. Current “Confined Space” requirements regarding the number of personnel are to be followed.

**F 923.3 CLOSED CIRCUIT TELEVISION (CCTV)**

Closed Circuit Television (CCTV) Inspection is the standard method to remotely inspect the interior of a sewer, regardless of pipe size or shape, and is performed on the majority of sewers. It can be ordered and completed fairly quickly. LASAN has a program to CCTV over 800 miles of sewers throughout the City annually; the CCTV of a sewer can be requested. CCTV utilizes a tracked camera or a camera on a tether to remotely inspect the interior of the sewer, to verify the condition of the sewer, sags or joint offsets in the sewer alignment, grade breaks in a sewer reach, intrusion of roots, debris, wye locations, offset joints, breaks in alignment and grade, and missing or damaged pipe. CCTV used with continuous recording video monitoring is an excellent tool for detailed study. When the video is in high resolution color, another dimension is made available for study purposes. It is much easier to judge magnitude and degree of corrosion and location of voids behind the pipe wall with colored film. However, black and white does provide better clarity, but requires greater expertise for accurate problem interpretation.
CCTV is typically performed in low flow or dry conditions, moving downstream (with the flow). CCTV can also be performed moving upstream, referred to as a “reverse setup”; water splashes onto the camera lens. CCTV is able to stop and rotate the camera to record features on the sides of the pipe and some CCTV cameras can extend up into laterals and voids. CCTV records distance from the start of the inspection, typically starting at the edge of MH, not the center of the MH, typically a difference of two feet. To more accurately determine a sewer station, it is necessary to verify the width of the MH base and add one half the base width to the footage recorded on the CCTV. For larger diameter sewers, the CCTV camera can be located on a raft and floated downstream on a tether. For larger sewers, review the conditions of bends and curves; these tend to corrode more quickly than the straight portions.

**F 923.4 LASER AND SONAR PROFILING**

Laser and Sonar Profiling (Sonics) are two methods for the remote inspection of larger diameter sewers. Typically, the two methods are utilized together to inspect the entire section of pipe or structure, both the exposed upper portion of a pipe of structure and the lower and submerged portion of a pipe and/or structure.

Laser profiling inspection scans the interior of the pipe and/or structure and is able to assess and define the current limits of the pipe wall, the presence of voids outside the pipe wall, and can help correct inaccurate or missing information. Laser profiling also has the ability to identify the breakdown in sewer liners based on depth of substrate lost. A key in getting sound acceptable readings is to have specifications that identify the rate and/or spacing of scanning intervals. Designer should discuss objective of data collection and size of pipe with local suppliers of this technology to ensure the proper requirements are incorporated into the project.

Sonar profiling is the only available remote inspection technique not dependent on the removal or control of sewage flows in the pipe or structure. The sonar scans will define the current field limits of the pipe and/or structure for a submerged or semi-submerged pipe to identify silt build-up and damage and/or corrosion to the pipe wall or structure in fully surcharged or semi-surcharged pipes. The Sonar imaging is taken by a remotely controlled, self-propelled vehicle, which also carries a CCTV camera for use in semi-surcharged pipes. Sonar is able to inspect pipelines from 8” in diameter to in excess of 15 feet in diameter. Sonar is typically deployed on small robots such as crawlers, Remotely Operated Vehicles (ROVs), and/or on flotation
platforms which can be propelled or move with the flow. The head of the sonar, unit is a transducer which has the ability to inspect at right angles to the direction of the travel through the pipe, being able to capture a cross sectional 360 degree profile of the pipe. Sonar inspection can obtain data in one or two hours for a two mile long pipeline. One caution is that where little to no flow is present, most sonar equipment are ineffective.

Data retrieved is plotted over the original size and shape of the pipe, from record drawings, providing for graphic representation of the deterioration of the pipe, depth of flow in the sewer, and location and depth. This information is typically made available to bidders during the Bid & Award phase of a project.

**F 923.5 MAINTENANCE HOLES AND LAMPING**

Collection system structures, such as Maintenance Holes (MH) and Lamp Holes (LH) are useful in identifying and detecting problems with a sewer; such as inflow, infiltration, and structural problems in the pipeline and the structures. MH are large structures designed for entry for maintenance and operations. LH were smaller diameter vertical pipes to allow for lowering a light source down to illuminate the top portion of a large diameter sewer for inspection from an adjacent MH. Structural corrosion, concrete or steel, typically begins at the surface of a material and degrades the adjoining material. Corrosion starts at the surface of structures due to turbulence of flow which can cause erosion and/or sulfide break out, the initiator of the cycle for corrosion. Also, infiltration/inflow, cross connections, and illegal connections can be observed at the maintenance holes.

MH should be located in the field, either by field inspection, observation, or survey. The MH frame and cover, shaft, and base are to be inspected and evaluated. Verify the MH size is correct for the sewer pipe diameter. MH frame and cover are to be flush with the adjacent street surface or above surrounding grade if located in an easement. The frame and cover are to be inspected for appropriate size for the sewer and condition, with respect to current standard. LASAN is replacing undersized sewer MH frames and covers (24 and 27 inch) and replacing them with large diameter frames and covers for ease of access, requiring the removal of a section of the MH shaft down until the interior diameter is sufficient to allow the installation of the large diameter frame and cover. The MH shaft is to be inspected for condition, missing bricks or mortar, being
“out of round”, and if MH is still existing. The MH base is to be inspected for condition of the channel and base, missing brick, etc. MH steps are to be removed per the “Brown Book”; steps are to be removed and the steel drilled back and sealed with epoxy. LASAN with a request will inspect MH and prepare a report on condition and needed work.

Drop MHs are designed and constructed to address the intersection of two or more sewers either discharging into or from a MH at different elevations. If the elevation difference between two of the sewers is less than two feet, the MH channel can be sloped to address the elevation differences. If the elevation difference is over two feet, a sewer drop is to be constructed. Drop MHs are typically deep. For some older Drop MHs, the drop connection separates from the MH wall and with time and sewer flows, a void is created outside the wall of the sewer, which can result in a localized collapse of the street adjacent to the MH frame and cover. During MH inspections, if a Drop MH is encountered, review the drop connection.

Lamping a sewer utilizes the LH to observe the straightness of a pipe reach, that the line is open and flowing, and to observe corrosion at the soffit of the pipe. A light source is lowered through the opening to illuminate the pipe; previously a mirror on the end of a long pole was utilized, currently a laser reflecting at the next structure or a CCTV camera. LASAN is systematically replacing LH with MH as part of sewer projects.

F 923.6 GROUND SURFACE CONDITION

Driving and/or walking the pipeline route provides above ground information for determining certain geological or surface conditions. Features above ground which may affect the sewer system are swales, surface drainage, physical interferences, buildings, streets, ground features, types and volumes of traffic, industries contributing flow, etc. Review for settlement of the ground surface over the sewer and at MH and LH. In some cases, ground movement (landslides) may have eliminated the MH or portions of the sewer. Ground movement on hillsides may have also opened up sewer pipe joints. There is the possibility of localized ground settlement around the MH shaft after installation, “cratering”, which requires the removal and refilling of the area surrounding the structure and properly compacting.
**F 923.7  PUMPING STATIONS AND OTHER STRUCTURES**

It is necessary to check the location and condition of all reinforced concrete structures, such as pumping or lifting stations, large junctions, major drops, pressure force mains and/or receiving maintenance holes. Prior to going to the field, review plans of facilities and structures adjacent to the collection system and structures. On the west side, Venice, sewers are sometimes constructed in the soffits of storm drains, or completely exposed in the upper portion of storm drains. Some sewers have been realigned for storm drains, building construction, etc, without BOE having any knowledge.

**F 923.8  SMOKE TESTING**

Smoke testing is used to verify undocumented sewer connections, verify a sewer connection, broken pipes, locate defective sewer connection that could allow sewer gases into a building, locate RDI/I sources, roof, yard and area drains connections, cross connections between a sewer and storm drain, and broken service lines. Smoke testing for I/I can be performed when system flow monitoring indicates higher sewer flows during periods of rainfall. A non-toxic, non-staining “smoke” (usually zinc chloride mist) is forced through into a sewer MH with an air blower at the downstream (D/S) MH and the smoke discharges from where the sewer or sewer connections vent to the atmosphere, typically property roof vents. Smoke testing is ineffective when the pipeline is flowing full, groundwater is over the top of pipe, or when the pipeline has sags or water traps. Also, windy days may disperse the smoke and make detection difficult. A smoke test requires coordination. Field crews are to distribute a notice such as this (i.e. https://www.charlescountymd.gov/home/showdocument?id=384) door to door approximately 24 to 48 hours in advance. LASAN, Police, Fire, BCA, and adjacent home owners are to be notified of the scheduled smoke test day(s), with coordination prior to ordering the test. As of this revision, smoke testing is rarely performed.

**F 923.9  SEWER DYE TESTING**

Sewer dye testing is used to test for possible sources of SWI, such as area drains or catch basins suspected of being connected to the sewer pipelines, or sources of RDI indirectly contributing through the soil and pipe cracks, verify undocumented sewer connections, verify a sewer
connection, and to resolve sewage/groundwater contamination problems (working to decipher where unknown pipes and structures discharge. Sewer dye testing can be performed in conjunction with CCTV. Sewer dye can be a liquid or a tablet. The dye (Rhodamine B) is used in tablet form to minimize exposure to field personnel. Sewer dye comes in a variety of colors, is typically phosphorescent, and will stain fixtures. LASAN is notified and will coordinate with the testing. The nearest downstream MH is safely opened with the necessary traffic and personal safety measures taken. Coordination with the property owner is required for the test. The sewer cleanout on the house sewer is opened and sewer dye is inserted and water run down for a few minutes. If the property is connected to the sewer, the sewer dye will show up in the MH in a few minutes. Dye testing can be performed in coordination with and to complement smoke testing of suspect areas.

F 923.10 INFRARED THERMOGRAPHY

Infrared thermography (IRT) utilizes the ability to track differences in temperatures for locating breaks in a pipeline and voids around sewer pipelines. The benefits of IRT inspection is that it can be performed quickly, results can be shown graphically, leak locations can be identified, and thermal defects can be shown.

IRT can be utilized from above the alignment of a sewer, such as from a building, overhead equipment, or in an aircraft and focused on a pipeline alignment measuring the temperature difference in the pavement above the sewer. The use of thermography from above a street permits surveying large areas in a short time and locating problems in a non-destructive manner. It does require verifying suspect problem areas by “truth” borings. This is accomplished at a lower cost than random borings to find void areas. Infrared thermography can provide information for estimating the size and severity of the void, but not the depth below the ground. It is also more effective on shallow than deep sewers.

Another approach for the IRT is that it is placed into and run through a sewer pipe similar to a CCTV. The use of the IRT inside the sewer permits for a closer and more detailed inspection of damaged and open joints which allow for groundwater to enter the pipe. Groundwater enters sewers through open or cracked joints is typically at a lower temperature that the sewage. The temperature differential allows for the infrared thermography survey to locate the sources of
ground water infiltration, and consequently the location of the cracks and misalignment of the pipes due to subsidence. The temperature differential between the sewage and surrounding ground allows voids behind the sewer wall to be detected. The voids behind the pipe walls are due to the surrounding soil having been washed out. IRT thermo-images are able to image and evaluate the condition of the crown of a pipe, image and reveal invisible lining defects not readily revealed by traditional visual inspection using CCTV, and can identify image defects such as bubbles, wrinkling and delamination, or construction details.

**F 923.11 GROUND PENETRATING RADAR**

Ground penetrating radar has similar advantages (e.g., speed, non-disruptive, and non-destructive) to infrared thermography. Large areas can be surveyed in a relative short time to locate general problems. Other underground utilities and certain dense soils can provide some measurement interference. This method of inspection does provide the depth of the void; however, it does not provide its size or severity.

Ground penetrating radar is often used in combination with infrared thermography to provide complete information regarding the subsurface conditions.

**F 923.12 GROUNDWATER MONITORING**

Groundwater depths and normal fluctuations should be identified along pipeline alignments; typically from Geotech reports and soil borings. This information is necessary for determining groundwater infiltration and its impact on field investigations and any subsequent rehabilitation/replacement project activity. When it is know that groundwater exists or can exist in a pipeline area, it is suggested that observation wells be constructed and monitored. Ground water monitoring takes groundwater samples and tests for traces of sewage in an adjacent water sources. There are existing ground water monitoring stations/wells throughout the City of LA which can provide a record of data. If there are no existing groundwater monitoring wells near the subject sewer, groundwater monitoring wells and recording instruments will have to be installed.
F 924 SEWAGE FLOWS

Sewers are designed to collect and convey the projected ultimate sewage flows from a designated tributary area, at the time of design and construction. The City of Los Angeles has developed and grown, resulting in changes to the sewage discharges within a tributary area. Residential may have changed to office space, high density residential, commercial or manufacturing, all of which has an impact of the amount and type of sewage received. In the evaluation of a sewer for rehabilitation and/or replacement, it is necessary to understand the sewage flows, both the original design, current flows, and projected future flows.

F924.1 DESIGN FLOW

Sewers are designed and constructed to convey the tributary sewage flows for an area based on the current conditions at the time. Prior to the 1990’s, the maximum design capacity of a sewer had a depth of flow divided by the inside diameter of the pipe, (d/D), of ¾ full, with a minimum design flow velocity of 2 feet per second (fps); theoretically the minimum scouring design flow velocity needed to clear a brick. City sewer design parameters were changed in the 1990s to allow for Infiltration and Inflow (I/I) and the transmission of sewer gases. The current maximum design flow capacity of a sewer is a d/D of ½, and a minimum flow velocity of 3 fps. When sewer flows reach a depth of ½ d/D, theoretically it is time to evaluate the sewer for either upsizing to allow for more capacity or flow should be diverted through construction of a relief sewer. A d/D flow depth of ½ is referred to as “Trigger Flow”, as it is a trigger to evaluate a sewer to address flows in excess of the design maximum, Section 200.

In designing for a sewer rehabilitation for older sewers designed and constructed based on the previous criteria, meeting the current criteria without changing either the pipe diameter and pipe slope cannot be achieved; reference Manning’s equation. Sewer design is covered in Section F-200 of the Sewer Design Manual; which does allow for older sewers not conforming to the revised design standards. Although the Sewer Design Manual, Section F-200, has graphs for determining sewer flows, BOE has online programs for calculating sewer flows, as well as on the internet. Sewers should be designed to address and handle current and projected sewer flows. LASAN has Study data for flow projections.
F924.2 SYSTEM HYDRAULICS

Individual sewers interconnect to comprise a collection system. In evaluating a sewer and pipe capacity, one typically starts working downstream from a terminal sewer reach, connecting to adjacent sewer pipes of the same diameter and their flows, working downstream until the design capacity of the combined flows requires a larger diameter pipe. Based on the combined upstream design flows and physical properties of the sewer, the next larger size pipe is selected. Manning’s equation allows for more capacity if the slope of a pipe is increased. Section F-200 and F-300 of the Sewer Design Manual are referenced.

Sewers are both gravity and force main. Gravity sewer flows are typically laminar. The majority of collection system projects relate to gravity sewers. If sewer flows significantly exceed the design capacity, the sewer may surcharge and go under pressure, become a force main, which results in laterals and structures surcharging. In surcharging, deeper sewer laterals may flood the basement of properties. Force main sewers require pump stations, constant review, and maintenance. Force mains terminate into a MH, after which flow is by gravity.

The collection system network should be reviewed for locations that contribute large flows, such as pumping stations, hotels, apartment building, and industrial facilities, all of which have the ability to exceed the carrying capacity of the sewer and lead to sewage backups and spills.

In reviewing the CCTV, look at the flow patterns in the sewer, are they laminar? turbulent? are there areas where the flow patterns change? Changes in the flow patterns are indicators of issues with the pipe, such as: breaks, offset joints, changes in grade, missing pipe, sag in the pipe alignment, changes in grade, protruding pipe, debris on the invert, etc.

F924.3 SEWER FLOW GAUGING

It is necessary to have current data on sewage flows for the project sewer. Initially, evaluate the existing sewage flow data and records from LASAN. This data can be augmented with actual current flow data relevant to the sewers being evaluated. Sewer flow gauging for specific sewers can be requested, it is not feasible to gauge every sewer line. The requested flow gauging should
supplement the gauging data from the existing permanent gauging stations. The flow gauging information should be used to identify sewer flow data and to confirm any hydraulic modeling work. The sewer nodes for gauging need to be selected. Gauging locations should be selected at strategic locations within the established collection network. A collection system should be evaluated for the most appropriate and representative locations to gauge. BOE Survey performs the sewer flow gauging. A flow gauging request is to be prepared, noting the MH locations by the node identifier (SIMMS #). Sewer flow gauging should be 24 hours a day with a duration of at least one month in order to capture a good data set. The ordering, performing, and receiving of the sewer flow gauging data takes time and should be ordered early (i.e. within the first 3 months) in the design process. In the review of the flow data, identify flow patterns, times of day, large flows on a regular basis, a pump station, etc. As with all engineering data, review the flow data carefully and evaluate discrepancies in the flows that do not correlate with the observable information; such as: if the neighborhood has not changed measurably since the sewer was constructed, why are flows so high? or low? do the flows exceed the capacity of the pipe? Review the flow data in conjunction with the plan view of the sewer.

F 925 DATA EVALUATION AND SUMMARY

The evaluation process is to provide the necessary information about the existing sewer collection system in order to initiate design to provide LASAN with the requested project and to provide a complete design.

F925.1 REVIEW DATA

The evaluation of the sewer and related collection system facilities should provide sufficient information to review the existing sewer and collection system, provide a summary of current conditions, identify deficiencies and necessary repairs, identify impacts to the proposed project, availability of a street or easement for construction, identify project options with costs and schedules, and results in a project recommendation.

The review and evaluation will have reviewed historic and existing plans, studies and reports, maintenance and operations, sewer location and alignment, sewer flows, geotechnical issues and
requirements, environmental issues and clearances, street paving restrictions, permitting requirements, conflicts and issues, and reserved the street(s) for construction.

Inspection of the sewer and collection system will have identified construction interferences, physical or remote inspection of the sewer and facilities, performed a CCTV inspection and/or a Laser & Sonar inspection of the sewer, inspection of the related collection facilities, reviewed the ground surface condition of the sewer alignment, reviewed adjacent facilities, and, as required, performed a smoke test of the sewer, sewer dye test of the sewer, infrared thermography of the sewer, ground penetrating radar of the sewer alignment, and/or groundwater monitoring adjacent to the sewer.

Sewage flows tributary to the project sewer(s) will have identified existing sewer flow data and current sewer flow data. LASAN relevant flow gauging and historic data will be collected. Current relevant sewer flow gauging data will have been collected.

The LASAN project request and Technical Memorandum defines the proposed scope of work, budget, and schedule. The review and evaluation will identify issues, problems, solutions, alternatives, and a recommended project.

**F925.2 CONCLUSIONS**

The collected data should determine the guidelines for developing the project recommendations. In developing project recommendations, although one data set may determine the recommendations, typically it is a combination of data that will determine the project recommendations.

- Requirements of LASAN project request and Technical Memorandum.
- LASAN budget and schedule.
- Studies and reports provide for an understanding of prior work related to the sewer and collection system and planned work.
- Operations and maintenance reports provide information about system issues and concerns which should be addressed.
- Permitting requirements and coordination.
- Environmental review and clearances.
- Project location and site specific issues and/or access limitations such as due to sewers along easements instead of the public right-of-way or due to surface improvements.
- Review of street reservations and paving projects may determine construction schedules or needed project coordination.
- Inspection of the sewer and collection system facilities for field issues and concerns, actual sewage flows, physical condition of the pipes and structures, alignment conflicts, site conditions, geotechnical requirements.
- Evaluation of project alternatives.
- Recommendation of project, scope, budget, and schedule.

F925.3  RECOMMENDATIONS

The project recommendations are based on the requirements of the LASAN project request and Technical Memorandum, as reviewed in light of the information and data collected. Typically, there are multiple project options/alternatives. The project requirements and constraints will eliminate the majority of alternatives, resulting in a recommendation. The one basic common to all projects alternative is the “No project alternative”, which based on the project requirements will be disregarded, but is always an option. Dependent on the facility conditions, sewage flows, capacity, accessibility, construction schedule, environmental and permitting, a number of project options should be developed with costs and schedule, and the “pros” and “cons” for each, with a final recommendation proposed for the project based on supporting information.
F 930  FLOW MONITORING

F 930.1  INTRODUCTION

The objective of a flow monitoring program is to quantify the magnitude of flow occurring in the pipeline. It is also desirable to obtain flow measurements during and after a rainfall event in order to aid the design and construction efforts.

Setting a flow monitoring station requires several considerations, first of which is suitable hydraulics. Ideal sites are located in pipes displaying uniform flow with no immediate upstream or downstream pipe network changes. Sites should be reviewed for debris to ensure that the wetted area is calculated appropriately.

The objective of the data collection effort should determine the duration of monitoring. Typical installations should be performed during dry weather conditions for at least three full days. A minimum monitoring period of seven days is recommended when the magnitude of flow is anticipated to vary substantially from weekday to weekend.

By determining and interpreting these flows correctly, dry weather and wet weather flows can be quantified. Also, with representative locations of monitoring points, problem piping systems can be identified for I/I purposes.

F 930.2  FLOW MEASURING DEVICES

The following are devices used to measure flow and an assessment of their suitability:

A. Weirs have proven to be unacceptable because of clogging behind the weirs and obstructions of the weir crest.

B. Flumes normally provide accurate information. However, an expensive upstream stilling well is usually necessary. Under some conditions this can be justified.

C. Level-Only devices measure depth of flow at selected pipes through an ultrasonic sensor. Level data is provided to the requestor and a flow value can be determined using Manning’s equation and known pipe attributes as calculated per the equation below:

\[ Q = VA \]

Where:
Q = flow (cfs)
A = Area of flow (sq. ft.)
V = Velocity (ft/sec)
\[ V = \frac{1.4865^{1/2} R^{2/3}}{n} \]
S = Slope of pipeline (in ft/ft)
R = Hydraulic radius (ft) [i.e. Area/Wetted Perimeter]
n = Roughness Factor or friction factor, usually 0.014

These devices are typically installed via topside access and do not account for debris or other hydraulic irregularities. These sites can be monitored for a minimum duration of 24 hours up to a maximum duration of seven (7) days.

D. Near-time devices measure depth of flow and surface velocity at set locations throughout the collection system. The surface velocity is multiplied by a velocity multiplier to determine an average velocity. These devices utilize the continuity equation to calculate flow from the measured parameters.

\[ Q = VA \]

Where:
Q = flow (cfs)
A = Area (sq. ft.)
V = Average Velocity
(calculated from the surface velocity measurement multiplied by a site specific factor)

These devices are typically installed in large diameter. These devices collect a new data point every 15 minutes and transmit to a cloud-based server via cellular communication. The data is available for the requestor via a web-based application.

F 930.3 DETERMINING I/I FLOWS

It is necessary to determine the pipeline's base flow. Depths shall be determined during the low flow level time of the day, usually at night. The low-flow times, less the known service flows, (i.e., industry or 24 hour operations) provides the infiltration discharges. This flow can be considered groundwater and/or water supply pipeline leakage infiltration. If it is determined that groundwater does not exist in the contributing area, then the source shall be located. If it is considered to be groundwater, then observation wells at or near the pipeline shall be monitored in order to determine seasonal fluctuations.
It is possible to correlate groundwater levels with normal base flow infiltration. During rainfall
events the inflow effects are normally the cause for rapidly rising sewer levels that are initially observed. Inflow can also be excessive from low lying ground surface areas subjected to surface runoff that find their way into the pipeline system or cross connections from the drain piping network.

**F 931 DATA EVALUATION SUMMARY**

The data evaluation leads to conclusions that enable development of a systematized summary of the pipeline survey. It is necessary to identify major problems with their respective solutions and to prioritize reaches critical to these solutions in order to develop an effective plan for rehabilitation.

**F 931.1 CONCLUSIONS**

Elimination of the majority of extraneous flows or leaks may be attainable, however the following factors should be considered before adoption of such a plan:

A. Determine what a clean or unpolluted flow leak really is, e.g., subsurface drainage may be a contaminated leachate or contain toxic material washed from basement floors, or wash outs from internal leaks.

B. Determine whether more corrosive sewage and odor conditions may develop because of lowered flow when major clean extraneous sources are eliminated.

C. Determine affects of lowered or more concentrated flow on the existing bare concrete piping system.

D. Assess affect on the public of any sudden decision to eliminate extraneous sources and the associated problems of enforcement

E. Evaluate affects of the flow sources into the drainage collection system and the ultimate disposal thereof.

Cost estimates for the individual phases of the evaluation survey depend upon the actual conditions in the pipeline system. The evaluation cost items are:

A. Physical survey
B. Rainfall simulation
C. Preparatory cleaning
D. Internal inspection
E. Survey report.

The primary goal is the development of a cost-effective solution (Section F 970), but the most important factor of consideration remains the overall impact on water quality.

The elimination of an extraneous flow source appears to be the obvious engineering choice, but its removal may degrade the overall water quality in the sewer. Other means of handling the extraneous flows may have subsequent impact on the environment and public, and this should not be overlooked.

**F 931.2 RECOMMENDATIONS**

Any rehabilitation program should include guidelines for evaluating repair methods, such as:

A. The necessary pipe sizes to maintain needed capacity.

B. The maximum size/shape of pipe that can actually be installed inside the existing sewer.

C. Acceptable rehabilitation methods to solve the structural problems encountered in each reach or service area.

D. Identification of sewer reaches which cannot be rehabilitated and should be replaced.

E. Estimated costs for rehabilitation as well as replacement.

F. An outline of technical specifications for each of the rehabilitation techniques.

G. A schedule for rehabilitation or replacement that ensures taking care of the most serious problems first.

H. Size of pipe that can be installed inside the existing sewer
F 940 REHABILITATION METHODS AND MATERIALS

F 941 INTRODUCTION

The selection of rehabilitation methods and materials depends on an understanding of the specific problems to be corrected. It is also important to evaluate external as well as internal factors before a decision can be made on the methods and materials that will most effectively solve the problem.

The effects of the pipe zone soil-structure and groundwater conditions are essential considerations in the analysis of pipeline rehabilitation. Groundwater can rise and fall, creating a soil pumping action adjacent to the leaking or failing pipe. The movement of groundwater can affect the soil around the pipeline. The soil type and grain size can impact the rate of this soil pumping action and its effects on the pipeline. Soil structure and groundwater conditions also greatly influence the feasibility of certain methods or materials.

Other factors which significantly influence the choice of methods and materials are:

A. Accessibility
B. Magnitude of flows
C. Available bypassing or rerouting flows
D. Mechanism of failure or problem
E. Type and magnitude of problem
F. Rights-of-way
G. Lateral connections
H. Length, size, and shape of pipe(line)
I. Need for up-sizing

The best rehabilitation procedure chosen for a pipeline repair is the one that takes into account all of these conditions, and meets the parameters for solving the entire problem.

F 942 METHODS AND MATERIALS

The various internal and external rehabilitation methods and materials are outlined as follows:
REHABILITATION METHODS

A. Pipeline Preparation

1. Cleaning
2. Closed Circuit Television (CCTV)
3. Laser Profiling & Sonar
4. Root Control
5. Groundwater Monitoring

B. External

1. Chemical Grouting
   a. Acrylamide Base Gel

2. Cement Grouting
   a. Cement
   b. Micro-fine Cement
   c. Compaction

C. Internal

1. Chemical Grouting
   a. Acrylamide Base Gel
   b. Acrylic Base Gel
   c. Acrylate Base Gel
   d. Urethane Base Gel
   e. Urethane Base Foam

2. Lined Reinforced Shotcrete Placement

3. Lined Concrete (reinforced or unreinforced) Placement

4. Panelized Liners
   a. Fiberglass Reinforced Plastic
   b. Reinforced Plastic Mortar
   c. Polyethylene (PE)
   d. Polyvinyl Chloride (PVC)
5. Continuous Slip line Pipe
   a. Polyethylene (extruded)
   b. Polypropylene (extruded)

6. Segmented Slip line Pipe
   a. Polyethylene (external profile)
   b. Polyethylene (internal profile)
   c. Polyvinyl Chloride
   d. Reinforced Plastic Mortar
   e. Fiberglass Reinforced Plastic
   f. Ductile Iron (cement lined)
   g. Ductile Iron (polylined)
   h. Steel

7. Cured-in-Place-Pipe (CIPP)

8. Deformed Pipe
   a. Deformed HDPE
   b. Folded PVC
   c. Thermal Reduction Process

9. Spiral Wound Pipe
   a. PVC Lining System

10. Coatings and Linings

11. Mechanical Sealing Devices

12. Spot (point) Repair

13. Trenchless Replacement
   a. Pipe Bursting
   b. Micro Tunneling
c. Directional Drilling
d. Pipe Jacking; and
e. Fluid Jet Cutting


The following table lists rehabilitation options, advantages, disadvantages and diameter ranges.

**TABLE F 942A**
**PIPELINE REHABILITATION OPTIONS**

<table>
<thead>
<tr>
<th>Rehabilitation Option</th>
<th>Principal Advantages</th>
<th>Principal Disadvantages</th>
<th>Diameter Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipeline Preparation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleaning</td>
<td>Increases effective capacity May resolve localized problems</td>
<td>May be costly and cause damage May become a routine requirement</td>
<td>All</td>
</tr>
<tr>
<td>Root Removal</td>
<td>May increase effective capacity May resolve localized problems</td>
<td>May be costly Problem likely to recur</td>
<td>All</td>
</tr>
<tr>
<td>Internal Grouting</td>
<td>Seals leaking joints and minor cracks Prevents soil loss Low cost and causes minimal disruption Can reduce infiltration Can include root inhibitor</td>
<td>Infiltration may find other routes of entry Existing sewer must be structurally sound</td>
<td>All</td>
</tr>
<tr>
<td>External Grouting</td>
<td>Improves soil conditions surrounding</td>
<td>Difficult to assess effectiveness Can be costly</td>
<td>All</td>
</tr>
</tbody>
</table>
### TABLE OF 942A (cont'd)

**PIPELINE REHABILITATION OPTIONS**

<table>
<thead>
<tr>
<th>Rehabilitation Option</th>
<th>Principal Advantages</th>
<th>Principal Disadvantages</th>
<th>Diameter Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pipeline Preparation (cont’d)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Short Pipe (PE, PB, PVC, RPM, FRP, DI, Steel) | High strength-to-weight ratio  
Variety of cross section can be manufactured  
Minimal disruption | Some materials easily damaged during installation  
Larger pipes may require stage grouting  
External lateral connection | 4” to 144” |
| Cured-in-place pipe | Rapid installation  
No excavation  
Accommodates bends and minor deformation  
Maximizes capacity  
Grouting not required  
Internal lateral connection | Full bypass pumping necessary | 4” to 108” |
| Fold - Deformed Pipe | Rapid installation  
Continuous pipes  
Maximizes capacity  
No excavation  
Grouting not required  
Internal lateral connection | Limited strength compared to CIPP | 2.5” to 24” |
TABLE OF 942A (cont'd)
PIPELINE REHABILITATION OPTIONS

<table>
<thead>
<tr>
<th>Rehabilitation Option</th>
<th>Principal Advantages</th>
<th>Principal Disadvantages</th>
<th>Diameter Range</th>
</tr>
</thead>
</table>
| Swage Lining / Roll Down | Rapid installation  
Maximizes capacity  
Minimal excavation  
Grouting not required  
Internal lateral connection | Host pipe must be strong enough to resist re-expansion of pulled & squeezed down HDPE | 3” to 24” |
| Spiral Wound Liner | Can be wound into place using either an external (stationed at MH) or internal (goes through the pipe) winder. Most are fixed diameter, but some can expand to the inner pipe surface. Mainly for round pipes, although, at least one system can accommodate non-round shapes | Typically, a by-pass is required  
City of LA requires sealing of lateral connections  
Liner is considered non-structural. Some systems allow for grouting along its annular space which, as a system, can be considered structural | Varies with product, 6in. minimum to max of 120in + |
| Panelized PVC Liner | Tailor-made inside the conduit  
No excavation required  
External lateral connection  
Maximizes capacity  
Non-circular available | Joints rely on sealants  
Relies on existing pipe for support  
Required careful grouting of annulus  
Large diameter requires person entry | 36” to 120” |
| Coatings | Connections easily accommodate  
Zero / minimal excavation  
Variety of cross sections possible | Difficult to supervise  
May be labor intensive  
Control of infiltration required  
Surface Preparation required | 4” and larger |
| Mechanical Sealing | Seals leaking joints and minor cracks  
Prevents soil loss  
Low cost and causes minimal disruption  
Can reduce infiltration | Infiltration may find other routes of entry  
Existing sewer must be structurally sound  
Suitable for person entry sewers only | Person-entry only |
### TABLE OF 942A (cont'd)

**PIPELINE REHABILITATION OPTIONS**

<table>
<thead>
<tr>
<th>Rehabilitation Option</th>
<th>Principal Advantages</th>
<th>Principal Disadvantages</th>
<th>Diameter Range</th>
</tr>
</thead>
</table>
| Spot (Point) Repairs           | Deals with isolated problems                              | Requires excavation for small conduits  
May require extensive work on brick sewers                                  | All             |
| **Pipe Linings**                |                                                            |                                           |                 |
| Reinforced Shotcrete placement | Variety of cross sections possible                        | Requires person entry – may be labor intensive  
Lacks corrosion resistance                                                  | 36” and larger  |
| Concrete Placement             | Same as above                                              | Same as above                                                                            | 36” and larger  |
| Segmented Linings (Slip Lining) | High strength-to-weight ratio  
Variety of cross sections can be manufactured  
Can be installed in the wet.                      | Requires pits and jacking equipment to push pipe train.  
May require stage grouting  
Curbs may need open cut.  
Loss of cross-sect. capacity                                  | 36” and larger  |
| Continuous Pipe (Fusion-welded Polyethylene / Polybutylene / Polypropylene) | Quick insertion  
Large-radius bends accommodated  
Circular cross section only  
Insertion trench disruptive  
High loss of area in smaller sizes  
Less cost effective where deep  
External lateral connection | Circular cross section only  
Insertion trench disruptive  
High loss of area in smaller sizes  
Less cost effective where deep  
External lateral connection | 4” to 63”         |
## TABLE F 942A (cont'd)
**PIPELINE REHABILITATION OPTIONS**

<table>
<thead>
<tr>
<th>Rehabilitation Option</th>
<th>Principal Advantages</th>
<th>Principal Disadvantages</th>
<th>Diameter Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trenchless Replacement</strong></td>
<td>Can replace a variety of materials</td>
<td>Potential damage to adjacent laterals</td>
<td>4” to 20” existing pipe</td>
</tr>
<tr>
<td><strong>Pipe Bursting</strong></td>
<td>Can replace a variety of materials</td>
<td>Potential damage to adjacent laterals</td>
<td>4” to 20” existing pipe</td>
</tr>
<tr>
<td></td>
<td>Not dependent on condition of existing conduit</td>
<td>Lateral connections require disconnection</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Size for size or size increase</td>
<td>Full bypass pumping required</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Only suitable for brittle pipes</td>
<td></td>
</tr>
<tr>
<td><strong>Microtunnelling</strong></td>
<td>High groundwater heads</td>
<td>Service connections</td>
<td>6” to 36”</td>
</tr>
<tr>
<td>(Includes pipe jacking)</td>
<td>Slurry can be water</td>
<td>Bentonite slurry requires treatment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Can deal with cobbles</td>
<td>Off-line only</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Small diameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shafts</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Can excavate plain, weak concrete</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Directional Drilling</strong></td>
<td>Rapid installation</td>
<td>Surface disruption</td>
<td>2” to 48”</td>
</tr>
<tr>
<td></td>
<td>Long distances</td>
<td>Generally not suitable for gravity lines</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Can be used in tidal / surf zone and under water</td>
<td>Difficult to use in sandy / granular material</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Variety of pipe materials</td>
<td>Off-line only</td>
<td></td>
</tr>
</tbody>
</table>


### TABLE F 942A (cont'd)
**PIPELINE REHABILITATION OPTIONS**

<table>
<thead>
<tr>
<th>Rehabilitation Option</th>
<th>Principal Advantages</th>
<th>Principal Disadvantages</th>
<th>Diameter Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid Jet Cutting</td>
<td>Range of up to 400 feet Accurate steeringCapable of steering around obstructionsMinimal surface disruptionSmall self-contained equipment</td>
<td>Possibly of service damage operation difficult in sandy or granular soilsNot suitable for gravity linesOff-line only</td>
<td>2” to 14”</td>
</tr>
<tr>
<td>Conventional Replacement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open Cut</td>
<td>Removes all problems in length Traditional design</td>
<td>Expensive, particularly if deep Disruptive</td>
<td>All</td>
</tr>
<tr>
<td>Tunneling</td>
<td>Removes all problems on length Traditional designMinimizes disruption Flexibility on line / elevation</td>
<td>Usually more expensive than open cut May need expensive ancillary works Extensive Geotech Studies</td>
<td>Greater than 36”</td>
</tr>
</tbody>
</table>

Table 942 B defines size designation for circular and irregularly shaped pipelines.

### TABLE F 942 B
**PIPELINE SHAPE AND SIZE DESIGNATIONS**

<table>
<thead>
<tr>
<th>Circular shape</th>
<th>Existing Pipe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small diameter</td>
<td>15-inch and smaller</td>
</tr>
<tr>
<td>Intermediate diameter</td>
<td>16-inch to 33-inch</td>
</tr>
<tr>
<td>Large diameter</td>
<td>34-inch and larger</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Irregular shape</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Small size circumference</td>
<td>60-inch and less</td>
</tr>
<tr>
<td>Intermediate size circumference</td>
<td>61-inch to 100-inch</td>
</tr>
<tr>
<td>Large size circumference</td>
<td>101-inch and larger</td>
</tr>
</tbody>
</table>
PIPELINE PREPARATION

Prior to initiating any rehabilitation work, it is necessary to prepare the pipeline.

F 943.1 CLEANING

The purpose of cleaning is to remove debris, roots and foreign materials in preparation for rehabilitation. The degree of cleaning depends on the type(s) of rehabilitation work planned. CCTV shall be used to verify the effectiveness of the cleaning performed.

Cleaning equipment used may include a hydraulically propelled, high-velocity jet (hydrocleaner) or mechanically powered equipment. The proper equipment is usually determined in advance and normally depends on pipe type and condition and contractors means and methods. Cleaning operations similar to those used in operations and maintenance of the sewer system may be used. See F 834.

F 943.2 CLOSED CIRCUIT TELEVISION (CCTV)

After cleaning is completed, the pipeline sections are visually inspected by CCTV. The television camera shall be one specifically designed for pipeline work and shall be at the highest resolution available. The lighting for the camera must be suitable to allow a clear picture of the entire periphery of the pipe. See F 920 and Section 500 of the Brownbook, latest edition.

F 943.3 ROOT REMOVAL

Root removal from the pipeline is necessary to prepare the sewer for rehabilitation. Special attention should be given during the cleaning operation to ensure complete removal. Removal procedures usually require the use of mechanical equipment, such as rodding machines, bucket machines, winches using root cutters, porcupines and high velocity jet cleaners.

Chemical root treatment may be used for a more complete removal. However, be aware that this method is generally not done during a project's construction phase due to time constraints. Pipeline cleaning and/or root removal should not be done prior to chemical root treatment. The chemicals attack the root tips, therefore, they must be intact for proper kill of the root system. When extensive grease, root masses or debris preclude application of the chemical, some prior cleaning will be necessary. Proper chemical root treatment requires several months of exposure prior to chemical grouting of pipeline joints.
Chemical root treatment (Foaming Method) is intended to kill roots and to inhibit regrowth without damaging the trees or plants, the environment, or the wastewater treatment plant process. The chemical root treatment must be EPA registered and labeled for use in sewer pipelines. The Manufacturers Safety Data Sheet (MSDS) shall be obtained and reviewed prior to any use. The active ingredient for killing roots is usually a nonsystemic herbicide which will kill roots at low concentrations. The active ingredient must be detoxified by natural processes following its use. The common composition of such a chemical is:

<table>
<thead>
<tr>
<th>Active Ingredients</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium Methylthiocarbamate (anhydrous)</td>
<td>24.25</td>
</tr>
<tr>
<td>Dichlobenil (2, 6 - dichlorobenzonitrile)</td>
<td>1.77</td>
</tr>
<tr>
<td>Inert Ingredients:</td>
<td>73.98</td>
</tr>
</tbody>
</table>

One such chemical is a water soluble, foaming, surface-active formulation of VAPAM plus Dichlobenil, placed in the sewer in the following concentration:

<table>
<thead>
<tr>
<th>To Water</th>
<th>Add Chemical</th>
<th>Amt. Foam Produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Gal.</td>
<td>1 Qt.</td>
<td>100 Gal.</td>
</tr>
</tbody>
</table>

Sewer pipe capacity:

<table>
<thead>
<tr>
<th>Pipe Dia. (inches)</th>
<th>Foam per L.F. (Gals)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0.7</td>
</tr>
<tr>
<td>6</td>
<td>1.5</td>
</tr>
<tr>
<td>8</td>
<td>2.5</td>
</tr>
<tr>
<td>10</td>
<td>4.0</td>
</tr>
<tr>
<td>12</td>
<td>6.0</td>
</tr>
</tbody>
</table>
F 944 EXTERNAL REHABILITATION

External rehabilitation is performed by means of excavating to expose the damaged sewer and employing repair methods to restore structural integrity.

F 944.1 CHEMICAL GROUTING

Chemical grouts consist of a mixture of three or more water soluble chemicals which produce stiff gels from properly catalyzed solutions. The grouts produce a solid precipitate as opposed to cement or cement/clay grouts that consist of suspensions of solid particles in a fluid. The reaction in the solution may be either chemical or physiochemical and may involve only the constituents of the solution or these constituents reacting with other substances encountered. In the latter type, the reaction causes a decrease in fluidity and a tendency to solidify and form occlusions in channels or fill voids in the material into which the grout has been injected.

F 944.1.1 ACRYLAMIDE BASE GEL

The most widely used chemical grout for curtain walls, especially in the fine soils is acrylamide base gel. Acrylamide grout is mixed in proportions that produce stiff gels from dilute water solutions when properly reacted.

Before a successful application can be made with acrylamide grout, the following criteria shall be evaluated:

A. The desired result
B. The nature of the grout zone
C. The application equipment
D. Alternative procedures
E. The plan of injection

The grout injection plan shall include gel times to be used, quantities of acrylamide and the probable layout for grout injection points. After work starts, the work plan shall be modified based on additional information that is developed during the job.

No natural soil or rock formations has yet been found in which a gel will not form. However, the injected solution must remain in the grout zone until gelation occurs. In dry soils and in flowing groundwater, there often is a tendency for the grout to disperse. Gravity and capillary forces in dry soils disperse the grout solution and may cause the gel to be ineffective. As in pipe joint grouting, dispersion can be avoided by saturating the soil prior to grouting and by the use of very
short gel times. In soil void work, however, a dry soil mass cannot be as efficiently stabilized as a soil mass below the water table.

Dilution around the outer edges of the grout bulb may occur in wet soils when long gel times are used. The flowing groundwater distorts the normal shape of the stabilized mass and can displace it in the direction of flow.

In turbulent flow conditions, dilution can be minimized by short gel times. In open formations or in fissures, solids such as bentonite or cement may be added to the grout solution to help produce a more complete block to flowing water. Acrylamide application is most successful in saturated or partially saturated soils.

Acrylamide is used primarily to reduce leakage rather than increase strength. It does, however, improve the structural integrity indirectly by stabilizing the surrounding soil mass. Acrylamide is a toxic chemical that can be absorbed into the body through broken skin, inhalation, and swallowing. Because of this toxicity, potential hazards in handling and usage can occur if not supervised by technically qualified personnel. Acrylamide materials will be discussed in Subsection F 945.1.1.1.

F 944.2 CEMENT GROUTING

Cement grout consists of a slurry (particulate suspension) of cement and water. Materials such as sand, bentonite, or accelerators may be added. Because of its particulate nature the use of cement grout is normally restricted to fractured rock and large-grained soils, where the voids are large enough to facilitate penetration and permeation.

F 944.2.1 CEMENT

Portland cement grout can be used to form impermeable subsurface barriers but is restricted in application to medium sands or coarser materials because of the larger size of cement particles (See micro-fine cement). For purposes of filling voids and washouts adjacent to sewer pipelines, various Portland cements have been used successfully. Type III cement is often selected because of its small particle size.

A range of water cement ratios can be used depending on subsurface conditions. Strength characteristics are generally not important where grouting is primarily intended to fill voids
surrounding a buried sewer pipeline. Proper design of the water to cement ratio results in grout mixtures which are easy to mix and inject, and have strengths of 500 to 1,000 psi. Clays can be added to cement for grouting, to form gels and to prevent settlement of the cement from suspension. They do, however, have the problem of no well-defined setting time and they have a slow strength development. Because of this, they are normally not utilized in sewer rehabilitation void grouting when groundwater is present.

Portland cement grouts may also be used as a filler and accelerator in silicate grouts and may be compatibly mixed with acrylamide to improve water shutoff capabilities and injection characteristics. For extremely large void filling applications, other cements such as pozzolan and fly ash mixes can be used and are more economical than straight Portland cement and soil-cement mixtures.

**F 944.2.2 MICRO-FINE CEMENT**

Micro-fine cement consists of finely ground cement that allows it to penetrate fine sands that ordinary Portland cement cannot penetrate. Beside excellent permeability, it provides needed strength and durability with a set time of 4 to 5 hours. When combined with sodium silicate, with no organics, a 1 to 3 minute gel time can be attained for underground water control.

**F 944.2.3 COMPACTION GROUTING**

Compaction grouting is the injection of very stiff, low-slump, mortar-type grout under relatively high pressure to displace and compact soils in place. Compaction grouting acts as a radial hydraulic jack, physically displacing the soil particles and moving them closer together. The technique is used to strengthen loose, disturbed or soft soils or for control of settlement. Compaction grouting is used primarily on large pipelines applied through the pipe wall into the surrounding soil.

**F 945 INTERNAL REHABILITATION**

Internal rehabilitation methods are performed from within the pipeline, either remotely or through point entry or person entry, in order to complete the work. The various installation methods are discussed in this section.

**F 945.1 CHEMICAL GROUTING**

Chemical grouting is most commonly used to reduce infiltration. It can be used to seal
deteriorated and leaking pipe joints, service connections, open joints, maintenance holes and structures. Grouting will not provide structural repair, and is inappropriate for longitudinal or circumferential cracks, broken or crushed pipes. Although chemical grouting is normally used in small diameter pipes, intermediate and large diameter pipes can also be successfully grouted at the joints with special equipment.

Grouting of pipelines is generally accomplished using a sealing packer and CCTV camera. The packer is usually made of a hollow metal cylinder having an inflatable rubber sleeve on each end of a center band. The grout is pumped into the space created between the two inflated sleeves straddling the pipe joint. Depending upon the type of packer, the grout and the initiator solutions are mixed together, applied into this space and forced through the joint leak into the surrounding soil. The grout displaces the groundwater and fills the voids between the soil particles (Figure 945.1).

A remote CCTV is used to position the packer on the pipe joint and to inspect the joints before and after the sealing operation (See Figure F945.1). The sealing packer and CCTV are pulled by cables through a sewer section from maintenance hole to maintenance hole. In addition, air or water testing equipment is used to determine the effectiveness of the sealing.

On person entry sewers, maintenance holes and structures, leaking joints and/or walls can be injected with chemical grouts using a nozzle-type applicator (Figure 945.2).

There are several different types of chemical grouts which are categorized as either gel or foam. With each of the grouts there are a multitude of different types of additives, e.g. initiators, activators, inhibitors and various fillers. The general grout formulations are chemicals and water. When there is groundwater present, normal practice dictates that a higher concentration of chemicals are utilized due to the dilution potential. Because of soil and moisture variability, formulating the correct mixture is largely dependent on trial and error, rather than scientific principles.

The various parameters that affect the performance are:

A. Viscosity control;
B. Gel time variables
C. Influence of temperature
D. Influence of pH
E. Presence of entrained oxygen in the solution
F. Contact with particular metals
G. Influence of ultraviolet rays
H. Presence of mineral salts  
I. Velocity of groundwater flows  
J. Capabilities of placement equipment  
K. Other soils and water conditions  

The properties of the grout also vary in:  

A. appearance  
B. solubility  
C. swelling and shrinkage  
D. corrosiveness  
E. stability  
F. strength  

The various additives for grouts also affect:  

A. viscosity  
B. density  
C. color  
D. strength  
E. shrinkage  

Therefore, the environmental conditions shall be taken into consideration for proper formulation and this shall be done on a case-by-case basis.  

Another critical aspect of effective grouting is the proper operation of the equipment, i.e. the grout packer, pumps, tanks, formulation, mixing and application. The pre-mixing of the final grout mixture is conducted in two separate tanks. One is the grout tank and the other is the catalyst tank. The grout tank contains water, grout and buffer, while the catalyst tank contains water, oxidizer catalyst and at times fillers.  

F 945.1.1 CHEMICAL GEL GROUTS  

The most commonly used gel grouts are of the acrylamide, acrylic, acrylate and urethane base types. All the gels are resistant to most chemicals found in sewer pipelines. All produce a gel-soil mixture that is susceptible to shrinkage cracking. All except the urethane base gels are susceptible to dehydration. These deficiencies can be reduced by using chemical additives. In addition to the chemical differences in composition, discussed under materials, there are the
following important differences:

Acrylamide base gel is significantly more toxic than the others. (Grout toxicities are of concern only during handling and placement or installation). The non-toxic urethane base gels are EPA approved for potable water pipelines. Urethane gels use water as the catalyst, where as the other gels use other chemicals. Therefore, the urethane gels require avoiding additional water contamination for proper curing.

F 945.1.1.1 ACRYLAMIDE BASE GEL

Acrylamide grout is a mixture of three or more water soluble chemicals. The acrylamide itself is the base chemical in the mixture. The concentration of acrylamide is normally at a minimum of 10% of the total mixture weight.

Catalysts such as triethanolamine (TEA) or T+ and ammonium persulfate (AP) are part of the mixture. The T+ is normally 1%, where the AP is 0.5% of the total mixture. The catalyst percentages are increased for shortening the gel times. Also, gel times will be slower if the temperature of the grout mixture decreases, etc. A rule of thumb is that gel time is reduced by half for each 10°F increase in temperature. The controlled reaction time can be varied from about ten seconds to one hour. The desired reaction gel time is normally set faster where high or flowing groundwater is encountered to prevent dilution of the grout mix.

The catalyst T+ acts as a buffer, where the AP is a granular strong oxidizing initiator chemical. A shrinkage control agent is sometimes added to the mixture for protection against freezing temperatures or dehydrating conditions required for the gel. One or more catalyst aids are also added in order to reduce the amount of other catalysts required to achieve a specific gel time. There are chemicals available to achieve increases in compressive and tensile strengths as well as elongation properties. Potassium Ferricyanide behaves as an inhibitor and can be used to extend the gel time.

A filler such as diatomaceous earth (Celite) can be added to improve shrinkage characteristics which also shortens the gel time. Additives for external grouting are: Celite, silica flour, sawdust or bentonite for also reducing shrinkage in large void filling. The use of Portland cement for external grouting reduces the gel time, however, it forms a more rigid mass. The additives increase the viscosity, thereby reducing the penetrability of the mixture, and prevent it from being filtered out from the chemical sealant. Certain chemical additives will maintain a true
single phase chemical grout whereas particulate additives transform the grout into a two phase system. Depending upon the soil grain sizes and other conditions, the additive is normally at a proportion of 5% to 30% by weight of the mixture. Where fine soils are present, the use of fillers should be less than 5%.

The amount of water can vary for the mixture but is normally in the range of 75% to 90%. The grout mixture, without fillers, has flowability similar to water.

**F 945.1.1.2 ACrylic Base Gel**

The acrylic grouts are water solutions of acrylic resins with several types for different applications. After being mixed with catalysts a cohesive gel is formed. The set time can be closely controlled from a few seconds for flowing water condition to several hours for normal conditions.

These grouts are good for use in sewer pipe joints, maintenance holes and structures. The acrylic grouts have a viscosity similar to water prior to gelation. These grouts have a tendency to swell in water allowing a water tight sealing effect.

The standard formulation for the acrylic gel is:

A. Water (44 gal.)
B. Acrylic grout (14 gal.)
C. TEA (0.5 gal. or 1%)
D. Sodium persulfate (5 lbs.)

**F 945.1.1.3 Acrylate Base Gel**

The acrylate grouts are very similar to the aforementioned grouts and need not be discussed in detail.

The standard formulation, by weight, for the acrylate gel is:

A. Water (61%)
B. Acrylate grout (35%)
C. TEA (2%) and AP (2%) and
D. AP (2%)

In those situations where shrinkage control is paramount the suggested formulation, by weight, would be:
A. Water (56%)
B. Acrylate grout (35%)
C. TEA (2%)
D. Ethylene glycol (2%)

It should be noted that the acrylate grout is in a water solution at 40% concentration.

**F 945.1.1.4 URETHANE BASE GEL**

Urethane grout is a solution of a prepolymer which cures upon reaction with water. During the reaction the gel remains hydrophilic, i.e., it absorbs water plus holds it within a cured gel mass. Upon being cured, the resultant gel is resistant to the passage of water. Since the prepolymer is cured by water, premature contamination by other water must be avoided during application.

The formulation obviously is water sensitive and various water to grout ratios provide various strengths. The ratio needed to provide a strong gel ranges from 5:1 to 15:1, by volume. Ratio less than this will produce a foam reaction, where ratios greater will produce a weak gel.

An example formulation would involve an 8:1 ratio of compounded material for pipe joint grouting, e.g.:

- Water Side Tank:
  - Water - 40 gals. (333 lbs.)
  - Shrink Control - 10 gals. (80 lbs).
  - Celite - 50 lbs.

The normal procedure is that the water is added to a 50 gallon tank. Then the shrink control is added and thoroughly mixed. This is followed by the addition of an optional filler, e.g. Celite, with volumetric adjustments made due to tank capacity. The mixture containing filler is continuously agitated. Under application conditions 8 to 10 gallons of the mixture is combined with each gallon of urethane chemical for grouting.

**F 945.1.1.5 URETHANE BASE FOAM**

Urethane foam is used primarily to stop infiltration into maintenance holes. These leaks occur through cracks in the foundation or base (or wall), through joints formed by the base, corbel or upper frame interfaces or through pipe penetrations into the maintenance hole wall. Grout
injections are placed into predrilled holes and the grout is injected under pressure.

When cured it forms a flexible gasket or plug in the leakage path. When mixed with an equal amount of water, the grout expands and quickly cures to a tough, flexible closed-cell rubber. In some applications the material is used without premixing with water, however, it will eventually require an equal amount of water for total cure.

**F 945.2 REINFORCED SHOTCRETE PLACEMENT**

Shotcrete is the application of concrete or mortar conveyed through a hose and pneumatically projected at high velocity onto a surface. Shotcrete includes both the wet and dry mix processes, but the term "Shotcrete" usually refers to the wet process, whereas the dry mix process has come to be commonly referred to as "Gunité". Shotcrete and Gunité linings can provide structural strength and improved hydraulic performance, with some improvement in corrosion resistance. See Figures F 945.2 and F 945.3.

Shotcrete and Gunité linings are used in large diameter (42 inch and larger) sewers. These linings can also be used in maintenance holes and other structures. Shotcrete walls are normally three or four inches in thickness (Figure 945.3). The sewer must be thoroughly cleaned and dewatered prior to rehabilitation. This can be done either through flow diversion or via a bypass system.

The shotcrete processes, are similar in materials use and generally utilize steel or mesh for reinforcing purposes. Also, various latex polymers can be added for improved bond strength, reduced absorption and permeability and increased chemical resistance.

**Table F 945.2A**

Typical Shotcrete and Gunité Mixes

<table>
<thead>
<tr>
<th>Wet Mix (Shotcrete) Design</th>
<th>Quantity per cubic yard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement (Type I, II, or V)</td>
<td>750 lbs.</td>
</tr>
<tr>
<td>3/8&quot; Pea Gravel</td>
<td>800 lbs.</td>
</tr>
<tr>
<td>Concrete Sand</td>
<td>2,040 lbs.</td>
</tr>
<tr>
<td>Super plasticizer (Optional)</td>
<td>Standard dosage</td>
</tr>
<tr>
<td>A. E. A.</td>
<td>As required for 4-7% air</td>
</tr>
<tr>
<td>Liquid Accelerator (Optional)</td>
<td>3-5% by weight of cement</td>
</tr>
<tr>
<td>Water</td>
<td>286 lbs.</td>
</tr>
</tbody>
</table>
Table F 945.2B
Dry Mix (Gunite) Design

1 part Cement (Type I, II, or V)
3 to 4 1/2 parts Concrete Sand
Accelerator/Admixture (Optional)
Maximum 4 gallons of water

A comparison of wet and dry mix shotcrete:

Table F 945.2C
Comparison of Shotcrete (Wet Mix) and Gunite (Dry Mix)

<table>
<thead>
<tr>
<th></th>
<th>Shotcrete</th>
<th>Gunite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rebound</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Dust</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Compound Air Required</td>
<td>Lower</td>
<td>Higher</td>
</tr>
<tr>
<td>W/C Ratio Control</td>
<td>Support Crew</td>
<td>Nozzleman</td>
</tr>
<tr>
<td>Volume Rate</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Nozzleman Skill Required</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Compressive Strength</td>
<td>Lower</td>
<td>Higher</td>
</tr>
<tr>
<td>Mix Design</td>
<td>Flexible</td>
<td>Less Flexible</td>
</tr>
<tr>
<td>Small Volume Work</td>
<td>Poor</td>
<td>Good</td>
</tr>
</tbody>
</table>

Shotcrete that can be placed with not more than 3 to 3 1/2 gallons of water per sack of cement will possess high density and have less shrinkage. Shotcrete can have twice the in-place density or strength as poured or hand-placed structural concrete.

Due to the extremely high density and low permeability of well-placed shotcrete, the penetration of water is held to a minimum. Shotcrete is usually more chemically resistant to acids than ordinary concrete. The percentage of voids can be less than one-half that of poured concrete, and water absorption is somewhat less than five percent. Nevertheless, a supplemental lining system is required to ensure total corrosion protection of the cementitious substrate. Various panelized liners systems can be incorporated onto the finished cement but do require much effort and planning. Instead, the most cost effective corrosion protection systems tend to be PVC post-installed liner sheets.
Rehabilitating with lined reinforced or nonreinforced concrete is an effective method for a variety of conduit shapes, particularly for non-round configurations. The slip form or fixed form construction practices are utilized for concrete placement. This method is used in large diameter (48 inch and larger) sewers with adequate access where materials can be handled effectively and forms can be mobilized. The sewer must be thoroughly cleaned and dewatered prior to rehabilitation.

**F 945.3.1 SURFACE PREPARATION**

To eliminate contamination of the new concrete and improve the interaction between the remaining portion of the host pipe and new concrete liner, the existing concrete surface must be effectively cleaned. Past projects have used high pressure water blasting to sandblasting. Use caution when the host pipe is a brick sewer. These sewers tend to have limited strength and the use of aggressive cleaning could result in severe damage or instability of the sewer. In such cases, one may consider using a general pressure washer plus the application and removal of a non-toxic acid neutralizer. See BOE Specification Section 03314, "Surface Cleaning and Preparation" for concrete sewers and Section 02590, "Cleaning of Brick Host Pipe" for additional guidance.

**F 945.3.2 REINFORCEMENT & THICKNESS**

A structurally reinforced or nonreinforced concrete can be designed for rehabilitation of an existing pipeline. The new concrete wall can be varied in thickness, depending upon the design. Typically, the structural condition of the existing conduit determines whether or not steel reinforcing is required. However, the initial design approach should be to use unreinforced concrete. This simplifies the installation and eliminates the potential for rebar corrosion. However, the resulting thickness is greater than for a reinforced liner, for pre-design purposes assume a thickness of 4 to 6 inches. When the resulting thickness cannot be accommodated, a reinforced option may be considered. Reinforcement may be needed for non-360 degree liner such as to anchor an arch infill or if multiple concrete lifts are used resulting in a cold joint at the maximum flexural stress area. Reinforcing steel can be single or multiple layers of welded wire mesh or hand-placed cages attached to the existing pipe wall by threaded inserts. When used, the designed steel reinforcement is affixed to the existing pipe. Where steel corrosion is a concern, the use of epoxy coated bars or even stainless steel bars should be considered. Discuss this issue with the project's Structural Engineer to ensure any cost increases are captured. For pre-design purposes, assume a thickness of 2.5 to 4 inches.

**F 945.3.3 SPECIALIZED FORMWORK**
The forms are positioned providing the desired finished wall section prior to the concrete being poured. Modern forms tend to be of steel, collapsible, and either self-motorized or moved using an auxiliary form carrier that moves the form along the alignment. While these forms tend to be part of the Contractor's "Means and Methods", one should specify the minimum length of form required to coincide with the target pour length per day, location of permissible longitudinal and circumferential construction joints, pressure gages, and acceptable tolerance level. In addition, where curves exist along the alignment, short special steel forms, reinforced reduced wall thicknesses, timber forms, or other means of accommodating these curvilinear surfaces must be identified. Also, be aware that existing casted sewers where the as-built show a uniform arc, the actual construction may be composed of segmented straight chords which may affect form travel and placement as well as final liner thickness. A laser & sonar survey is recommended when using these forms to ensure accurate up-to-date information of the sewer's dimension, radius, etc, is known, accounted for in the design, and is shared with the bidders.

F 945.3.4   PROTECTIVE LINING

Various panelized liners and liner sheets can be incorporated into the forming for total corrosion protection. Means of ensuring these corrosion preventive liners are properly set, jointed, absent of wrinkles, and sealed around grout ports, must be provided by the form. In addition, any proposed protective liner must be able to accommodate construction joints, curved alignments, and transitions to maintenance holes, appurtenances, or reducing/increasing segments along the alignment.

F 945.3.5   CONCRETE MIX DESIGN

The concrete mix can also be varied and various additives and cements can be utilized. Due to internal casting and limited work space, it is common to use self-consolidating concrete (SCC). These mixes are by nature quite flowable and avoids having to vibrate in tight spaces. Proper testing should be perform when using SCC to ensure proper filling of form. See BOE Specification Section 03314 and 03316 for working examples of how to specify SCC for sewer environments.

F 945.4   PANELIZED LINERS

Panelized or segmented liners can be manufactured in virtually any shape and length from a number of different types of materials, discussed below. These liners can be installed in one or several segments, or in one sheet circumferentially and joined together longitudinally. This work is generally accomplished in a dry sewer; therefore, bypassing of sewage is required. The most effective use of these panelized liners are when incorporated as part of a concrete pour, or when
non-shrink structural grout is pumped behind them.

Segmented liners manufactured from a wide assortment of materials have varying resistance to corrosion. These liners can be incorporated with concrete placement or pressure grout can be applied after their erection.

Because of the increased number of joints, generous effort should be dedicated to the evaluation of their material, configuration, durability, strength, and ease & assurance of proper jointing, when approving these products.

As with all sanitary products, panelized/segmented liners must be pre-approved by the Engineer of Design, prior to its use. Such approval typically involves the successful passing of applicable testing, including the City's chemical resistance test.

### 945.4.1 FIBERGLASS REINFORCED CEMENT

These products were introduced in Europe for rehabilitating their sewers. One must note that most of their sewers are combined systems of sewer and stormwater. While panels were being introduced in the late 80's with the use of alkali-resistant (AR) glass, no known GFRC panel manufacturer for use in sewer environment is known today. Also, there are no known examples of panels successfully passing the City's chemical resistance test. While it is listed here for information only as it may appear in some older As-built, it is not approved for use.

### 945.4.2 FIBERGLASS REINFORCED PLASTIC

Fiberglass reinforced plastic (FRP) liners are prefabricated thin panels designed for large diameter (42 inch and larger) sewers. After the existing pipeline is thoroughly cleaned and dewatered the segments are provided in variable lengths which overlap at circumferential and longitudinal joints. They are corrosion resistant and generally impermeable to the sewage fluid and gases.

This method provides flexibility to accommodate variations in grade, slopes, cross-sections and deterioration. The linings are not designed to support earth loads, however, they are effective in maintaining the existing pipe's remaining structural integrity. The initial interior smooth surface can improve hydraulic capacity; however, long term affect is currently unknown. Although the segmented sections are lightweight and easy to handle, the installation is labor-intensive and slow.

The FRP liners are normally one-half inch in thickness, but can vary. These liners are composed of thermosetting plastic resin and chopped, fiberglass rovings. The fiberglass must have a
surface finish that is compatible with the type of resin employed. The fiberglass reinforcement is of the acid corrosion resistant variety ("E" type glass). The resins employed are normally, Bisphenol A, vinylester or isophthalic, acid resistant types. These liners are highly resistant to abrasion with negligible absorption and permeability features.

945.4.3 REINFORCED PLASTIC MORTAR

Reinforced plastic mortar (RPM) liners are thicker segments, corrosion resistant, and are assembled within a dry sewer. Their weight is approximately 2/3 to 3/4 of conventional concrete.

The primary difference between FRP and RPM liners is the addition of a fine sand/resin mortar in the matrix, for RPM. The same resin/fiberglass designs are used, however, a sand free inner surface must be provided due to its inherent corrosion resistance shortcomings. Generally, a vinyl ester inner layer is used due to its ability to successfully pass the City's chemical resistance test.

F 945.4.4 POLYETHYLENE (PE)

Polyethylene (PE) panels are no longer as common but different products appear on occasion. They are still seen in systems used for maintenance hole rehabilitation, but not as often for mainline sewer rehab. This is not to be confused with PE sheets that are placed on a form and casted with the concrete behind it. As with all panelized systems, one must have a clear understanding of the joints' durability. Also, these systems are not as rigid as the prior mentioned. As such, its anticipated that some type of bracing and/or forming may be required. See discussion on Coil Profile Strip System for additional information.

F 945.4.5 POLYVINYL CHLORIDE (PVC)

Polyvinyl Chloride (PVC) panels are also somewhat rare. As with PE, they are more seen in maintenance hole rehab systems. Besides placing similar considerations as all other panelized systems, PVC has a lower temperature limit than the others. As such, care must be taken to ensure high strength/early strength concrete's heat of hydration does not destabilize the system.

F 945.4.6 STEEL

Welded steel pipe liners are made by butt or offset butt electrically welded straight or spiral seam cylinders, fabricated from plates or sheets. The plates or sheets comply with the physical and chemical requirements of ASTM A-570, or to ASTM A-283. The wall thickness will be
determined by the design but will usually be 3/8 to 1/2 inch depending upon the corrosion potential. The finished in-place liners will be pressure grouted and lined with 1/2 to 3/4 inch cement mortar having corrosion resistant additives. The longevity of this method can be somewhat limited and is discussed in F 950. It should be noted that at a significantly higher first cost, stainless steel 300 series would be preferred.

945.5 CONTINUOUS SLIPLINE PIPE

The continuous pipe method (sliplining) is the insertion of a smaller diameter pipe inside of an existing pipe, primarily by pulling, utilizing the hole in the ground as access for trenchless construction.

Sliplining of existing deteriorated pipelines can be accomplished by use of a continuous slipliner of different types of olefin plastics. The sliplining methods will be discussed in this subsection for the various material types. The use of slipliners requires the construction of an insertion pit which is used as access for the pipe. Upon completion of the work, the access pit is backfilled and compacted. Sliplining pipes are manufactured from a wide assortment of different types of materials having various resistance to corrosion (Figures 945.4 & 945.5). Typical detailed design examples are provided at the end of this Section. (See Figure F 945.5)

F 945.5.1 POLYETHYLENE PIPE (EXTRUDED)

PE is normally manufactured in 39 foot lengths (12 meters). These lengths are fused together at the job site. After the insertion pit(s) are located and excavated, the top part of the existing pipe is removed for access into the line. The PE pipe is then pulled into the pit and into the existing pipeline. Pipe pulls have been done up to 1,000 feet or more dependent upon the slipliner diameter. Pulls of 800 feet are normal and depend upon the existing pipe diameter and alignment. The butt-fusion process is very sensitive because the proper fusion temperature must be reached to attain proper strength. The larger the diameter, the thicker the wall, and the longer it takes for a proper fusion. Also, after the fusion is made a certain time period is required for proper curing prior to the pull. Inside bead formed at butt fusion joint, especially for diameters up to 12 inch, should be trimmed to avoid constriction. This is important if line is mandrelled-bead reads as "deflection" and may exceed specifications - especially in small diameters.

The pipe is attached to an acceptable pulling head and connected to a winch, usually electrical, and cabled to the pulling end of the operation. Rollers are used above ground to facilitate the
movement of the pipe, avoiding sharp objects that may damage the pipe during the pull. The sliliner is pulled through the entire section, without stopping, during the insertion. The pipe liner is usually cable pulled into the terminal maintenance hole at least two extra feet. The pipe is stretched during the pull operation and requires approximately 24 hours to contract to its normal length. Service connections are usually exposed and then connected to the liner after the twenty four hour waiting period using a heat fusion saddle or tapping saddle. The entire connection shall be sealed and anchored by encasement in concrete, cement-stabilized sand or other approved material. The surrounding soil shall be compacted to a high density prior to backfilling, to minimize settlement.

When 1 inch or more of annular space exists between the liner outside and old pipe inside diameters, grouting is recommended for the entire length to achieve stability and strength. Access for the grouting operation is normally at maintenance holes, insertion pits and service connections. The pipe must be designed to withstand these grouting pressures.

When less than 1 inch of annular space is available, grouting is infeasible, and other measures must be taken to prevent damage from instability. The entry points at maintenance holes must be sealed, and the service connections should be concrete encased in order to minimize liner pipe movement that may shear the saddles. For PE installation under certain flow conditions, bypassing the sewage may be necessary.

PE pipe is manufactured in three types of resin: low, medium and high density. The one used for sewer slilining is of the high density (HDPE) variety. High density compounds are rigid, hard, strong, tough and corrosion resistant. Structural characteristics are a function of wall thickness design as in most plastic and homogeneous materials. Due to the low modulus of elasticity, careful design considerations must be given to buckling. PE pipe is characterized by the Standard Dimensional Ratio (SDR), and pipe grades are classified by environmental stress-cracking resistance. ASTM Standards are available for reference, testing and design. The PE material standards are: D3350. The ASTM D-3350 Standard is normally referenced for pipe cell classification for material properties. See the Bureau's Approved Product List of established material values to use for design and installation for the individual approved products.

945.5.2 POLYPROPYLENE PIPE (EXTRUDED)
The Polypropylene (PP) sliplining method is virtually the same as PE extruded pipe. PP pipe is extruded and has similar stiffness but better chemical, temperature and strength characteristics than PE. The PP pipe is manufactured in accordance to ASTM D-4101. See the Bureau's Approved Product List of established material values to use for design and installation for the individual approved products.

945.6 SEGMENTED SLIPLINE PIPE

In the City of Los Angeles, the segmented (short) slipline pipe method is primarily used to rehabilitate existing deteriorated pipelines using "short" gasketed pipe lengths. This trenchless method involves the insertion of a smaller diameter pipe inside of an existing (host) pipe, by pushing. Because advancement of the pipe is through pushing of the pipe train, a clear understanding of the axial load path along the joint and the establishment of allowable axial compression strength values is critical. While flush joints are the ideal configuration to avoid high point loads and an overly raised invert, traditional bell & spigot joints have been installed successfully in the past provided their profile is not too aggressive.

The slipline pipe, or carrier pipe, is typically introduced while the host pipe is in service (i.e. flow inside the pipe). This aids during installation of the slipline and avoids the need for expensive by-pass systems. Depending on the slipline pipe size, material, and thickness, the vertical capacity loss of the host pipe can be up to 8-inches. As such, the practical minimum host pipe size is about 36-inch vertical diameter. This assumes a relatively straight and flat alignment. Smaller pipes have been sliplined; however, it was done under careful consideration of anticipated future flows, length of run, and surface access in the event something goes wrong. If aggressive vertical slopes or curves exist, this lower limit must be increased. See BOE Specification Section 02760 for the general specification addressing this method of rehabilitation. (See Figure F 945.6)

The method requires the construction of insertion pits, depending on the length of each run, which are used as access for the pipe to be inserted and pushed in. Prior to introducing the slipline pipe in, the host pipe is cleaned using an appropriate sized mandrel. Pipe insertion commences soon after cleaning. Grouting is then followed for stabilizing and/or load transfer of the system, depending on how it was designed. The minimum annular space is measured at the top. This can vary depending on the condition of the existing (host) pipe, its cross-section, and type of material. Typically, a minimum of 2-inches of annular space is recommended for round pipes. For non-round pipes, 3-inches is recommended. However, if the non-round host pipe is made of brick, 4 to 6 inches of annular space may need to be considered, depending on its level of damage, as these pipes tend to sag down due to the loss in arch strength resulting in a reduced vertical clearance. In addition, for tall oval shapes, the pipe has the potential to "tip over". As
such, stabilizers may need to be incorporated into the pipe body toward the top 1/3.

Pushing around a radial alignment has presented challenges in the past. In these cases, it is best to either carry the pipe in or open cut the curve portion. Beveled joints have also been used when attempting to push along a curve. These joint configurations need to be restrained once connected, else the individual pipe pieces tend to rotate, resulting in the continuous twisting of the pipe train, which eventually results in getting the pipe train stuck midway, and/or misorientation of the lead pipe. This latter condition occurs even when the pipe is round.

It is highly recommended that laser profiling be performed of the host prior to fabrication of the slipline pipe. This is particularly important if the use of stabilizers is introduced. Upon completion of the slipline work, laterals are reinstated, the annulus is filled with grout, the access pits are backfilled and compacted or used for the introduction of a maintenance hole.

This method will be discussed in this Subsection for the various material types available. These materials, in the form of manufactured pipe, have varying resistance to corrosion but essentially meet the typical 50yr. minimum life criterion. Lastly, it should be noted, that several of these pipe systems started as direct burial pipe. As such, their joint and axial capacity determined if they were suitable for segmented slipline installation. See the Bureau's Approved Product List of established material values to use for design and allowed installation methods for the individual approved products.

945.6.1 POLYETHYLENE (EXTERNAL PROFILE)

This PE pipe product is manufactured in 20 foot lengths. These lengths are generally connected using a bell and spigot joint configuration utilizing an elastomeric sealing gasket. The spiral rib design permits a constant inside diameter with a varying outside profile rib dependent upon design conditions. Depending on the manufacturer, some versions also bring a third layer of material that is connected to the ribbed exterior, resulting in a stiffer pipe with a smooth exterior.

A jacking pit is excavated approximately 5 feet longer than the pipe segment length and 2 feet wider than the existing sewer pipe outside diameter. However, the insertion pit dimensions are normally dictated by the dimensions of the liner jacking equipment. The top half of the old pipe, in the pit, is removed for liner pipe access. The pipe is placed and is pushed, one segment after another, until the entire pipe train within the reach is installed.

Upon completion of the insertion procedure the annular space between the pipes is pressure grouted. The entire jacking operation can be accomplished under a sewer flowing condition. The liner can be inserted upstream or downstream, even when the existing pipe is flowing at half
capacity, alignment permitting. The jacking pit and other procedures are virtually identical to the aforementioned PE (external profile) pipe.

Spiral rib is manufactured from HDPE resin. This PE pipe should be manufactured in accordance to ASTM F-894. This pipe must also meet the aforementioned physical and chemical parameters.

The axial capacities is not as high as other products so it limits its pushing length. However, for the shorter spectrum of reaches, and when a generous amount of flow is present, it can be a very economical option.

Care must be taken when considering ribbed pipe for slipline installations in rehabilitation projects. Due to the ribbed profile, the invert may end up riding much higher than the original host pipe. This could be a problem with sewers that have a rather flat slope, particularly at the connection point. Also, while the ribbed profile is well suited for providing additional stiffness without significantly increasing the weight in direct burial installations may result in an unacceptable amount of capacity loss when compared to the original host pipe, depending on the future use of the line. If the loss is acceptable or for temporary applications, this type of pipe should be considered.

F 945.6.2 POLYPROPYLENE (INTERNAL PROFILE)

This PP pipe product is manufactured in twenty foot lengths. These lengths are generally connected together using a bell and spigot joint configuration, utilizing an elastomeric sealing gasket. The internal profile design permits constant inside and outside diameters. Service connections or laterals are made similar to the procedures used for PE extruded pipe.

PP AND PE pipe products have comparable properties as it relates to their use in a sewer environment and many of the aforementioned items for PP apply to PE.

F 945.6.3 POLYVINYL CHLORIDE

Polyvinyl Chloride (PVC) is manufactured in 10 or 20 foot lengths. It has been utilized in 3 foot joints when inserted from within a maintenance hole. The lengths are generally connected together using a bell and spigot configuration utilizing an elastomeric sealing gasket. However, a solvent cement has been used under a sewer bypass condition (check MSDS sheets). The jacking pit and other procedures are virtually identical to the aforementioned PE Corewall pipe.
PVC pipe is extruded of plastic materials having a cell classification of 12454-B, 13364-A or 13364-B as defined in ASTM D1784. These cell classes are the only ones that shall be permitted.

The pipe must also meet ASTM D-3034, for small diameters or ASTM F-679 for large diameters. Additives and fillers, including but not limited to stabilizers, antioxidants, lubricants, colorants, etc., are to be 10 parts or less by weight per 100 parts of PVC resin in the compound. They typically come in SDRs of 36 and 25.

The axial capacities is not as high as other products so it limits its pushing length. However, for the shorter spectrum of reaches, and when a generous amount of flow is present, it can be a very economical option. Also, as with the PE external profile, care must be taken when considering ribbed pipe for slipline installations in rehabilitation projects. Due to the bell and spigot joint, the invert may end up riding higher than the invert of the original host pipe.

945.6.4 REINFORCED PLASTIC MORTAR

The Reinforced Polymer Mortar Pipe (RPMP) is manufactured in variable lengths, some as long as 40 feet. These lengths are generally connected using a bell and spigot joint configuration utilizing an elastomeric sealing gasket. Today, there are at least three manufacturing methods: centrifugal cast, hand laid, and filament wound.

The centrifugal manufacturing process provides a constant outside diameter having a slightly larger dimension at the joint. Various thicknesses are available. When thicker walled pipe is used, the joints can be recessed so that the outside diameter is constant. Centrifugally cast pipe uses a polyester resin, chopped fiberglass roving (a spool of continuous glass strands/fibers) and sand. The materials are introduced in a controlled manner within the mandrel as it spins. This composite wall can be varied in composition and thickness for adjusting wall stiffness and strengths.

The hand laid manufacturing process uses a stationary mandrel on which glass fiber mats, and a sand resin mortar is placed, providing a constant inside diameter. Because its hand laid, and due to shipping considerations, the pipe lengths are 8 feet long or less. However, because its hand laid, unique project specific specials can be fabricated including variable size transition pieces as well as pipe segments with constant curvature for installations around curved alignments.

The filament winding manufacturing process provides a constant inside diameter. The outside diameter is normally controlled by the bell size which is slightly larger than the barrel size. With
this latter method, either the mandrel oscillates back and forth as the pipe is built, or the equipment itself moves along the mandrel. Also, note that due to the use of a continuous filament glass robbing, the filament wound process tends to have the highest ring modulus of the three.

Of the above three methods, fabricators using hand laid and filament wound are able to produce both round and non-round cross-sections. The non-round sections are typically used for the rehabilitation of existing pipes. Fabricators of round pipe mainly use centrifugal casting and filament wound manufacturing methods. With these, they can produce both general gravity based pipe as well as pressure pipe.

For all three manufacturing methods, a resin rich lining, typically vinyl ester based, is included on the inside of the pipe in order to provides excellent corrosion resistant features. Any cut surface should be coated with vinyl ester resin. Either pipe is manufactured to meet ASTM D-3262 for stiffness and structural requirements and SSPWC for chemical resistance. And, regardless of the individual capabilities or strengths for each of the three manufacturing pipe methods, they can all be quite competitive when bid against each other.

The jacking pit and other procedures are virtually identical to the aforementioned PE (external profile) pipe.

**F 945.6.5  DUCTILE IRON (CEMENT LINED OR POLYLINED)**

Ductile Iron pipe is normally manufactured in 20 foot lengths. These lengths are generally connected together using a bell and spigot joint configuration utilizing an elastomeric sealing gasket. The centrifugal manufacturing process provides a constant outside diameter, however, the bell is several inches larger and controls the size for insertion. The jacking pit and other procedures are virtually identical to the aforementioned PE pipe. Normally, these pipes would be used as part of a pressurized system or where a shallow installation is planned.

Ductile Iron pipe shall be manufactured according to the AWWA C-151 Standard. The sizes, classes, grades or thicknesses shall be determined by the designer. Due to the high flexural modulus the concern for the buckling resistance is at a minimum, but shall be calculated. The cement mortar lining should be double the normal amount as follows: 1/8 inch for 3 inch to 12 inch; 3/16 inch for 14 inch to 24 inch; and 1/4 inch for 30 inch and larger.
When internal corrosion is of concern and sulfide control is not incorporated into the design sewer flows, it is recommended to use the 40 mil minimum polylining. This polylining shall be placed throughout the inner surface of the pipe length, from spigot end face to beyond the sealing elastomeric gasket.

**F 945.6.6 STEEL**

Steel pipe is normally manufactured in 40 foot lengths, however, 20 foot lengths are also available. These lengths are generally connected together by welding the plain ends. The welded joint closures necessitate bypassing the sewage flows during construction. The joint welding can be completed within the insertion pit area. Typically, these are used to rehabilitate pressurized lines and as such, tend to have a cement mortar lining. The jacking pit and most of the other procedures are virtually identical to the aforementioned PE pipe. The steel pipe material was discussed in Subsection F 945.4.6. In most current jobs, steel pipes primarily being used as casings whereby they provide temporary ground support for the second-pass pipe and the annular space grouted. When designing the final second-pass pipe, the dimension of the casing is considered for direct pipe loading however, the casing’s strength from a long-term consideration, is ignored.

**F 945.7 CURED-IN-PLACE-PIPE (CIPP)**

The CIPP rehabilitation method has been in use for several decades. More recently, this method has expanded through the increased use of glass reinforced felts, new resins, and the introduction of using ultra-violet light as the means of curing the liner.

**F 945.7.1 HEAT CURED CIPP**

When using a heat-cured CIPP method, a resin saturated material is inverted into the existing pipeline, either hydrostatically or with air pressure, and then heat cured. (See Figure F 945.7) The sewage flow must be bypassed around the area of work prior to inversion. After the pipeline has been cleaned and televised, the saturated fabric is inserted through a maintenance hole or convenient entry point. After the application of the inversion process, the temperature of the water or air is increased by use of a heat exchanger or the application of steam. This cures the resin saturated material, forming a hard impermeable pipe within the old pipe. The inversion forces and heat press the fabric material tightly against the existing pipe, typically creating dimples at the service connections or laterals. After the resin sets, the downstream closed end is carefully cut and removed in order to avoid creating a vacuum which may collapse the newly formed pipeline (Figure 945.7).
The final activity is pulling a CCTV through the line for final inspection. In tandem, and connected to the CCTV, is a cutting device used to restore the service connections by locating the dimples visually with the camera. However since dimples are not always generated, particularly if the liner is thick or reinforced, referring to pre-survey data collected prior to insertion of the liner is the best practice.

The components of the cured-in-place-pipe are:

A. flexible needled felt  
B. thermosetting resin  
C. catalyst

The flexible needled felt can be made of a woven or a non woven, or a combination woven and non woven material.

The primary function of the felt is to carry and place the thermosetting resin which cures into the shape of the conduit. Thermosetting polyester resins utilize cobalt, perkodox and/or trigonox for catalyzing and accelerating the polymerization. The catalyst quantities vary from one-half to five percent of the total resin mix. Thermosetting vinylester resins utilize the same type catalysts in like concentrations. Thermosetting epoxy resins are significantly more complex on placement and curing. The epoxy resin manufacturer normally provides a proprietary curing agent, for a given type resin, in quantities varying from 2 to 33%.

See the Bureau’s Approved Product List of established material values to use for design and installation for the individual approved products. In establishing the values listed, BOE conducted a benchmark study of methods used to design CIPP liners for sewer rehabilitation projects. The intent was to optimize the design process and reduce disputes with contractors over non-compliance issues. When conventional unreinforced felts are used, as well as using established resins that have successfully passed BOE’s chemical resistance testing, the following material values may be used for structural design:

- Initial Flexural Modulus: 250,000 psi (1723.7 MPa)  
- Initial Tensile Strength: 3,000 psi (20.7 MPa)  
- Long-term (50yr design life) Flexural Modulus: 100,000 psi (689.5 Mpa)

The long-term flexural modulus could be increased to a maximum value of 125,000 psi (861.9
MPa) if the CIPP liner product has undergone and completed long-term creep modulus testing per ASTM D2990, and if justified by the test results and regression analysis of the flexural properties of the system.

Recent manufacturing practices are introducing glass reinforced felts that tend to significantly increase the material design value of the product over conventional felts but using the same resins and the typical CIPP process. While the above default values may be used for these types of compositions, designating higher material values require that full material short-term and long-term testing be performed.

**945.7.2 UV-CURED CIPP**

The ultra-violet (UV) light cured CIPP method consists of using a pull-in-place method to install a resin saturated liner into the existing pipeline being rehabilitated, expanding the liner with air, and curing the liner using a UV light-train. Most liners used with this method are glass-reinforced. While the technology can be used to rehabilitate lines from 6-inch up to 72 inches, the capabilities of each city-approved manufacturer and their corresponding certified installers may be the limiting factor in determining the available size range. Other associated limiting factors could include the cable length and size of light source each installer can secure or has experience using. Freight weight of the liner may also be a factor as the liner comes pre-saturated – there is no field saturation possible at this time. Check with manufacturers during a project’s Pre-Design Phase to ensure all of these factors are evaluated. However, due to their typical higher design material values, UV-Cured CIPP when a decision is made to use this technology, ensure to incorporate the appropriate specification (i.e Section 02582) from the BOE Master Specification Library.

The installation begins with the pipeline cleaned and televised as well as surveying the exact location of all laterals. Because most UV tubes are glass reinforced, they seldom leave a noticeable dimple to easily identify the lateral locations. Therefore, it is imperative that the lateral locations are accurately pre-surveyed. Next a plastic slip sheet is placed on the invert to protect the liner and help reduce the drag during insertion. The saturated fabric is then inserted through a maintenance hole or convenient entry point. The insertion occurs by pulling the liner into the pipeline using some type of winching equipment, typically stationed on the opposite side. Care must be taken not to damage the liner’s outer foil which keeps the tube from premature exposure to ultra-violet light. Most manufacturers use an inner and outer film to protect the liner during the installation and curing process.

Once the liner is in place, the light source, or light train, is inserted into the liner and end caps installed. Prior to insertion, the light source is checked to ensure all the lights and any on-board
telemetry is working properly. Never look directly at the light source or touch it when it is turned on to avoid any injury. The tube is then inflated as recommended by the manufacturer. The light train is pulled through the liner using an inner cable that passes through the end caps. At this time, the inside of the liner is visually inspected with an on-board camera to ensure the liner has been properly prepared. If needed, the liner can be deflated, reset, and re-inspected. When all is set, the ultra-violet lights are turned on and the light train is pulled through the liner at a predetermined rate to ensure proper curing of the resin. Typically, the rate is reduced at the start and end of the run to ensure the ends they are fully cured.

Samples are collected from either end where the tube extend out of the pipeline. Ideally, a ring sample should be secured for testing verification. If this is not possible, a sufficiently long portion of the tube should be secured. Glass reinforced tubes samples tend to be difficult to prepare for testing. Therefore, ensure the preparation and chain of custody of the samples has been thoroughly discussed with the Contractor prior to the actual lining.

Unlike design material values for conventional unreinforced felt liners, reinforced liners UV cured or otherwise, are established using product specific testing. This is true even when the same manufacturer is using the same resin. See the Bureau's Approved Product List of established material values to use for design and installation for the individual approved products.

**945.8 DEFORMED PIPE**

This method utilizes extruded polyethylene or polyvinyl chloride materials that are either deformed during the manufacturing process or during installation. These methods are similar in many respects, however, differences are apparent and these are discussed in this Subsection.

It is normal to monitor the existing pipeline by use of a CCTV camera. A proofing pig should be pulled through the line to verify dimensions and remove protruding laterals, etc, prior to liner insertion.

**945.8.1 DEFORMED HDPE**

The extruded HDPE pipe is deformed 25% to 30% and wound on a large containment spool. This spool is transported to the job location. A cable is strung through the deteriorated pipe and attached to the deformed pipe. The HDPE pipe is then pulled through an existing maintenance hole or access point (Figure 945.8).

Appropriate sleeves and rollers are used to protect the deformed pipe during installation. When
the deformed pipe is in place it is cut and the processing manifolds (pipe end closing assembly used for heat and pressure control within liner) is inserted and secured at both pipe ends. The temperature and pressure measuring instruments are attached to the deformed pipe at both ends.

Through the use of steam and air pressure, the deformed pipe is progressively reformed to conform to the existing pipe wall. After the pressure and temperature are held at set levels for a set time, a cool down period is started. When this process returns to ambient condition, the equipment is detached and service laterals are normally reinstated through an internal remotely controlled tapping apparatus.

945.8.2 FOLDED PVC

The extruded PVC pipe is deformed/folded 20% to 25% and wound on a large containment spool. This spool is transported to the job location. A heat containment tube is normally placed inside the deteriorated pipe in order to assist in the retention of heat necessary to soften the folded pipe. A cable is strung through the containment tube and attached to the folded pipe. The heated PVC pipe is then pulled through an existing maintenance hole at the access point. Care is taken not to damage the folded pipe during installation. After the PVC pipe is fully extended within the existing pipe, the folded pipe is cut off at the starting point. Through the use of steam and air pressure, a mandrel is pushed through the folded pipe, progressively rerounding the pipe. The PVC pipe conforms to the existing pipe wall providing a tight-fitting pipe within a pipe. After the pressure and temperature is held at set levels for a set time, a cool down period is started. When this process returns to ambient condition, the equipment is detached and service laterals are normally reinstated through an internal remotely controlled tapping apparatus (Figure 945.8).

945.9 SPIRAL WOUND (COILED PROFILE) PIPE

The spiral wound rehabilitation method normally uses strips of extruded thermoplastic material. The base material can consist of PVC, HDPE, and may include steel reinforcing ribs either externally connected to the plastic or encapsulated within the plastic itself. The strips are transported to the job location in rolled bundles. The various spiral wound methods are either rubber gasket or activated polyurethane adhesive, sealed or unsealed.

945.9.1 PVC LINING SYSTEM

The PVC strips are machine formed using clips at the strip interface and pushed through the deteriorated pipe from a maintenance hole on small diameter pipes. Certain systems are able to
expand just enough to press themselves against the inner surface of the host pipe. For City of Los Angeles projects, the voids/gaps created by the profile cross-section during reinstatement of the lateral connections must be sealed using an approved sealant or grout to prevent any root intrusion between the lining and the host pipe, due to substandard laterals.

On large diameter pipes the machine can be utilized with person-entry assistance or panels can be affixed to the pipes inner wall. The strips and panels are manufactured with a profile backing that provides space for injecting grout. The PVC and grout composite provides long term buckling resistance and strength, however, design relationships must be calculated. Unless grouting is performed in lifts, the coiled pipe must be supported with temporary shoring during grouting, particularly for non-round shapes. Steel reinforced strips are only available for the larger diameter pipes. Also, by using this reinforcement, non-round shapes can also be considered for rehabilitation using this method. Consider the use of BOE Specification S03318 when using this system on large diameter sewers.

Service laterals are normally reinstated through external excavation and reconnection on the non-person-entry diameters. Person-entry diameters permit internal service lateral reinstatement.

**F 945.10 COATINGS AND LININGS**

There are hundreds of coatings and linings systems available that are marketed for protecting cementitious-based materials that are subjected to sewage environment. However, only pre-approved products may be used in City project. See listing on the Bureau of Engineering website. Protective linings, which include field-applied coatings, are not intended or approved for structural repairs. Protective linings are used as a chemically resistant barrier to isolate cementitious products, such as, concrete or mortar from sewer exposure. These linings and coatings have been classified as Type I or Type II, with Type I being the more robust. Type II Lining/Coating will no longer be allowed on new MH shafts based on unacceptable construction performance. See Table below for a listing of structure and type of liner permitted.
Table F 945.10
Protective Linings And Coatings
For Corrosion Protection (Non-Structural)

<table>
<thead>
<tr>
<th>Type</th>
<th>Approved Uses</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>New Pipes &amp; Structures</td>
<td>New MH Shafts</td>
</tr>
<tr>
<td>Type I</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
|        | - Cast-in-place lining with welded joints.  
  - Anticipated service life is 50 years. |
| Type II| No            | No              | Yes                                 |
|        | - Sprayed coatings: sensitive to surface and ambient conditions, and applicator skill. Unproven for overhead applications. 
  - Anticipated service life is 10 - 15 years. |

The intent of the above table is to minimize sewer maintenance by ensuring that the best available protective lining system is used. Categorically, field-applied coatings are not equal to the cast-in-place, solid sheet linings in performance, durability, cost or versatility. The Bureau of Engineering Brown Book Section 210-2 defines the application of protective lining systems. As noted, approved liners must successfully pass the SSPWC Chemical Resistance Test (Pickle Jar Test) as identified in Section 211-2.

Type II lining/coatings are applicable for rehabilitation of existing MH shafts, small existing sanitary sewer structures, or any other existing structure that can be easily accessed in order to replace its damaged existing lining. An exception exists in the application of a Type II liner onto new brick sewers in terminal hillside MH shafts. Most, if not all, Type II linings are post-installed onto an existing substrate. As such, they requires proper surface preparation. It is necessary to clean any concrete surface in advance of applying any protective material. Also, most protective materials require a dry surface for developing a long term adhesive bond.

As noted in the table above, Type I is the required system for new construction. Most Type I lining/coating systems are either a solid sheet cast-in-place lining with welded joints, a solid sheet anchored on an approved epoxy bed, or a tight-fit solid sheet/bag lining with approved epoxy sealed end joints. They are anticipated to have a long service life. The most commonly
used solid sheet linings are made of either polyethylene (PE) or polyvinyl chloride (PVC). See below for a general discussion of each.

F 945.10.1 POLYETHYLENE (PE)

Polyethylene (PE) sheets can be placed in the pipeline covering the upper 270 or 300 degree inner circumference. The invert is left unlined to allow any captured moisture behind the line to escape. The sheets are normally wrapped or adhered to forms and concrete is cast against it. Use of staples is not an acceptable means of attaching the sheet to the form. Such practices introduce pin holes to the form where cases can enter and attach the concrete. The joining together of the sheets circumferentially and longitudinally is achieved by use of a special fusion welding system. The extrusion or butt welding method is used for sealing the ends. This can also be used for protecting sanitary structures including maintenance holes. In the case of concrete or brick structures, all surfaces that can potentially be exposed to hydrogen sulfide gas is covered.

Polyethylene sheet liners can be manufactured in thickness of 80 to 200 mil. The sheet thickness is designed with consideration for anticipated temperature range, diameter of the pipe and the degree of circumference to be covered. The high density polyethylene (HDPE) sheets must be free of extractable plasticizers or copolymers, maintaining physical properties having low level shrinkage or swelling from normal sewage conditions. In general, PE has good corrosion resistance properties, especially High Density PE (HDPE). Medium Density PE (MDPE) has also been used from time to time. See BOE’s product approval list for the current PE Density and thickness sheet permitted. PE tends to be more rigid than PVC. As such consideration must be given to surfaces with small radii, transition / conic shapes, etcetera, whereby precut pieces are welded together. PE also is difficult to mate with other materials. When transitioning from PE to PVC or any other material, provide the detailing, epoxy sealing, and material specifications required. Past options have included specialized stainless steel / transition couplers or specialized composite transition material prepared at the extrusion plant.

A spark test is required to be performed after the liner is placed to verify that no pin holes or unsealed openings have been left behind where the concrete substrate can be attacked. The test involved introducing a surge of electric current onto the structure and passing a wand over the lined surface. When a pinhole or other imperfection exists, the current uses it to close the circuit, create a spark, and an alarm on the unit to go off. Remedial work is then performed to correct the problem.

F 945.10.2 POLYVINYL CHLORIDE (PVC)

PVC sheets are placed in the pipeline and structures by methods similar to those described above
for PE. The PVC liners are composed of high molecular weight PVC resin combined with chemical resistant pigments and plasticizers. The PVC liner is extruded of plastic materials having a cell classification of 12454-B, 13364-A or 13364-B as defined in ASTM D1784. These cell classes are the only ones that shall be considered. See BOE's product approval list for the specific PVC sheets/systems permitted.

The liners are normally 65 mils (0.065 inches) in thickness. The liners have a minimum elongation of approximately 200% (ASTM D412) and a tensile strength of 2200 psi (ASTM D638). The Shore Durometer D hardness is approximately 50 at ambient temperature (ASTM D2240). The standard sheets are 4 feet by 8 feet, having a 3/8 inch high tee section, spaced 2 1/2 inches apart circumferentially and placed longitudinally.

PVC sheets are more pliable than PE material. As such, the material can general contour itself around most small radii edges and shapes. In addition, add-on strips, welding strips, and a variety of specialty prefabricated pieces are available that allow for proper sealing of material joints as well as accommodate various appurtenances, piping, etc. within a structure. On the other hand, due to the "soft" nature of the material, it may not be suitable where high debris loads, cavitation, abrasion, or high velocity conditions may exist. In such cases, PE liners should be used.

See discussions above under PE for spark testing considerations.

**F 945.11 MECHANICAL SEALING DEVICES**

Mechanical sealing devices require surface preparation for proper seating and sealing. These devices are used for sealing leaking and or corroded joints (See Figure F 945.11) and/or spot repairs in small lines. These can be used in pipelines and/or maintenance holes. Configuration must be such that it does not promote the accumulation of debris, nor prevent the passage of maintenance and cleaning equipment. Materials, configuration, and method of installation must be approved by the Engineer of Design.

**F 945.12 SPOT (POINT) REPAIR**

Point repairs may be used to correct isolated or severe problems in a pipeline segment, and can be an initial step in the use of other rehabilitation methods. Point repairs, are usually limited to the replacement of only a short portion of a pipeline or lateral connection.
The technical considerations and the factors influencing the cost of a point repair are the same as those described in a following section for excavation and replacement. When making point repairs, special consideration shall be given to the materials and methods to be used to connect the replacement pipe to the existing pipeline. Flexible couplings are often used to join pipes together. Concrete collars and encasement also are used occasionally. The repair of pipe connections to maintenance holes is another type of point repair. This is covered in the following section.

F 945.13 REPLACEMENT

It is not always possible or desirable to rehabilitate an existing pipeline. Hydraulic capacity is frequently a problem and, while renovated systems can exhibit lower friction coefficients and give small increases in capacity, new larger pipes is frequently the better option. Similarly, the existing pipe network may not be located in the most appropriate locations to serve both existing and proposed infrastructure or even future flow demands due to population growth. In such cases it will be necessary to replace or supplement the existing pipes.

In arriving at a decision to install a new pipeline, an equally important consideration is the method by which the pipe will be installed. The chosen method often also dictates the type of pipe that may be used. In arriving at this decision the typical choices are conventional open cut / trench installations or some form of trenchless technology and/or tunneling. Trenching techniques are severely disruptive, particularly in heavily urbanized areas. However, direct burial / open cut techniques may be the only way to navigate through clusters of unknown utilities and/or underground obstructions. In addition, for relatively shallow installations, it may be the most cost effective. On the other hand, trenchless methods presents benefits that go beyond the direct cost of placing the pipe. There are social and environmental benefits that can be realized through reducing disruption to traffic patterns, sidewalk use, or local businesses.

Tunneling may fall under the umbrella of trenchless installation techniques but typically, it is seen as its own category. Usually, this method is employed when installing large size pipes along deep alignments through mixed ground conditions. Tunnel boring machines are used to bore through the ground, leaving some type of soil support system along the way. In general, they are few in number as it relates to number of projects using it. However, the traditional trenchless methods are employed to install small to medium size pipes. In recent years, trenchless replacement and construction techniques have been gaining ground on the more traditional methods of direct burial and tunneling. These include pipe bursting, microtunnelling, directional drilling, pipe jacking, and fluid jet cutting. In addition, minimum excavation techniques are also becoming more popular in less congested environments. None of these
systems can be considered appropriate in all circumstances. Particular limitations include the close proximity of other buried utilities, the presence of large boulders in the soil, and solid rock.

**F 945.13.1 PIPE BURSTING**

Pipe bursting is the method of inserting a new pipe of equal or larger diameter into an existing pipeline by fragmenting the existing pipe and forcing the material into the surrounding soil. The enlarged hole is then available for inserting the new pipe. (See Figure F 945.13.1).

The bursting of the pipe material is accomplished by the use of pneumatic or hydraulic bursters. Depending on the specific system, the mole is either directionally guided or towed by a winch, the new pipe being either towed or jacked in immediately behind the mole.

Several designs of bursting heads have been developed, consisting in their simplest form of a series of tubes increasing in size from the front of the machine. Each size increase is accomplished by a conical shaped transition piece. Special expanding knuckles are fitted to the mole to crack the joints. Hydraulic expanding bursting machines have also been developed.

A sleeve pipe is towed directly behind the mole to protect the final pipe from scoring damage by the broken pipe fragments. After the moling operation is completed, the sleeve is lined with HDPE which forms the final pipeline.

Various other final pipe materials have also been used with varying success, including vitrified clay, fiberglass reinforced plastic, and concrete pipes.

The method is suitable for the replacement of pipes manufactured from brittle material such as vitrified clay, unreinforced concrete, asbestos cement, PVC and cast iron. It is not suitable for the replacement of steel, ductile iron, reinforced concrete pipes, polyethylene pipes, or ABS composite.

The size suitability of the system is shown in Table F 945.13.1.
The maximum length between insertion pits will depend on many factors including the existing pipe material, joint design, pipe surrounding material and ground conditions. Typically, the length of insertion should be limited to 200 to 300 feet.

Joints can cause considerable delay to the progress of the insertion. It is preferable to approach the bell from the rear, and moles now incorporate stress raising fins to break out joints.

Pipe surrounding material has a particularly noticeable effect. The effect of concrete surround is dependent on the extent of the concrete, its strength, and the bursting capability of the moling equipment. The material surrounding the pipe must be able to accommodate the necessary enlargement of the pipe and not induce frictional affects that cannot be overcome. Trees in the vicinity of a sewer can reduce the rate of progress due to large roots. The ease of replacement increases as the soil type changes from sands and gravels to clays. Moling in sands or cohesionless materials, and particularly wet sands, tends to result in shorter drive lengths than for clays due to the high friction effects caused by almost immediate soil relaxation into the replacement pipe.

The principal advantages of the system are:

A. Speed of installation - with rates of up to 100 feet of installed pipe per hour, a considerable saving over trenching in an urban environment. The insertion rates are often quoted at feet per minute, which does not take account of set-up time, including pipe welding (if continuously welded pipe is used), excavation of the insertion pit and laterals, reconnection and ancillary works. Rates of between 0.5 and 4 feet per minute have been achieved, although hard ground conditions can reduce the rate considerably.
B. Reduced reinstatement costs - particularly in dense urban areas.

C. Improved environmental and traffic management - experience has shown that this may be overstated. Consideration should be given to the location of lead-in trenches, the number of open holes necessary for the reconnection of laterals, and the space required for laying out the pipe.

D. Cost saving with respect to diversion of the utility plant - this is somewhat offset by concern about the effects of the vibrations caused by the system.

E. Lower unit replacement costs - typically 20 to 40 percent lower than conventional open cut methods.

The equipment has a limited size capability, although as the system develops and becomes more widely available, the size range may increase.

The principal disadvantages of the system are:

A. Surrounding materials - the system is only suitable for brittle materials, and cannot always cope with concrete surround. This can be a particular problem if the pipeline construction is not known or only isolated sections are surrounded in concrete. In sewers constructed near bedrock, or on piles, the forces exerted by the bursting machine will be uneven, resulting in a tendency for the equipment to rise. Similar problems may exist where large boulders are located close to the existing pipeline.

B. Rates of progress - particularly dependent on the pipe material and ground conditions, making it difficult to precisely predict construction times.

C. Laterals - it is necessary to excavate all lateral connections and disconnect them before bursting to limit damage, and reconnect them only after the new pipe is fully installed. This may be a problem where large numbers of laterals are involved, and services to the consumers may be cut for an extended period, if construction problems occur.

D. Expansive action - one of the greatest perceived disadvantages is the risk of damage to adjacent services, structures, and the ground surface, particularly where surfaces are
paved. The expansive action of the mole results in movements in the material surrounding the pipeline. The amount of movement depends on the soil material, the degree of expansion, and the type of pipe surround, etc. Movement is transmitted through the surrounding material, including strains and bending forces in adjacent pipelines, particularly transverse crossings. These forces can cause movement of the pipeline and, depending on the magnitude of the force and the condition of the pipe, could cause structural damage or leakage at a joint. A significant amount of research has been completed in this area, leading ultimately to pipe proximity charts. Shallow operations will be significantly influenced by the close proximity of the ground surface, leading to a generally upward movement during expansion, with disturbance localized and intensified above the moling process. In deeper expansions, such as those typically experienced for sewers, the zone of disturbance is more likely to be contained by compression in the surrounding soil. In homogeneous soils the expansions will be radial, while the presence of a hard layer below the expansion, i.e. bedrock, piles, trench bottom with weaker backfill, the ground movement will be directed upwards. The degree to which movement is localized and contained by volume change will depend on the strength and compressibility of the backfill.

E. Surface disturbance - will vary from slight heave associated with little visible damage to pronounced heave with severe surface cracking and opening of existing joints and defects. Much of the disturbance will be transient, produced during moling, with some subsequent convergence.

F 945.13.2 MICROTUNNELING

Microtunneling has a high unit construction cost when compared to traditional open trench systems. Unless the disruption costs are high and are included in the total construction cost, microtunneling will not be competitive.

In relation to extraneous flows, microtunneling may be considered as an option in urban areas where an existing pipeline is to be abandoned, or requires upsizing, but is still below the size for conventional tunneling.

Microtunneling is a method of excavation to permit the installation of a pipe by pipe jacking. This requires the use of a remote controlled, steerable tunnel boring machine in the size range of 6 to 36 inch diameter. The machines fall into two categories, auger systems and slurry systems.
See micros F 945.13.2A and F 945.13.2B.

F 945.13.2.1 AUGER SYSTEMS

Auger systems incorporate a series of helical augers within the tunnel boring to transport soil from the cutting head to the jacking pit or starting shaft, where it is removed. The cutting head is connected directly to the auger flight and is driven from an electric motor located in the jacking shaft. A choice of cutting heads is available for differing soil conditions. Crushing heads are also available to deal with cobbles, and recent developments include equipment that can remove existing sewers. Steering is accomplished by activating several small hydraulic steering jacks near the front of the machine. Directional control is achieved using a laser beam emitter located in the jacking pit, and a target located on the rear of the tunneling machine. Groundwater at the level of the tunneling machine can result in over-excavation. This can be limited by the injection of slurry, water, or compressed air at the cutting head.

F 945.13.2.2 SLURRY SYSTEMS

A small diameter discharge pipe installed within the lining of the tunnel carries the soil removed by the slurry shield machine directly to a treatment tank at ground level. The slurry liquid normally consists of a bentonite/water mixture, although water alone may be suitable in some soils or machines. In soils containing cobbles or stones, a crushing head is needed to grind the material down to a consistency suitable for passing through the small diameter discharge pipe. The drive to the cutting head is applied directly from a motor and gearbox located at the front of the tunneling shield. Steering and control takes place in a manner similar to that used in the auger system (Figure 945.13.2B).

F 945.13.2.3 PIPE INSTALLATION

The pipeline is jacked behind the microtunneling machine, thereby providing the forward motion of the machine. Additional lengths of pipe are added at the insertion pit, the cycle continuing until the complete pipe string is pushed or jacked forward. Pipes are manufactured from a variety of materials including concrete, vitrified clay, fiber reinforced plastic, fiber reinforced cement, asbestos cement, ductile iron, and steel. Special joints have been developed to provide a smooth internal and external profile, the joints being contained within the pipe wall. The joint should also be designed to cope with the jacking forces, and be capable of small deflections.
without leakage. Other specific requirements of a jacking pipe are that it should be able to withstand direct and eccentric jacking forces, soil and traffic loads should be supported safely, and the pipe material should have sufficient durability for the sewer environment.

The advantages of microtunneling are the close control of line and grade, and capability of installing a permanent lining in standard lengths between access points. The ability to work in difficult ground conditions and in congested areas with minimal surface disruption. Also, it is competitive at depths greater than 15 to 20 feet.

Disadvantages include high initial capital cost, requiring extensive support services. Larger obstacles such as boulders can cause considerable difficulty. The system is only suitable for applications where deep pipes require replacement with larger pipes, or where there is insufficient scope for reducing extraneous flows in upstream sewers, creating a need for additional interceptor sewers in the downstream reaches.

**F 945.13.3 OTHER TRENCHLESS SYSTEMS**

The other trenchless type systems are available, and in recent years have made significant strides in their development. Not all of these methods are directly applicable for use in the installation of a main line sewer due to accuracy, distance, grade, or size limitations. However, under the right conditions, they may provide the most cost effective minimum disruptive solution to a particular project. Such techniques include steerable systems such as directional drilling, and non-steerable systems such as auger boring, pilot tubing, impact ramming, and impact moling.

**F 945.13.3.1 HORIZONTAL DIRECTIONAL DRILLING (HDD)**

Horizontal directional drilling has been used predominantly for the installation of long, vertically curved pipelines, usually under bodies of water such as rivers, estuaries, and canals (See Figure F 945.13.3.1). Using substantial surface equipment, and being capable of drives well in excess of 3,300 feet, the technique is best suited to major installations which warrant the use of the expensive and heavy equipment. However, with the experience gained over the years this method has been in place, runs with minimal slope have been achieved making it usable for gravity sewers, particularly for short runs along sloping surface grade.
The technique involves the drilling of a small diameter pilot hole in a shallow arc. A washover pipe slightly larger than the pilot tube follows the drill string, acting both as temporary support enlargement. The completed pilot bore is enlarged using back reaming techniques until large enough to receive the final pipe, which is normally steel, although PE and bundles of pipes have also been used.

**F 945.13.3.2 AUGER BORING**

Auger boring consists of a rotary cutting head followed by an auger flight that is used for soil removal. In so doing, a steel casing is left behind. The equipment has a wide use in crossing type work, but it does have accuracy constraints.

**F 945.13.3.3 PILOT TUBE**

This method, also known as Guided Boring and Pilot Tube Microtunneling is a multi-stage approach for installing to line and grade. The initial step involves the insertion of a the pilot tube which is guided by rotating its slanted steering head and integrated camera-theodolite system. This is followed by a reaming head that makes the hole larger and a train of auger casings through which the spoil is removed. Thirdly, the final pipe is installed which pushes out the auger casing. An alternate version of the above integrates the auger within the final pipe.

Soft and displaceable cohesive soils are ideal for this method. Cohesionless soils or the presence of cobbles and boulder can lead to challenging installation conditions. Where the final pipe is coupled with the auger system, it must be able to handle the jacking forces needed to widen the pilot hole and advance the pipe train.

**F 945.13.3.4 IMPACT MOLING**

Also known as soil displacement hammers and piercing tools, use compressed air to drive a cylindrical percussive hammer through the soil to form a hole, typically one (1) bigger than the final pipe. The soil is simply consolidated, and the pipeline is pulled/pushed through in the opposite direction. This is generally used for small service pressure lines up to 4-in diameter. The system is typically non-steerable, intended for very short crossings in soils with some level of cohesion, and is usually not appropriate for gravity lines.

**F 945.13.3.5 IMPACT RAMMING**

Impact ramming is a development of impact moling where a large impact mole, located in a drive pit, is used to hammer a steel casing into the ground. Soil enters the open ended sleeve,
and is removed by jetting, mechanical cutting, or simply pushing out the soil plug. The system is limited in drive length to about 100 feet, and is only applicable to medium and larger crossing type work over modest lengths.

F 945.13.4 CONVENTIONAL REPLACEMENT

The ultimate, and perhaps most complete solution to extraneous flow problems is complete replacement of the pipeline. This is also achieved, to some degree, with some of the lining and trenchless replacement options, in that a new pipe is provided.

Traditional open cut techniques are often economical in relatively open suburban and rural environments, where the disruption can easily be accommodated. In heavily congested urban areas, or where the sewers are deep, lining and trenchless systems become more cost competitive.

Tunnelling only becomes an option when large sewers with severe extraneous flow problems are to be rehabilitated.

F 945.14 SEWER BYPASSING

When a sewer pipeline needs to be replaced or rehabilitated, it may require the particular portion of the alignment to be dry. Two potential methods to dry out the portion of the line are 1) bypass the flow; 2) divert the flow. Bypassing is defined as pumping flow from a point in a system and discharging flow into the same system such that flow in the system does not increase. On the other hand, a diversion is defined as flow that is physically diverted (bulkhead, diversion structure) or pumped from one system and onto a separate system such that the flow increases in the other separate system.

Designers to ensure which method is intended to be implemented in a project. If a diversion is the intent, designers must coordinate with the Bureau of Sanitation to ensure that the system receiving the extra flow has the capacity to do so and drying out the original system or reducing the flow temporarily has little to no negative impact.
F 945.15 MAINTENANCE HOLE REHABILITATION

Maintenance holes (MH) are rehabilitated to correct structural deficiencies, to address maintenance concerns, and to eliminate extraneous flows. Maintenance hole rehabilitation may also minimize or prevent corrosion of the internal surface caused by sulfuric acid formed when hydrogen sulfide gas is released from the sewerage into the sewer environment (Figure 945.15). This latter form of rehabilitation is intended to extend the service life of the MH resulting in cost savings to the collection program. However, as with any rehabilitation, the long-term cost benefits of replacement must always be considered. Many methods to rehabilitate maintenance holes are currently available. New products and rehabilitation technologies are continually being developed. In the end, the evaluation of each method should consider:

a. The type or types of problem
b. The physical characteristics of the structure such as the construction material
c. The condition and age
d. The location of the maintenance hole with respect to traffic and accessibility
e. The risk of damage or injury associated with the current condition of the structure
f. The cost/value in terms of rehabilitation performance.
g. The cost/benefit consideration of full replacement with a new maintenance hole.

F 945.15.1 MAINTENANCE HOLE CONDITIONS

The following subsections discuss maintenance hole conditions which could result in maintenance hole rehabilitation work.

F 945.15.1.1 STRUCTURAL DEGRADATION

The definition of structural degradation varies with maintenance hole material composition, shape, and size. Structural degradation does not necessarily mean structural failure. For purposes of maintenance hole inspections, structural degradation may be defined as damage to
any of the structural components of a maintenance hole.

As it relates to the structural concrete surface itself, structural degradation could include joint displacement of individual components, cracked and/or spall surfaces, corrosion of reinforcement, loss of vertical and/or bearing capacity, and/or complete disintegration of the concrete walls. As it relates to brick maintenance holes, this may include delamination of the bricks, loose or missing bricks, softened and/or degraded mortar, or bulging surfaces.

Structural degradation can occur due to the following:

A. Movement and Displacement: Structural degradation of maintenance holes will occur with three dimensional displacement and movement. In areas where temperature variations are common, degradation of the frame seal, chimney and top portion of the cone can occur. Vertical separation can be dramatic, particularly where maintenance hole frame castings are monolithically encased with rigid and flexible pavement. Horizontal movement of the frame occurs as the encased frame reacts to the thermal expansion and contraction of the surrounding pavement caused by temperature variations. Three dimensional movement can also occur to the entire maintenance hole structure due to settlement and movement of the ground around the maintenance hole. This differential movement can be pronounced in certain clay or unstable soils. Such loading can impose unbalanced point loadings and increase tensile stress failures. Maintenance holes made of brick and block are particularly susceptible to displacement and joint separation where unstable soils exist. Traffic induced loads can result in three dimensional movement of the maintenance hole cover, frame and chimney section causing cracks and fractures. Strong ground shaking, lateral spreading or liquefaction as a result of seismic activity may also result in lateral and/or vertical displacement of the MH.

B. Corrosion Environments: When sulfides are present in the wastewater stream due to the natural biodegradation of the sewage, structural deterioration is likely to occur to all cementitious-based surfaces such as concrete or brick mortar. The factors that control sulfide generation are:

1. Wastewater velocity

2. Ambient water pH, and air temperature within the sewer system

3. Oxygen availability
4. High flows (reduced air space).

5. Hydraulic jumps / turbulent flows.

Under extreme conditions, total structural degradation of unprotected concrete and brick maintenance holes can occur in less than five years. Hydrogen sulfide structural degradation of a maintenance hole can be controlled through effective maintenance hole rehabilitation, although wider measures may also be appropriate to control the generation of the sulfides.

**F 945.15.1.2 EXCESSIVE EXTRANEOUS FLOW**

Recent studies have indicated that a significant percentage of identified extraneous flow is from defective maintenance holes. Factors which need to be considered when evaluating and quantifying potential extraneous flow from maintenance holes include:

- A. Ground saturation
- B. Water table fluctuations
- C. Inspection data on type and condition of maintenance hole

A relative ranking of several common maintenance hole extraneous flow sources that contribute to the problem of excessive wet weather flows are listed in Table F 945.15.1.2.

**Table F 945.15.1.2**

<table>
<thead>
<tr>
<th>Source Defect</th>
<th>Extraneous Flow Type</th>
<th>GPM Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vented Cover(^{(1)})</td>
<td>Inflow</td>
<td>1.0 - 3.0</td>
</tr>
<tr>
<td>Poor cover/rim fit</td>
<td>Inflow</td>
<td>0.1 - 5.0</td>
</tr>
<tr>
<td>Frame seal</td>
<td>Inflow</td>
<td>0.5 - 5.0</td>
</tr>
<tr>
<td>Cone(^{(2)})</td>
<td>Infiltration(^{(3)})</td>
<td>0.1 - 5.0</td>
</tr>
<tr>
<td>Wall(^{(2)})</td>
<td>Infiltration</td>
<td>0.1 - 2.0</td>
</tr>
<tr>
<td>Bench/trough</td>
<td>Infiltration</td>
<td>0.1 - 2.0</td>
</tr>
</tbody>
</table>

(1) Includes pickhole vent chips that are subject to ponding
(2) Priority brick, block, precast, cast-in-place
(3) Rainfall induced

With the consideration that most of our sewer lines that are part of the collection system benefit from some level of venting through the covers in that it prevents line pressurization as well as help reduce H2S concentrations, the small percentage of flows that do enter through covers is generally acceptable. There are instances where local flooding is a problem or high odor concerns exist such that the venting must be prevented. The Bureau of Sanitation's concern has been with those inflows occurring through the cone, wall, and bench areas, particularly after a storm event. As such, Std Plan S-150 requires the use of gasketed joints and taped joints along grade rings and near the base to reduce these inflows in large diameter MH.

F 945.15.1.3 MAINTENANCE

Conditions that hinder normal maintenance and operations of a collection system should be considered in maintenance hole rehabilitation. These conditions include:

A. Deteriorated maintenance hole steps (must be removed as they are no longer allowed)
B. Offset frames
C. Buried maintenance holes
D. Maintenance holes that are inaccessible due to location
E. Other utilities passing through maintenance holes
F. Non-structural problems that affect operations and maintenance access to the collection system.

1. Certain terminus maintenance holes may require increased viewing of the connected lines that its present base may not offer and as such, the base needs to be rehabilitated.
2. Existing MH hardware modification and/or removal may trigger the need to rehabilitate the MH in order to ensure its proper performance.
3. Existing MH size may no longer be adequate for performing maintenance of the adjoining line(s) including ability to lower cleaning equipment into the line.
4. Minimum finished inside MH diameter of 30 inches
5. Reconstruction of MH to conform with the required MH Frame and Cover size per Table F462.

F 945.15.2 REHABILITATION METHODS

The rehabilitation of maintenance holes can be divided into the following area:
F 945.15.2.1 CONTROL OF MH INFLOW AND INFILTRATIONS (I/I)

Inflow of stormwater or Infiltration from groundwater should be one of the first things to address when seeking rehabilitation a maintenance hole. Failure to do so can result in unnecessary increase in flow levels and treating of clean water. Also, it prevents further evaluation and repair of other degrading conditions in need of rehabilitation. Infiltration can occur from the lid down to the lowest joint connecting an in-line pipe with the MH. This may be due to a bad initial installation, deterioration of the MH walls, lateral movement, all combined with a high water table, or surface conditions that result in inadequate drainage near the footprint of the shaft.

Infiltration may take various forms such a constant gradual seepage through existing joints and/or cracks, or quite visible "active" leaks draining into the maintenance hole. While some nuisance infiltration may occur through a pick-hole of a MH lid, it is not acceptable to experience infiltration through the base of the cover or through the grade rings below it.

Addressing I/I begins with ensuring proper construction and installation of a maintenance hole. For existing structures, one may resort to a variety of methods both external and internal to stop these leaks. Below are some of the more typical methods employed.

F 945.15.2.1.1 EXTERNAL/INTERNAL JOINT/CHIMNEY SEALS

Today's market has multiple vendors who manufacture seals for externally or internal applications that seal a series of grade rings, or chimney sections so as to prevent I/I. Due to low water head demands, they need not be as robust as external wraps used along joint toward the bottom of the shaft. However, they must be durable enough to maintain their performance similar to a Type II liner. See Std Plan S-150 for a sample of required specifications.

F 945.15.2.1.2 CHEMICAL GROUTING

Chemical grouting systems have achieved success in reducing extraneous flows into maintenance hole structures. When applied properly, the process is a cost-effective option. Grouts do not add to the structural integrity of the maintenance hole. The success of grouts in reducing maintenance hole extraneous flows is largely dependent on:
A. Soils conditions
B. Groundwater conditions
C. Injection patterns
D. Gel time/grout mixture
E. Containment of excessive grout migration
F. Selection of the proper type of grout

There is a wide range of grouts on the market for pressure application. These include acrylamide, acrylate, acrylic, urethane gel, and urethane foam. (See F 945.1)

The common applications for pressure grouts are for:

A. Brick maintenance holes
B. Active extraneous flows
C. Structurally sound maintenance holes
D. Cohesive soils with optimal moisture content
E. To improve and fill voids or stabilize the surrounding soil

Careful inspection of the contractor's work during the actual grouting operation is essential to insure adequate grouting of the structure. A test program should be performed after grouting to verify proper maintenance hole sealing. Some considerations for high-pressure grouting applications are as follows:

A. Ambient air temperature above 40 degrees F
B. Chemically stable and resistant to acids, alkalis, and organics
C. Controllable reaction times
D. 15 percent shrinkage control
E. Viscosity of approximately 2 centipoise
F. Constant viscosity during injection period

Differing gel types should be considered for use on different areas and depths of the maintenance hole structure. This approach has been successfully applied in some projects, although other projects have been successful utilizing only one type of gel for all depths. For projects with varying gel types, urethane foams have been used in the upper 5 feet of the maintenance hole with urethane or acrylamide gels in the lower sections.

When grouting active inflows, one must be vigilant to reinspect the MH to ensure no new points of inflows have emerged.
F 945.15.2.2  STRUCTURAL RESTORATION OF EXISTING SUBSTRATE

Once any active infiltration has been arrested, structural restoration of the existing maintenance hole must be addressed. In general, the City relies on the concrete, brick, or pipe maintenance hole as the sole basis for the structural strength of the shaft. Liners or coatings are only intended to provide corrosion protection of the maintenance hole. Where the amount of damage is significant, a full inner poured-in-place casting maybe necessary provided it is justified by a life-cycle cost analysis. Alternatively, it may be more cost effective to replace the maintenance hole.

Various methods and systems are available when restoring the structural integrity of maintenance holes. Selection of the material may vary depending on the level of damage observed. However, it will initially depend on the maintenance hole’s construction material.

Brick MH:
Restoration of brick maintenance holes tend to be easily achieved and usually involved a localized area of the shaft. Most cases simply involve replacing missing, delaminated, and/or broken bricks and repointing the joints using a non-shrink high strength mortar, following the brick work depicted in S-141. On occasion, one may encounter elaborate brick work, particularly when connected to an adjacent brick structure. Even for the chimney area, the brickwork may follow a unique pattern to achieve the transition to the top of the shaft. As such, when this type of rehabilitation work is required, one should pay close attention to the existing brick work and make a note in the project documents if the need for a highly experienced mason will be required to perform the restoration.

On occasion, inspection may reveal severe structural damage such as large lateral displacement, wide fissures along the grout joints, and/or large voids where bricks have fallen away revealing soil behind. In such cases, it may be more economical to completely or partially replace the MH. Secure recommendations from the Structural Division in arriving at a final decision.

Concrete/Precast MH:
Restoration of a concrete maintenance holes can greatly vary in degree and complexity. Because the substrate is subject to the degrading effects of a sewer’s acidic environment, only a portion of the original wall thickness may be structurally sound. More traditional damage observed may include cracks and/or spalling, delamination, or simply offset joints due to unbalanced/seismic loading. If the shaft has reinforcement bars/wires, inconspicuous small cracks could result in significant spalling due to the corrosion of the steel. Repair of the above damage typically involves grinding and chipping of the unsound concrete, crack injection with suitable fillers, and patching with appropriately formulated repair products. Where clearly identifiable movement
and/shifting has occurred, it may necessitate complete or partial replacement of the MH.

F 945.15.2.2.1 ASSESSMENT

Proper assessment of a maintenance hole's current condition will enable one to properly identify the appropriate longer-lasting repair method. It will also yield the most cost effective solution in the long run as it will avoid using methods or materials that may address the damage observed but not the cause. When performing this assessment, the maximum care must be taken to ensure a safe work environment is maintained at all times. Assessments should only be done by experienced staff, or under their supervision.

Most assessments can be done from the surface using various tools and/or equipment. For general evaluations, the use of simple tools may suffice such as a mirror or bright flashlight and a long blunt object to sound the surface. For more detailed assessment, arrange for the use of a pole mounted camera and/or CCTV system. At no time should one cross the plane of the opening unless one intends to enter the maintenance hole following appropriate CalOSHA regulations for permitted confined space entry.

Upon completion, an assessment report must be prepared which includes and addresses the following items:

- Location, coordinates, and MH SIMM number, including nearest cross-street.
- Size of MH, size of cover, depth to invert or bench, and configuration (chimney vs flat top,), and whether it has an eccentric or concentric alignment.
- Material (Brick, Concrete, Clay Pipe, Plastic Pipe, etc.)
- Number, location and approximate size of lines being serviced by the MH.
- Describe horizontal location based on hour hand with 12 o'clock aligning with true North.
- General Condition and visual assessment of the following:
  - Presence of lining, if any, and its condition.
  - Proper seating of cover onto frame, and whether height adjustment is needed.
  - Evidence and location/depth of active infiltration
  - Displacement/offsets and its location/depth
  - Damage and location/depth of brick and/or mortar joints
  - Damage and location/depth of concrete surface
  - Presence of stairs, gas traps, other appurtenances
  - Condition of the maintenance hole base
- Evaluate the integrity of the MH walls by striking them with a blunt object (i.e. steel rod) without creating any sparks. A "ping" sound represents a solid substrate. A "thud" sound suggests damaged substrate or void below the surface.
- Secure pictures and video footage of damaged areas and inflows to the extent possible.
Also capture surface/roadway access and/or limitations for use in future project scoping.

Conducting the above assessment requires advanced planning, proper PPE, coordination with the Bureau of Sanitation to assist with traffic control & MH access, right-of-entry if applicable, and securing the appropriate tools and inspection equipment. Also, on occasion, one may encounter a maintenance hole that is actively venting. The venting may present a hazardous condition and at the very minimum make visibility inside the hole difficult. In such cases, terminate the assessment of that maintenance hole(s) until the Bureau of Sanitation can mitigate the issue.

**F 945.15.2.3 STRUCTURAL RECONSTRUCTION**

When localized repairs are extensive and/or not cost-effective to perform, maintenance hole reconstruction may be a viable alternative to full replacement. This typically signifies a structural rehabilitation of a maintenance hole is any method that totally restores its structural integrity through in-place, non-destructive methods. In-situ rehabilitation methods, such as poured-in-place concrete, have been used in a variety of applications. The application of reconstruction methods has been limited to the following conditions:

A. Standard maintenance hole dimensions, i.e. 48 inch inside diameter and larger  
B. Substantial structural degradation  
C. Accessible location  
D. Project size  
E. Life-cycle cost justification

The condition of most maintenance hole structures does not justify structural reconstruction on the sole basis of reducing and controlling extraneous flows -- reconstruction methods are not cost competitive with pressure grouting systems based on initial construction cost. Consideration should be given to a life-cycle cost analysis of reconstruction. As noted earlier, the City relies on the concrete, brick, or pipe maintenance hole as the sole basis for the structural strength of the shaft. Liners or coatings are only intended to provide corrosion protection of the maintenance hole.

Pour-in-place concrete method can be achieved using a temporary inner form and/or braced corrosion resisting liners. Alternatively, an approved pipe is used as a permanent inner form. A typical section through a rehabilitated maintenance hole is shown in Figure F 945.15.2.3.

General recommendations for structural reconstruction methods that need to be used are:
A. Minimum finished inside wall diameter of 36 inches
B. Six-bag (Type I or II) portland cement mix design
C. Minimum 28-day compressive strength of 3,500 psi
D. Minimum wall thickness of 3 inches for maintenance hole depths up to 10 feet, special analysis beyond 10 feet
E. Type V or II/V cement mixes preferred.

Any reconstruction should be designed to withstand the external pressures imposed by the groundwater. Vertical traffic/ground loadings will need to be carried by the existing maintenance hole structure, as it would be difficult to stand the lining on suitable foundations or provide sufficient thickness to carry the vertical loads without restricting the access size.

If vertical structural deterioration is the problem, total replacement may be the most economic solution. The economies of such rehabilitation depend on such factors as severity of chemical attack or corrosion, location, depth of maintenance hole and water table, number of maintenance holes requiring rehabilitation or replacement, and wastewater flow control measures needed.

In some situations, structural rehabilitation is not practical, and replacement is necessary. The details of maintenance hole construction are widely known, and replacement should always include safety and operational considerations. Additionally, replacement often is preferable to other rehabilitation measures where temperature fluctuations create special problems.

Rehabilitation should also include measures to ensure maintenance hole safety and efficient channel hydraulics. As such, any existing access ladder rungs and step must be completely removed. These are subject to corrosion and provide a false sense adequate support.

The efficiency of the present channel should also be evaluated. If the flow is restricted or if disturbances are causing extraordinary head losses, repair work should improve the hydraulic characteristics. The existing base may have to be partly removed and reconstructed to provide better geometry and/or surface finish. Flows must be plugged temporarily and quick-setting products used, or flows temporarily rerouted while the structure is being repaired. Flexible sleeves can also be used to contain flows during repair.

Another important consideration is the entry requirement of maintenance equipment. Cleaning tools, TV cameras, and in-line rehabilitation tools, such as grouting packers all require about 24 inches of straight pipe access. The channel should be built accordingly and self-cleaning
benching provided.

**F 945.15.2.4  CORROSION PROTECTION**

Maintenance holes subjected to corrosive atmospheres must be protected with a non-cement type coating or lining. The marketplace offers a variety of plastic, polymer, and epoxy coatings that are effective in protecting the maintenance hole walls from the corrosion of sulfuric acid. Bituminous coatings have not proven to be effective in corrosion control of maintenance holes. The effectiveness of corrosion protection is highly dependent on the preparation and cleaning of the substrate wall of the maintenance hole. As noted in Section F 945.10, Type I and Type II liners and coatings are available for the purpose providing the needed protection to these structures.

**F 945.15.2.5  MAINTENANCE HOLE LEAKAGE**

Leakage problems common with maintenance hole frames and covers include surface water entering through the holes in the cover, through the space between the cover and the frame, and subsurface water entering under the maintenance hole frame. As noted earlier, the Bureau of Sanitation found the level of inflows acceptable considering the benefit of the corresponding venting that occurs, except at locations prone to severe flooding.

Maintenance hole covers can be sealed by either replacing them with new watertight covers; by sealing existing covers through the use of rubber cover gaskets and rubber vent and pick hole plugs; or by installing watertight inserts under the existing maintenance hole covers. However, before proposing to seal a MH, consult with the Bureau of Sanitation.

The maintenance hole frame-chimney joint area can be sealed internally without excavation when frame alignment and chimney condition permit or either internally or externally when realignment or replacement of the frame or reconstruction of the chimney and/or cone requires excavation. This sealing can be achieved by either installing a flexible manufactured seal, designed for this purpose, or by applying a flexible material to either the surface of the chimney and frame or between the adjusting rings and under the frame.

The method used must not only be watertight but must also have the flexibility to allow for the
repeated movement of the frame through out the project's design life.
F 945.16 SEWER LATERAL REHABILITATION

Service lateral sewers are pipelines that branch off the sewer main and connect building sewers to the public sewer main. Lateral sewers may be as small as 4 inches in diameter, normally ranging from 15 to 100 feet in length.

Lateral sewers are built with any one of several BOE approved products and are usually laid at a minimum self-cleansing grade from the building to the immediate vicinity of the main sewer. At the main sewer, the grade may change abruptly in order for the line to descend to the main sewer. Lateral sewers normally enter sewer mains at angles ranging from 30 to 90 degrees from the axial flow direction and at vertical angles ranging from 0 to 90 degrees. Use of the same trench to route potable water service connections and the lateral sewer is not permitted.

The construction and maintenance of lateral sewers is complicated because separate agencies have jurisdiction over different portions of the sewers. The connection between the building's plumbing and drain system and the property line is often considered an extension of the infrastructure facilities; therefore, it is ordinarily installed under plumbing or building codes and tested and approved by plumbing officials or building inspectors. The section of the lateral sewer between the property line and the street sewer, including the sewer main connection, usually is installed under sewer use rules. Inspection and approval are the responsibility of the Department of Public Works. In addition, only materials pre-approved by the Bureau of Engineering, Engineer of Design, are permitted to be used within the Public Right-of-Way. Lastly, the City of Los Angeles Municipal Code indicates that the City's maintenance responsibility begins at the wye connection of the lateral to the City's main sewer. As such, maintenance, repair, and/or replacement of the lateral beyond the wye are the responsibility of the property owner.

F 945.16.1 REHABILITATION METHODS

While the responsibility for rehabilitation of laterals largely falls onto the property owner, only Department of Public Works Bureau of Engineering pre-approved products may be used. Alternatively, the property owner may seek to secure a project specific approval of a particular product. Some of the rehabilitation methods used for larger main sewers are also applicable for service laterals. These include chemical grouting, cured-in-place pipe lining, deformed pipe
lining, pipe bursting, and spray-on lining. The reduction in capacity imposed by conventional sliplining methods in smaller pipelines makes such rehabilitation an unlikely option.

Unlike rehabilitation of main sewers, access to lateral sewers can often be limited, making rehabilitation more difficult. This is often combined with the additional problems of tree roots, structures and landscaping over the sewers. However, these problems also have a greater impact on the conventional replacement systems.
F 946  MISCELLANEOUS METHODS AND MATERIALS

There are several relatively new rehabilitation methods and materials that are being introduced into the United States. Most of this technology has been developed internationally, is proprietary and is gradually being promoted into this country. The Design Standard and Investigation Group (DSIG), overseen by the Engineer of Design, is constantly evaluation various new products for inclusion into the Bureau of Engineer Approved Products List. Only requests from the manufacturer are evaluated -- third party representatives may not apply on behalf of a product they simply market and distribute. The process begins with the manufacturer submitting a formal signed request on company letterhead to the Engineer of Design requesting that their particular product be considered for inclusion into the Approved Products List. As a minimum, this cover letter must be accompanied by the following:

- Indication of use being requested (sewer, storm drain, both, laterals, maintenance holes, etc.)
- Full and detailed description of the product (one product per letter) with exact information of all constituent parts, materials, and components that make up the product
- Location of fabrication
- Indication of installation method intended (sprayed, sliplined, coiled in place, personnel entry required, etc.) and specific installation requirements.
- List of certified installers, their experience, training received and basis of certification, California Contractor License, etc.
- Documentation of testing performed so far.
- List of recent customers and contact information
- Sample design calculations if applicable.
- Small physical sample.

Each request is evaluated and a determination made of its relevance to the City's needs, of such frequency that it warrants a City-wide approval, and of such unique nature that a specialized approval is required. If the request is accepted, the applicant must open a materials B-permit, funded with the minimum amount identified by DSIG, and the process formally begins. The funds are needed to pay for the administrative costs of evaluating the product. Testing and associated costs are the responsibility of the applicant.
If the testing yield acceptable results, and all other documentation is satisfactory, the product is approved for a period of time, with opportunities for renewal. On occasion, it is necessary to only grant a conditional approval in order to verify aspects of the products that can only be evaluated during an actual project.
F 950  REHABILITATION LIFE PROJECTIONS

F 951  INTRODUCTION

Materials for pipeline rehabilitation projects are often selected based on the lowest initial cost of the alternatives. When the alternative materials have different life spans, the material with the lowest initial cost may not be the most economical choice if its expected service life is shorter than that of the other materials.

Alternative materials should be evaluated by using the least-cost analysis. This method equates the cost of materials that have different service lives. Least-cost and life-cycle analysis will be discussed in detail in Section F 970.

In order to accomplish a correct least-cost or life-cycle analysis, it is first necessary to develop the expected longevity of each replacement pipe and/or rehabilitation alternative. Tables found in the following sections provide projected service life values.

F 952  REPLACEMENT PIPE LIFE

Replacement pipe life projections are listed below for various pipe materials:

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>DIAMETER (inches)</th>
<th>PROJECTED LIFE (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitrified Clay Pipe</td>
<td>4-42</td>
<td>75</td>
</tr>
<tr>
<td>Reinforced-Concrete-Pipe (with PVC liner)</td>
<td>42-120</td>
<td>50</td>
</tr>
<tr>
<td>Plastic Pipe</td>
<td>4-60</td>
<td>50+</td>
</tr>
<tr>
<td>Stainless Steel Pipe (Pumping Plants, requires special approval)</td>
<td>4-120</td>
<td>25 to 35</td>
</tr>
<tr>
<td>Ductile Iron (Force Main)</td>
<td>4-60</td>
<td>40 (50)</td>
</tr>
</tbody>
</table>

Note: The projected life values are based on proper design, construction, inspection, and maintenance of the facility, under normal (non-exacerbating/acute) conditions.

See Section 400 for a discussion of these pipe materials.
F 953   REHABILITATION MATERIALS

Rehabilitation pipe material life projections are listed below for each alternative.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Wall Design</th>
<th>Diameters (inches)</th>
<th>Projected Life (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyethylene</td>
<td>Solid</td>
<td>4-63*</td>
<td>50</td>
</tr>
<tr>
<td>Polyethylene</td>
<td>Corewall</td>
<td>18-72</td>
<td>50</td>
</tr>
<tr>
<td>Polybutylene</td>
<td>Solid</td>
<td>3-42*</td>
<td>50</td>
</tr>
<tr>
<td>Polyvinyl Chloride</td>
<td>Solid</td>
<td>4-36</td>
<td>50</td>
</tr>
<tr>
<td>Ductile Iron (FM)</td>
<td>Solid</td>
<td>4-60</td>
<td>40 (50)</td>
</tr>
<tr>
<td>Steel (Stainless)</td>
<td>Solid</td>
<td>4-120</td>
<td>10 (40)</td>
</tr>
<tr>
<td>Cured-in-place pipe</td>
<td>Composite</td>
<td>4-108</td>
<td>50</td>
</tr>
<tr>
<td>Reinforced Polymer Mortar Pipe</td>
<td>Composite</td>
<td>24-78</td>
<td>50</td>
</tr>
<tr>
<td>Ultra Violet Cured-in-place pipe</td>
<td>Composite</td>
<td>6-54</td>
<td>50</td>
</tr>
<tr>
<td>Polypropylene Pipe</td>
<td>Fused Layer</td>
<td>12-60</td>
<td>50</td>
</tr>
</tbody>
</table>

* Nominal outside diameters. All others are based on nominal inside diameters.

Note: The projected life values are based on proper design, construction, inspection, maintenance and operation.

Ductile iron pipe has excellent long term longevity. The selection of cement or polylining should be determined by the sewer corrosivity.

Steel pipe has excellent structural characteristics and can be varied in thickness. Steel does have low corrosion resistance, therefore it has been given a projected ten year life. In general, exposed unprotected/uncoated steel should not be used in sewer environments.

Certain grades of stainless steel (Series 300) have excellent corrosion resistance features and should be evaluated under some conditions. However, under highly aerated conditions, the projected life can be no better than 15 years or less.
Rehabilitation material life projections are listed below for each alternative.

### Table F 953B

<table>
<thead>
<tr>
<th>Material</th>
<th>Projected Life (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chemical Grouting:</strong></td>
<td></td>
</tr>
<tr>
<td>Acrylamide</td>
<td>20</td>
</tr>
<tr>
<td>Acrylic</td>
<td>20</td>
</tr>
<tr>
<td>Acrylate</td>
<td>20</td>
</tr>
<tr>
<td>Urethane</td>
<td>20</td>
</tr>
<tr>
<td>Urethane Foam</td>
<td>20</td>
</tr>
<tr>
<td><strong>Reinforced Shotcrete:</strong></td>
<td>--</td>
</tr>
<tr>
<td>Concrete</td>
<td>--</td>
</tr>
<tr>
<td><strong>Panelized Liners:</strong></td>
<td></td>
</tr>
<tr>
<td>Fiberglass Reinforced Plastic (FRP)</td>
<td>50*</td>
</tr>
<tr>
<td>Reinforced Plastic Mortar (RPM)</td>
<td>50*</td>
</tr>
<tr>
<td>Polyethylene</td>
<td>50</td>
</tr>
<tr>
<td>Polyvinyl Chloride</td>
<td>50</td>
</tr>
<tr>
<td>Steel (Stainless)</td>
<td>10 (40)</td>
</tr>
</tbody>
</table>

| Coatings and Linings              | **                      |
| Mechanical Sealing Devices        | **                      |

* Use of vinylester coating assumed

** Case-by-case basis

Note: The projected life values are based on proper design, construction, inspection, maintenance and operation.

Note: Reinforced shotcrete and concrete will degrade rapidly, therefore annual assessment of the sewers shall be conducted. Replacement or rehabilitation of the system with a material of adequate life expectancy shall be pursued immediately.
F 960 EVALUATION ASSESSMENTS

F 961 INTRODUCTION

The goal of rehabilitation work on sewers is to repair damage, to renew service life and, arrest future deterioration. There is also an option of deferring rehabilitation until the risk of collapse is unacceptable. Acceptable risk depends on many factors, external and internal to the sewer. This assumes sewers do not normally fail suddenly, without first showing signs of distress. In this case, scheduled monitoring of the system and documenting the progress of the deterioration is necessary. Due to the reality of limited available funds, the expenditure of construction funds is sometimes delayed until there is a risk of losing rehabilitation options as a result of increasing pipeline degradation.

The decision on which approach to take is directly dependent on the level of information available on the sewer system, and on the level of financing that can be provided for sewer rehabilitation.

Based on the information readily available such as CCTV, sewer information from as-built plans, and correlation of similar infrastructure the sewers’ physical conditional are assessed. The Bureau of Sanitation is responsible for conducting CCTV of the sewers and performing the sewer condition assessments from the CCTV when available. Table F961A, Sewer Condition Categories, is used to assess secondary and primary sewers of various sizes. The large critical diameter sewers are assessed per Table F961B, Large Diameter Sewer Condition Assessment.

Beyond the physical conditions of a particular sewer pipe, alignment, basin, etc, assessment can also incorporate other non-physical factors when establishing a Program-based ranking of sewer rehabilitation projects. The need for such ranking is intended to aid in decision making when leveraging limited resources, financial or otherwise, against the demands on the program. To this end, the Clean Water Program has established a ranking system through the designation of a Risk Score to each project. A risk score is based upon eight factors and used to determine project prioritization. Each of the factors is weighted based upon importance. For a complete discussion on Risk Scores, refer to the Project Prioritization Criteria Definitions found at the following location via the City's Intranet: http://san.ci.la.ca.us/fmd/prwcip.htm
### TABLE F 961A

<table>
<thead>
<tr>
<th>Category</th>
<th>Condition Description</th>
<th>Action Identified</th>
</tr>
</thead>
</table>
| A | Very Good  
  • Condition is almost like a new sewer pipe. | No Repairs  
  Future routine inspections 25 years |
| B | Good  
  • Light localized cracks  
  • Light localized corrosion  
  • Light localized roots | No Immediate Repairs except B-Root reaches may be lined  
  Routine Maintenance Program  
  Schedule next inspection in the order of sewer system priority (15 years). |
| C | Fair  
  • Moderate cracks/fractures  
  • Moderate continuous corrosion  
  • Moderate continuous infiltration  
  • Moderate continuous roots | Repairs as needed for C-Concrete  
  and C-Root reaches  
  Includes planning, environmental documentation, technical investigations, design, reviews, bid and award following established priorities. |
| D | Poor  
  • Severe cracks/fractures  
  • Broken pipes with holes  
  • Severe corrosion  
  • Severe infiltration/roots | Repairs  
  Includes regular bid and award, fast track construction, accelerate planning/design, and close monitoring to avoid emergency. |
| E | Emergency  
  • Collapsed pipe/street  
  • Dirt Pipe  
  • Crown of pipe is gone  
  • Void in backfill  
  • Full flow obstruction/blockage. | Emergency Repairs  
  Initiate Special Order Procedure “Urgent Necessity” |

**Notes:**  
1. All televised sewers are ranked on a priority point per foot basis according to the severity of their defects. The ranking list is further subdivided into categories to identify the urgency of the corrective work needed.  
2. The identification and ranking procedures are designed to err on the side of safety. Certain defects receive a high number of points to move them into the emergency category and to target them for immediate review. For example, upon discovery, a perceived emergency condition although questionable should be placed into Category E for immediate review by the P.E. in charge of emergencies.  
3. Upon verification of an emergency condition, Special order Procedures for emergency sewer repair work are initiated. If it is determined to not be an emergency the condition is upgraded to Category D. Once the emergency repair is completed, the repaired sewer is ranked according to the remaining defects.  
4. Category E condition sewers must be repaired as quickly as possible and therefore shall not be included on a priority list of pending projects.
### TABLE F 961B

**Large Diameter Sewer Condition Assessment**

<table>
<thead>
<tr>
<th>CCTV Rank</th>
<th>Condition Description</th>
<th>Recommended Action/Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Very Good Condition</td>
<td>Re-CCTV in 15 years.</td>
</tr>
<tr>
<td></td>
<td>• Condition is almost like new sewer pipe.</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Good Condition</td>
<td>Re-CCTV in 10 years.</td>
</tr>
<tr>
<td></td>
<td>• Light localized cracks.</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Fair Condition</td>
<td>Re-CCTV in 5 years.</td>
</tr>
<tr>
<td></td>
<td>• Moderate cracks/fractures.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Light corrosion.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Moderate infiltration.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Surcharge debris at crown.</td>
<td></td>
</tr>
<tr>
<td>D-3</td>
<td>Poor Condition</td>
<td>Re-CCTV in 3 years*, pre-design in 2-4 years** and schedule construction to start within 6-10 years.</td>
</tr>
<tr>
<td></td>
<td>• Reached life expectancy: 60-100 years old</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Severe cracks/fractures.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Moderate mortar corrosion.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Spalling of Bricks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Delamination</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Black discoloration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Bricks are crumbling</td>
<td></td>
</tr>
<tr>
<td>D-2</td>
<td>Very Poor Condition</td>
<td>Re-CCTV in 1-2 years, pre-design in 1-2 years**, and schedule construction to start within 5-6 years.</td>
</tr>
<tr>
<td></td>
<td>• Reached life expectancy: 100-125 years old</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Heavy to severe corrosion.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Large areas with tile missing.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Corrosion almost to rebar.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Cracks on Bricks and/or Mortar.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Missing Bricks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Shape Deformation.</td>
<td></td>
</tr>
<tr>
<td>D-1</td>
<td>Critical Condition</td>
<td>Re-CCTV within 1 year, pre-design in 1 year, and schedule construction to start within 3-5 years.</td>
</tr>
<tr>
<td></td>
<td>• Reached life expectancy: 125-150 years old</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Severe corrosion throughout.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Few areas with tile remaining.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Exposed rebar.</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Emergency Condition</td>
<td>Repair immediately</td>
</tr>
<tr>
<td></td>
<td>• Collapsed pipe/street.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Broken pipe with holes.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Dirt Pipe</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Crown of pipe is gone.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Void in backfill around pipe.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Full flow obstruction or blockage.</td>
<td></td>
</tr>
</tbody>
</table>

* For brick & Brick/Concrete Sewers Re-CCTV in 2 years.
** Unless otherwise directed by WESD Division Manager and approved by PRC to start pre-design sooner.
F 962 MONITOR

The purpose of this approach is to gather additional information to justify and support a decision to either rehabilitate or stabilize the existing sewer. By verifying the quality of the piping and the competence of the soil around the sewer, a proper plan can be formulated that provides, as a minimum, the stabilization of the sewer. Conversely, if problems are discovered through additional data collection, a higher level of rehabilitation may be necessary.

Various strategies and methods exist to achieve the intent of this approach. But in general, information gathering must be done in a methodical manner by formulating a logical procedure that accounts for the ranking listed above. Typically, this involves scheduled inspections, the monitoring of a sewer's performance (i.e. flow rates, gas concentrations, etc), and if need be, secure physical measurements, sampling, etc, which would be critical for design. The information gathered is inventoried for planning purposes in the capital program.

Currently, the Bureau of Sanitation is responsible for the collection systems' operation and maintenance. This also includes future planning and the monitoring of the existing system. As such, they are intrinsically involved evaluating available information and making the initial assessment of a sewer. Projects needing attention are then earmarked for possible rehabilitation projects to be designed by the Bureau of Engineering.

Some of the monitoring methods and equipment used are closed circuit televising, laser and sonar profiling, drones, gas meters, flow meters, and similar technologies.
F 963  STABILIZE

Stabilizing can include point (spot) repair of failed or failing pipe, and/or stabilization of pipe soil environment, and cost effectively extend the useful life of an existing sewer pipeline. Point repair is the replacing of a collapsed or seriously fractured pipe length in one or more areas between maintenance holes, in lieu of total pipeline rehabilitation or replacement. This alternative stabilizes the pipeline at those particular areas of distress. Once an initial point repair program is accomplished, subsequent repair would be done in response to new or deteriorating defects discovered during subsequent inspections. It is normally more cost effective to proceed to rehabilitation, coincidental with the initial point repair, for the entire pipeline, if it is warranted.

The general stabilization alternative may also include the modification and stabilization of soil around the pipeline. This work is intended to restore soil competence around the sewer and produce the uniform circumferential loading that favors the strengths of a pipe. The need for this work will be determined from the findings of the information gathering effort. Since the results of this work influence the load carrying capacity of the pipe, cement or chemical grout stabilization could be appropriate.

F 964  REHABILITATE

When the pipelines are found to have corrosion, breaks or fractures, or unsound materials and other signs of excessive loading or deterioration, an effort greater than stabilization is required to provide confidence in their future serviceability. Rehabilitation is the next level of effort and involves various lining systems constructed within the existing sewer (See F 942). The rehabilitation system can be designed to provide corrosion protection and certain levels of tolerance under structural duress (See tables this Subsection). Some rehabilitation methods can be designed to structurally support the soil loading conditions with or without the remaining strength of the existing pipe. Other rehabilitation methods require the composite support of the existing pipe. The pipeline size and environmental factors, such a accessibility, impact on current service requirements, etc. all influence the choice of a rehabilitation method or system. The selection criteria and screening will be discussed in Section F 970.
The following tables list the criteria to select acceptable rehabilitation methods for condition of existing pipe and pipeline. Condition I applies to unprotected concrete surfaces that have experienced surface corrosion with aggregate exposed, and minor cracks or fractures having no pipe wall displacement. In the event joints are leaking, or open, with minor displacement, chemical grouting or mechanical sealing devices may be used. It should be noted that point (spot) repair is normally used at needed locations. Also, total replacement may be considered desirable, but is usually unnecessary at this point.

Under Condition I, the following rehabilitation methods/materials may be appropriate:

**INTERNAL REHABILITATION**

**CONDITION I**

a. Reinforced Shotcrete

b. Concrete Placement

c. Segment Liners

1. Fiberglass Reinforced Cement
2. Fiberglass Reinforced Plastic
3. Reinforced Plastic Mortar
4. Polyethylene (sheets)
5. PVC (sheets)

d. Continuous Pipe

1. PE Pipe (extruded)
2. Pb Pipe (extruded)
3. PP Pipe (extruded)
e. Short Pipe:

   1. PE Pipe (external profile)
   2. PE Pipe (internal profile)
   3. PVC Pipe
   4. RPM Pipe
   5. FRP
   6. DIP (cl)
   7. DIP (pl)
   8. Steel Pipe

f. Inversion Lining (CIPP)

g. Deformed Pipe:

   1. Deformed HDPE
   2. Folded PVC
   3. Thermal Reduction Process

h. Spiral Wound Pipe

   1. PVC Lining System

i. Coatings and Linings

j. Spot (point) Repair

k. Trenchless Replacement

l. Replacement

Condition II applies to unprotected concrete surfaces that have experienced corrosion where steel reinforcement is exposed. Also, cracks or fractures having minor displacement may be rehabilitated. It should be noted that point (spot) repair is normally used at needed locations. Also, total replacement may be considered desirable.

Under Condition II, the following rehabilitation methods/materials may be appropriate:
INTERNAL REHABILITATION
CONDITION II

a. Reinforced Shotcrete
b. Concrete Placement
c. Continuous Pipe
   1. PE Pipe (extruded)
   2. Pb Pipe (extruded)
   3. PP Pipe (extruded)
d. Short Pipe
   1. PE Pipe (external profile)
   2. PE Pipe (internal profile)
   3. PVC Pipe
   4. RPM Pipe
   5. FRP Pipe
   6. DIP Pipe (pl)
e. Spiral Wound Pipe
   1. PVC Lining System
f. Inversion Lining (CIPP)
g. Point (spot) Repair
h. Trenchless Replacement
i. Replacement

Condition III applies to unprotected concrete surfaces that have experienced corrosion where in some locations steel reinforcement is missing or holes through the wall exist. Also, cracks or fractures having serious displacement, and holes or slab-outs occurring in the wall can normally be rehabilitated. The existing pipeline will require pulling a TV Camera or slipliner proofing section through the line, verifying available cross section to rehabilitate. It should be noted that point (spot) repair is normally required in addition to total rehabilitation. Also, total replacement may be considered more desirable. The life cycle and cost effectiveness comparison shall be discussed in detail in Section F 970.
Under Condition III, the following rehabilitation methods/materials may be appropriate:

**INTERNAL REHABILITATION**

**CONDITION III**

a. Continuous Pipe  
   1. PE Pipe (extruded)  
   2. Pb Pipe (extruded)  
   3. PP Pipe (extruded)

b. Short Pipe  
   1. PE Pipe (internal profile)  
   2. RPM Pipe  
   3. DIP (pl)

c. Spiral Wound Pipe  
   1. PVC Lining System *

d. Inversion Lining (CIPP)

e. Point (spot) Repair

f. Trenchless Replacement

g. Replacement

* Person-Entry pipe only - Structural preparation may be required depending on magnitude of holes.

** Depends on magnitude of holes.

**F 965**  

**REPLACEMENT**

When the pipelines are found to be beyond repair and/or rehabilitation, utilizing any of the methods, then total replacement is recommended. Normally this condition exists at specific locations and point repair or rehabilitation may be the most cost effective measure in the remaining system. Where pipelines that are determined to be hydraulically overloaded, and upgrade rehabilitation will not improve the flow condition, pipeline replacement or relief line construction is recommended.
METHOD SELECTION PROCEDURES

SPECIFIC APPLICATIONS

The methods employed for repairing or rehabilitating a leaking or failing pipe or pipeline system are contingent upon various parameters of the existing system. For example, pressure and non-pressure pipelines will require different methods, procedures and timing in accomplishing the remedial work.

Type and location of service will also have heavy impact on procedures and/or methodology employed in doing the repair. A large diameter pipeline, (e.g. sewer force main or gravity sewer), could have major environmental impact and any threat of failure usually requires immediate resolution. A small diameter pipeline at an extremity of the system is important, but the urgency of repair is not as significant. Pipeline operation and maintenance must be understood and properly managed to carry out repairs or rehabilitation. The major collection, transfer, and/or receiving points must be operated and controlled in a satisfactory manner during construction. Emergency and contingency plans must be worked out in advance and able to be put in operation at a moment's notice. The need for providing ongoing service cannot be overemphasized.

SELECTION CRITERIA

When it is determined that a sewer pipeline requires some work in order to keep it functioning satisfactorily for its intended purpose, it is necessary to evaluate all possible construction methods to accomplish the needed repair.

The selection criteria used for proper evaluation of the various methods shall include any viable rehabilitation and replacement alternative.

The selection process is accomplished through evaluation procedures as follows:

a. Screening
b. Life-cycle considerations
c. Least-cost analysis

These procedures will be discussed in detail in the following Subsections.
The initial screening of rehabilitation methods is discussed in Subsection F 964. After the pipeline condition is determined and the problem(s) identified, various methods can be considered viable if they are compatible with the developed degradation criteria.

The next series of screening criteria is listed below:

a. **Hydraulics:**
   1. Size reduction
   2. Pipe Shape or geometry
   3. Initial impact
   4. Long Term impact

Note: The Manning "n" value for sewers flowing $d/D = 0.50$ has been set at 0.014 for VCP, RCP, PVC lined RCP and all plastics (new or rehabilitated).

b. **Structural**
   1. External loadings
   2. Internal loadings
   3. Grouting annulus

c. **Corrosion:**
   1. $\text{H}_2\text{SO}_4$ resistance requirement
   2. Other.

Note: See Greenbook Section 2.10 - 2.3.3.

d. **Constructability:**
   1. Work activity on pipe/pipeline
   2. Bypass-Internal/External/None
   3. Access
   4. Groundwater impact
   5. Preparation of existing pipeline
   6. Right-of-Way needs
   7. Safety
   8. Other utility considerations
9. Traffic impact
10. Time required
11. Irregularities of existing pipe/pipeline
12. Ease of service connections
13. Inspection

e. Material Considerations:
   1. Proven technology
   2. Competitive alternatives
   3. Availability
   4. Quality control
   5. Longevity considerations
   6. Repairability
   7. Abrasion resistance
   8. Safety
   9. Cleaning needs
  10. Mobilization
  11. Inspection.

f. Benefit/Impact:

   1. Delay relief pipeline need
   2. Affect on future rehabilitation

g. Installation Rate

h. First Cost:
   1. Material
   2. Installation.

i. Design Life

j. Life-Cycle Evaluation:
   1. Cost effectiveness
   2. Life-cycle considerations
   3. Least-cost analysis

A rating system must be developed to compare the viability of various rehabilitation methods. The various screening categories will normally be very similar when comparing projects, however, with experience and location knowledge, the rating system on priorities may change. The viability of some alternatives will be obvious when compared to others for a given situation on a project. The rating system should be developed for the first seven items. The cost, design
life and life-cycle evaluation items should be analyzed after the rehabilitation list has been reduced to those that are viable. Normal practice is also to analyze replacement on all projects for comparison, unless it is obviously impractical for use, normally due to environmental constraints.

F 974 LIFE-CYCLE CONSIDERATIONS

Life-cycle costing is a method of calculating the total project cost over the life of the project, including the initial cost, operation and maintenance costs, and replacement costs. It is an especially good method for comparing costs of projects that have high operation and maintenance costs, or high replacement costs. Life-cycle costing compares total cost by converting all costs over the planning period to present worth in a common base year or to annual costs.

This method can be effectively used for comparing costs of pipeline repair, replacement, and rehabilitation over the planning period (project life). The repair alternative usually involves high annual costs. Rehabilitation and replacement involve higher initial cost, but lower operation and maintenance costs, and are generally more cost effective.

Experience with pipeline rehabilitation has generally been limited to the past 25 years, with increasing intensity during the past 10 years. The confidence in projecting longevities with plastics is lower than with the more conventional, historically used materials. (This was addressed in Section F 950, in detail.) Estimates accepted for longevities of the various materials will be critical to the results of life-cycle costing. Equally critical is the proper evaluation and use of tangible and intangible project cost items. These various factors are listed below.
Table F 974A
FACTORS TO EVALUATE - TANGIBLE ITEMS

<table>
<thead>
<tr>
<th>Inspection</th>
<th>Construction Time</th>
<th>As-Built Drawings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering</td>
<td>Construction Cost</td>
<td>Mapping</td>
</tr>
<tr>
<td>Rights-of-Way</td>
<td>Business Disruption</td>
<td>Rehabilitation Options</td>
</tr>
<tr>
<td>Easements</td>
<td>Mobilization</td>
<td>Service Laterals</td>
</tr>
<tr>
<td>Other Utilities</td>
<td>O &amp; M Savings</td>
<td>Materials</td>
</tr>
<tr>
<td>Cost to Business</td>
<td>Detour Costs</td>
<td>Material Storage</td>
</tr>
<tr>
<td>Cost to Government</td>
<td>Flow Bypassing Cost</td>
<td>Dewatering Cost</td>
</tr>
</tbody>
</table>

Table F 974B
FACTORS TO EVALUATE - INTANGIBLE ITEMS

<table>
<thead>
<tr>
<th>Noise</th>
<th>Pedestrian Inconvenience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety (pedestrians &amp; vehicular)</td>
<td>Traffic Inconvenience</td>
</tr>
<tr>
<td>Dust/Dirt</td>
<td>Settling of Curbs</td>
</tr>
<tr>
<td>Road Surface</td>
<td>Bidding Environment</td>
</tr>
<tr>
<td>Road Settlement</td>
<td>Telephone Complaints</td>
</tr>
<tr>
<td>Chuck Holes</td>
<td>Liability Exposure</td>
</tr>
<tr>
<td>Parking</td>
<td>Emergency Vehicles</td>
</tr>
<tr>
<td>City Reputation</td>
<td>Bus Rerouting</td>
</tr>
</tbody>
</table>

The direct and indirect cost to a pipe project of each of the tangible items are normally incorporated in a comparison of the various rehabilitation methods vis à vis that of replacement. The general relative first cost comparison is made between pipeline rehabilitation and replacement, as shown below. These comparisons are made for a pipeline experiencing a Condition II status. (See Subsection F 964)
## Table F 974C

**COST COMPARISON**

<table>
<thead>
<tr>
<th>Tangible Item</th>
<th>Rehabilitation</th>
<th>Replacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Engineering</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Rights-of-Way</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Easement</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Other Utilities</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Cost to Business</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Cost to Government</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Construction Time</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Construction Cost</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Business Disruption</td>
<td>x</td>
<td></td>
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<tr>
<td>Mobilization</td>
<td>*</td>
<td>*</td>
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<tr>
<td>O &amp; M Savings</td>
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<td>x</td>
</tr>
<tr>
<td>Detour Costs</td>
<td>x</td>
<td></td>
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<tr>
<td>Flow Bypassing Costs</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>As Built Drawings</td>
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<td></td>
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<td>Mapping</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Rehabilitation Options</td>
<td>**</td>
<td></td>
</tr>
<tr>
<td>Service Laterals</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Materials</td>
<td>*</td>
<td>*</td>
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<tr>
<td>Material Storage</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Dewatering Cost</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

- **x** Normally least cost
- ***** The various rehabilitation alternatives vs replacement (Rehab cost can vary between 50% & 150%)
- **** More viable rehabilitation alternatives reduce cost and induce competition.
### Table F 974D
COMPARISON EDGE

<table>
<thead>
<tr>
<th>Intangible Item</th>
<th>Rehabilitation</th>
<th>Replacement</th>
</tr>
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<tbody>
<tr>
<td>Noise</td>
<td>z</td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td>z</td>
<td></td>
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<tr>
<td>Dust - Dirt</td>
<td>z</td>
<td></td>
</tr>
<tr>
<td>Road Surface</td>
<td>z</td>
<td></td>
</tr>
<tr>
<td>Bus Rerouting</td>
<td>z</td>
<td></td>
</tr>
<tr>
<td>Emergency Vehicles</td>
<td>z</td>
<td></td>
</tr>
<tr>
<td>Parking</td>
<td>z</td>
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</tr>
<tr>
<td>City Reputation</td>
<td>z</td>
<td></td>
</tr>
<tr>
<td>Pedestrian Inconvenience</td>
<td>z</td>
<td></td>
</tr>
<tr>
<td>Traffic Inconvenience</td>
<td>z</td>
<td></td>
</tr>
<tr>
<td>Road Settlement</td>
<td>***</td>
<td></td>
</tr>
<tr>
<td>Settling Curbs</td>
<td>***</td>
<td></td>
</tr>
<tr>
<td>Bidding Environment</td>
<td>z</td>
<td></td>
</tr>
<tr>
<td>Telephone Complaints</td>
<td>z</td>
<td></td>
</tr>
<tr>
<td>Chuck Holes</td>
<td>z</td>
<td></td>
</tr>
<tr>
<td>Liability Exposure</td>
<td>z</td>
<td></td>
</tr>
</tbody>
</table>

z Normally has edge

*** Some authorities indicate a trench in a paved area reduces pavement life by one half to two-thirds. Also, curbs have a tendency to displace during and after trenching, causing cracks, etc.
F 975 LEAST-COST ANALYSIS

The well established principle of present value has been used for several decades by engineers to perform economic comparison analysis. The method, however, has certain vulnerabilities because of the assumptions that must be made about future interest and inflation rates.

Historical relationships between interest rates and inflation provide meaningful information. In the short run the volatility of interest and inflation differences can be significant. The two rates interact and influence each other so that in the long run they tend to move together, resulting in a relatively constant differential between the two. The planning period, i.e., 50 to 75 years, tends to balance these differences and in municipal work the inflation/interest ratio has been 0.9953 (See Formula) over the past 35 years.

The inclusion of indicators of inflation and interest rates over the life of the project allow for the adjustments described above. The following formula is used for calculating the effective current cost (or present value cost) of a material.

\[
ECC = P_o + P_r \left( \left[ \frac{1 + I}{1 + i} \right]^n + \left[ \frac{1 + I}{1 + i} \right]^{2n} + \ldots + \left[ \frac{1 + I}{1 + i} \right]^{mn} \right) + M_j \left[ \frac{1 + I}{1 + i} \right]^j + M_{j+1} \left[ \frac{1 + I}{1 + i} \right]^{j+1} + \ldots + M_{j+n} \left[ \frac{1 + I}{1 + i} \right]^{j+n}
\]

where:
- \( ECC \) = Effective current cost, $ (i.e., present value)
- \( P_o \) = Original material and installation cost, $
- \( P_r \) = Future replacement cost (current $), $
- \( I \) = Inflation rate, % (average rate over the life)
- \( i \) = Interest rate, % (average rate over the life)
- \( n \) = Usable material service life, year (See F 950)
- \( m \) = Number of times material would require replacement over the design life.
- \( M_j \) = Estimate maintenance cost (current) in the year j, $
- \frac{1 + I}{1 + i} = 0.9953

Note: The need for maintenance (\( M_j \)) generally starts 5 to 10 years after new construction.

This equation, when applied to each material (i.e., replacement and rehabilitation) under consideration, provides a ready means of equitable comparison between the alternatives (See F 940 and F 950). The following table provides an example of the various items for comparing replacement and rehabilitation alternatives.
Table F 975
Least Cost Analysis of Pipeline Rehabilitation Alternatives

<table>
<thead>
<tr>
<th></th>
<th>Alt. 1</th>
<th>Alt. 2</th>
<th>Alt. 3</th>
<th>Alt. 4</th>
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</thead>
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<tr>
<td>Inflation/Interest Ratio</td>
<td>0.9953</td>
<td>0.9953</td>
<td>0.9953</td>
<td>0.9953</td>
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<tr>
<td>Project design life, yr.</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>Est. service life, yr.</td>
<td>20</td>
<td>50</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>No. replacements required</td>
<td>3.75</td>
<td>1.5</td>
<td>1.5</td>
<td>1</td>
</tr>
<tr>
<td>Original cost</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Replacement Cost (curr. $)</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Effective Current Cost</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Rank (1 is lowest ECC)</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

F 976 INSPECTION

The purpose of inspection is to insure that the work is performed as specified in the contract and that results are achieved as expected by the City. The expected success of any pipeline rehabilitation/replacement project normally requires coordination between the Inspector and the Design Engineer. The intent of the Engineer's work shall not be circumvented in the field by the contractor and/or the inspector. When field conditions vary somewhat from those characterized in the plans and specifications, certain field modification may be required. These field changes shall be coordinated with the Design Engineer.
# LIST OF FIGURES

<table>
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<th>FIGURE NO.</th>
<th>TITLE</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
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<td>Figure 911 A</td>
<td>Detailed Investigation Flow Chart</td>
<td>Nov-2020</td>
</tr>
<tr>
<td>Figure 911 A</td>
<td>Detailed Investigation Flow Chart (Continued)</td>
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<tr>
<td>Figure 911 B</td>
<td>Cursory Investigation Flow Chart</td>
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<td>Internal Grouting Equipment</td>
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<tr>
<td>Figure F 945.2</td>
<td>Internal Grouting of Large Diameter Pipe Joints</td>
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<td>Figure F 945.3</td>
<td>Gunite/Shotcrete Wall Construction</td>
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<td>Figure F 945.4</td>
<td>Traditional Slip Lining</td>
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<tr>
<td>Figure F 945.5</td>
<td>Welding In Trench</td>
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<tr>
<td>Figure F 945.6</td>
<td>Insertion Method For Slipping With Short Pipes</td>
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<tr>
<td>Figure F 945.7</td>
<td>Cured-In-Place Pipe Installation</td>
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<tr>
<td>Figure F 945.8</td>
<td>Deformed Pipes</td>
<td></td>
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<tr>
<td>Figure F 945.11</td>
<td>Mechanical Seal</td>
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<tr>
<td>Figure F 945.13.1</td>
<td>Pipe bursting - Typical Layout</td>
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<td>Figure F 945.13.2A</td>
<td>Microtunneling (Auger System)</td>
<td></td>
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<tr>
<td>Figure F 945.13.2B</td>
<td>Microtunneling (Slurry System)</td>
<td></td>
</tr>
<tr>
<td>Figure F 945.13.3.1</td>
<td>Direction Drilling</td>
<td></td>
</tr>
<tr>
<td>Figure F 945.15</td>
<td>Typical Section Through Maintenance Hole Rehabilita-</td>
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</tr>
<tr>
<td>Figure F 945.15.2.3</td>
<td>Typical Section Through Rehabilitated Maintenance Hole</td>
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</tr>
<tr>
<td>APPENDIX A</td>
<td>FORMULAE AND SAMPLE CALCULATIONS</td>
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</tr>
<tr>
<td>APPENDIX B</td>
<td>SPECIFICATIONS</td>
<td></td>
</tr>
</tbody>
</table>
Phase I, Planning Investigations

Review System Records
Categorize Sewers
Identify Primary Sewers
Document Performance
Is detail investigation necessary?
Yes
Select detail investigation establish priorities
Improve system records and access
No
Select cursory investigation

See Figure 911-B

Phase II, Inspection Program

Assess system condition
Assess inflow/infiltration condition (Phase IIA)
Flow monitoring
Quality and quantify extraneous flows
Assess structural condition (Phase IIB)
Evaluate corrosion condition, etc.
Qualify and quantify problem areas
Assemble data
Identify systems needing rehabilitation/replacement
Assess hydraulics (Phase IIC)
Build hydraulic model
Confirm field conditions
Assess hydraulic performance
Locate areas of performance deficiencies

Figure F 911 A. Detailed Investigation Flow Chart
Phase III:
DEVELOP THE SYSTEM USAGE PLAN

Set Priorities for Each Problem
Consider Rehabilitation Options and/or Replacement
Develop Consistent Solutions to Problems
Identify Cost Effective Solution(s)
Establish System Usage Plan

Phase IV:
IMPLEMENT THE SYSTEM USAGE PLAN

Monitor Conditions of Primary Sewers
Adjust Hydraulic Model as Needed
Review Usage Plan as Needed
Design and Construct Rehabilitation/Replacement Projects

Figure F 911 A. Detailed Investigation Flow Chart (Continued)

Figure F 911 A
Figure F 911 B. Cursory Investigation Flow Chart
Closed Circuit Television Monitoring

Air Test and Sealing Packer

Grouted Joint

Figure F 945.1. Internal Grouting Equipment
Figure F 945.2. Internal Grouting Of Large Diameter Pipe Joints
Figure F945.3. Gunite/Shotcrete Wall Construction
Figure F 945.4. Traditional Slip Lining

Figure F945.5. Welding In Trench
Figure F 945.6. Insertion Method For Slipping With Short Pipes
STAGE 1

- Resin impregnated insitutube
- Manhole
- Inversion tube
- Damaged pipe

STAGE 2

STAGE 3

- Boiler and pump
Figure F 945.7. Cured-In-Place Pipe Installation
Figure F 945.8.  Deformed Pipes
Sealing Ring

Retaining Bands
Figure F 945.11. Mechanical Seal
Figure F 945. 13.1. Pipebursting - Typical Layout
Figure F 945. 13.2A. Microtunneling (Auger System)
Figure F 945.13.2B Microtunneling (Slurry System)
Figure F 945. 13.3.1. Directional Drilling
Figure F 945. 15. Typical Section Through Maintenance Hole Rehabilitation

- **Cover**
- **Frame Seal**
- **In-Place Portland Cement Comets**
- **Cast In-Place Protective Plastic Lining (If Required)**
- **Diameter 36” Min. (48” Normal)**
- **Reconstructed Bench and Trough**
- **Existing Bridge or Pre-Cast Maintenance Hole**
Figure F 945.15.2.3. Typical Section Through Rehabilitated Maintenance Hole