Final

Infiltration and Inflow Master Plan

PREPARED FOR

Ojai Valley Sanitary District
Jeff Palmer, General Manager
1072 Tico Road
Ojai CA 93023

PREPARED BY

MNS Engineers, Inc.
Nicholas Panofsky, PE

UNDER THE SUPERVISION OF:

Julia Aranda, PE
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1.0 Executive Summary

1.1 Background

The Ojai Valley Sanitary District provides sanitary sewer service for approximately 20,000 residents of the City of Ojai, and the surrounding unincorporated Ojai Valley. The collection system includes approximately 120 miles of 6-inch to 24-inch gravity sewer mains and force mains to convey wastewater to the Ojai Valley Wastewater Treatment Plant (WWTP). The OVSD service area includes four major basins, A through D, with 26 subbasins.

Infiltration and inflow (I/I) have been a major issue within the District’s system. During storm events, influent flow rates to the Ojai Valley WWTP have exceeded the capacity of the plant and caused the plant to violate effluent water quality regulations. The Ventura River nutrient Total Maximum Daily Load (TMDL) requires more stringent regulatory requirements that go into effect in 2025 and will place more stringent requirements on the WWTP effluent discharge. Reducing I/I flowing into the plant will help the District meet its water quality discharge limits.

The primary goal of this report is to develop a strategy to reduce I/I in the collection system.

1.2 Scope

The I/I Master Plan includes estimated costs of construction, construction issues, advantages and disadvantages of each replacement/rehabilitation method and their appropriate use. Figures are included in Appendix A to identify areas in need of replacement/rehabilitation to assist in prioritizing future projects.

1.3 Known System Issues

A review of available information indicated there were several basins in the system where I/I is more prevalent than others. Contributing factors to increased I/I include the following:

- Improper Installation
- Aging Pipe
- High Groundwater
- Cross Connections
- Sewer Laterals
- Manholes
- Basins with Higher Levels of I/I

The District has actively been working to reduce I/I in the system through a combination of sewer replacements and manhole and sewer main rehabilitations, however, a major I/I problem still exists.

1.4 Rehabilitation Technologies

One of the primary strategies for reducing I/I in the collection system, is to replace or rehabilitate collection system components, including manholes, main lines, and sewer laterals.
The available sewer main rehabilitation methods include:

- Smoke Testing
- Open Cut Replacements
- Point Repairs
- Pipe Bursting
- Cured-In-Place Pipe (CIPP) Rehabilitation
- Spiral Wound Liner Rehabilitation
- Spray-On Lining Rehabilitation
- Modified Cross Section Lining Rehabilitation
- Sliplining

The available manhole rehabilitation methods include:

- Replacing Manhole Frames and Covers
- Pressure Grouting
- Internal Structural Coatings
- In situ Structural Replacement
- Replacement of Manholes in their Entirety

There are also several options available for replacing or rehabilitating sewer laterals.

1.5 Development of Future Projects

In order to determine specific sewer rehabilitation project scopes, the District will need to conduct a preliminary design for each potential project. For each project, specific designs and budgetary cost estimates will need to be prepared. To achieve the maximum reduction in I/I, it is recommended that future projects be prioritized based on the known issues in each basin.

1.6 Conclusions and Rehabilitation Costs

The primary recommended strategies for reducing I/I include:

- Conduct smoke testing in areas with the highest levels of I/I to identify cross connections, and implement repair or rehabilitation to eliminate identified cross connections.
- Conduct inspections to identify manholes experiencing I/I, and rehabilitate or replace these manholes.
- Conduct inspections to identify sewer mains experiencing I/I, and rehabilitate or replace these mains.
- Implement a sewer lateral replacement program to encourage, and possibly require, residents to rehabilitate or replace aging laterals.
- Focus improvements on basins with the highest levels of I/I.

To complete the necessary system rehabilitations, the District should budget between $15,000,000 and $43,000,000. The necessary repair and rehabilitation will take place over a number of years.
2.0 Project Overview

This section describes the background and project description, scope of work, and basin descriptions.

2.1 Background and Project Description

The Ojai Valley Sanitary District provides sanitary sewer service for approximately 20,000 residents of the City of Ojai, and the surrounding unincorporated Ojai Valley. The collection system includes approximately 120 miles of 6-inch to 24-inch gravity sewer mains and force mains to convey wastewater to the Ojai Valley Wastewater Treatment Plant (WWTP).

The Ojai Valley Sanitary District originated in May 1985 as a result of the consolidation of the Ventura Avenue, Oak View, and Meiners Oaks Sanitary Districts, and the Sanitation Department of the City of Ojai. The predecessor Districts were established in the early 1960s in conjunction with construction of the Oak View Treatment Plant which served them as well as the City of Ojai. Ojai’s oldest sections were originally served by sewers and a treatment plant built in the 1920s.

Inflow occurs when stormwater flows directly into the sewer collection system. This could be through a manhole cover, or a cross connection between a storm drain system (such as roof leaders or yard drains) and the sewer collection system. Infiltration is typically caused by ground water entering the collection system at defects in mains, laterals, or manholes. A photo of a pipe defect allowing infiltration to occur is shown in Photo 2-1.

![Photo 2-1: Sewer Main Infiltration](image)

Infiltration and inflow (I/I) have been a major issue within the District’s system. During storm events, influent flow rates to the Ojai Valley WWTP have exceeded the capacity of the plant and caused the plant to violate effluent water quality regulations. The Ventura River nutrient Total Maximum Daily Load (TMDL) requires more stringent regulatory requirements that go effect in 2025 and will place more stringent requirements on the WWTP effluent discharge. Reducing I/I flowing into the plant will help the District meet its water quality discharge limits.
The primary goal of this report is to develop an Implementation Plan to reduce I/I in the system. The plan includes:

- Documenting the known issues within the system into a clear and concise format to facilitate decision making.
- Documenting and consolidating the known upgrades and rehabilitation work that has been completed within the system.
- Based on previous studies, documenting the areas where capital improvements will have the greatest impact at reducing I/I.
- Documenting technologies commonly used in the reduction of I/I.
- Providing unit cost estimates for various pipe and manhole repair and rehabilitation methods to assist the District in the development of capital improvement program over the next ten years.

2.2 Methodology

Existing sewer drawings, reports, pipe condition assessments, CCTV inspection videos, GIS maps and records, past project plans and scopes of work, groundwater elevation data, flow data, CMMS maintenance records, and other data as necessary and available were reviewed.

Appropriate replacement and rehabilitation methods to address the deficiencies identified from the review of data were investigated. These include point repairs, sliplining, cured-in-place pipe, and other methods. Replacement/rehabilitation methods for sewer pipelines, manholes and sewer laterals are addressed.

A workshop was held with District staff to discuss past, present and future replacement and rehabilitation efforts.

The I&I Master Plan includes estimated costs of construction, construction issues, advantages and disadvantages of each replacement/rehabilitation method and their appropriate use. Drawings/maps are included to identify areas in need of replacement/rehabilitation to assist in prioritizing future projects.

2.3 Basin Identification

The OVSD service area includes four major basins, A through D, with 26 subbasins. Basins are shown in the figures included in Appendix A.
3.0 Review of Existing Data

Data provided by OVSD included studies, flow monitoring data, CCTV inspection reports and GIS files. Each of these is discussed in the following subsections.

3.1 Previously Completed Studies

The District has completed many studies over the past 50 years. These studies were reviewed and information incorporated into this report as appropriate. The previous studies and reports are shown in Table 3-1.

Table 3-1
Previous Studies/Reports on Sewer System

<table>
<thead>
<tr>
<th>Title</th>
<th>Date</th>
<th>Prepared by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wastewater Collection System I&amp;I Study</td>
<td>Jan 1, 2010-Mar 31, 2010</td>
<td>ADS Environmental Services</td>
</tr>
<tr>
<td>Wastewater Collection System I&amp;I Study</td>
<td>Dec 17, 2008-Mar 18 2008</td>
<td>ADS Environmental Services</td>
</tr>
<tr>
<td>Evaluation of Existing Sewer Capacity</td>
<td>June 1996</td>
<td>Boyle Engineering Corporation</td>
</tr>
<tr>
<td>Woodland Ave. to Prospect Ave.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>District-Wide I/I Study and Reconnaissance</td>
<td>September 1992</td>
<td>Brown and Caldwell Consulting Engineers</td>
</tr>
<tr>
<td>Level Source Detection Program</td>
<td></td>
<td></td>
</tr>
<tr>
<td>District-Wide I/I Study and Reconnaissance</td>
<td>January 1989</td>
<td>Brown and Caldwell Consulting Engineers</td>
</tr>
<tr>
<td>Level Source Detection Program</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sewer System I/I Problem and Impact</td>
<td>February 1985</td>
<td>Henry Hyde and Associates</td>
</tr>
<tr>
<td>Sewer System Rehabilitation and Capital</td>
<td>March 1984</td>
<td>Boyle Engineering Corporation</td>
</tr>
<tr>
<td>Improvement Program</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sanitary Sewerage Plan</td>
<td>January 1967</td>
<td>McCandless-McWherter and Company</td>
</tr>
</tbody>
</table>

3.2 Summary of Existing System

The District provided GIS files for the existing sewer system, as well as a spreadsheet with system attribute information. The District has approximately 110 miles of gravity sewer, with piping ranging from 6-inches to 24-inches in diameter. Table 3-2 shows a summary of the sewer system by installation date.

Table 3-2
### Sewer System Piping by Installation Date

<table>
<thead>
<tr>
<th>Decade</th>
<th>Length (feet)</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1920-1929</td>
<td>10,209</td>
<td>1.74%</td>
</tr>
<tr>
<td>1930-1939</td>
<td>619</td>
<td>0.11%</td>
</tr>
<tr>
<td>1940-1949</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>1950-1959</td>
<td>23,287</td>
<td>3.97%</td>
</tr>
<tr>
<td>1960-1969</td>
<td>348,819</td>
<td>59.52%</td>
</tr>
<tr>
<td>1970-1979</td>
<td>45,102</td>
<td>7.70%</td>
</tr>
<tr>
<td>1980-1989</td>
<td>90,291</td>
<td>15.41%</td>
</tr>
<tr>
<td>1990-1999</td>
<td>53,998</td>
<td>9.21%</td>
</tr>
<tr>
<td>2000-Present</td>
<td>13,757</td>
<td>2.35%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>586,082</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>

Table 3-3 summarizes the District’s piping system by pipe material.

#### Table 3-3

<table>
<thead>
<tr>
<th>Pipe Type</th>
<th>Length (feet)</th>
<th>Percentage of Total Gravity System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitrified Clay</td>
<td>419,541</td>
<td>71.58%</td>
</tr>
<tr>
<td>Polyvinyl Chloride</td>
<td>128,776</td>
<td>21.97%</td>
</tr>
<tr>
<td>High Density Polyethylene&lt;sup&gt;2&lt;/sup&gt;</td>
<td>19,753</td>
<td>3.37%</td>
</tr>
<tr>
<td>Asbestos Cement</td>
<td>11,831</td>
<td>2.02%</td>
</tr>
<tr>
<td>Cast Iron</td>
<td>3,038</td>
<td>0.52%</td>
</tr>
<tr>
<td>Techite</td>
<td>2,415</td>
<td>0.41%</td>
</tr>
<tr>
<td>Ductile Iron</td>
<td>728</td>
<td>0.12%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>586,082</strong></td>
<td><strong>100.00%</strong></td>
</tr>
</tbody>
</table>

Notes:

1) Force main piping is not included, nor is Honor Farm piping
2) Assumes new pipe is HDPE
3.2.1 Individual Basin Summaries

The materials and installation dates of the sewer system in each basin have been summarized, similar to the total system summary above. The results of these summaries are included in tables in the basin maps included in Appendix A.

3.3 Known Problem Areas

A review of available information indicated there were several basins in the system where I/I is more prevalent than others. Contributing factors to increased I/I include the following:

**Improper Installation:** Pipe initially installed improperly can be a source of I/I. If pipe joints were not sealed properly, they can be an entry point for infiltration. Similarly, if pipe bedding material was not compacted properly during installation, or if improper bedding materials were used, settlement can cause pipe joints to separate, or can cause pipes to sag and crack. Open joints and cracked pipe provide avenues for groundwater to enter the system.

**Pipe Damage:** A variety of factors can lead to pipe damage providing additional routes for infiltration to enter the system. Failures can include joint separations, cracks, joint failures, or holes in existing pipe. These failures can be a result of degrading piping materials, subgrade settlement, roots, or other damage to the existing pipes. A photo of a cracked sewer main is included as Photo 3-1, and a photo of a sewer damaged by roots is included as Photo 3-2.

Photo 3-1: Cracked Sewer Main
High Groundwater: Areas with high groundwater are more likely to have I/I issues. Increased hydrostatic pressure on the exterior of sewer mains will increase the rate that water is pushed into the system as infiltration. The District monitors groundwater levels at several groundwater monitoring well locations within the service area.

Cross Connections: Cross connections occur when a storm drain of any type is connected directly into the sewer system. When this occurs, stormwater is uninhibited and will cause significant inflow. These cross connections could be connected directly into the sewer system, or could be roof leaders or yard drains connected directly into privately-owned sewer laterals.

Sewer Laterals: Sewer laterals connect individual properties to gravity sewer mains. Typically 4 inches in diameter, these short pipelines vary widely in materials of construction and quality of construction, commensurate with the time period in which they were installed. Typically a clean out is installed at the property line of a residence to allow access to the sewer lateral for cleaning and maintenance. The sewer lateral between a residence or other building and the property line cleanout is considered the upper lateral. Between the property line and the sewer main is considered the lower lateral.

Residential sewer laterals are often a source of I/I. I/I in laterals can result from all of the same issues associated with sewer mains, including cross connections on a residential property. Sewer laterals are believed to be a major contributor of I/I into the system. Some municipalities have estimated 40 to 60 percent of I/I is attributable to sewer laterals (City of Santa Rosa, 2006; USEPA, 1996). An estimate was developed to determine the linear footage of sewer laterals in the system. The District has approximately 7,500 connections. Average sewer lateral length in the United States is approximately 75 feet. This indicates there are approximately 562,500 linear feet of sewer laterals connecting to the collection system. This is nearly the same total linear footage as the entire gravity sewer collection system.

Known Sources of I/I: The District maintains an ongoing list of points where it is known that water is entering the sewer system. These areas contribute to I/I issues in the system.

High I/I Basins: In two previous flow analysis studies conducted by ADS Environmental Services, the level of I/I from each basin was evaluated. Some basins have significantly higher levels of I/I than others. It is believed the
source of the I/I is a combination of the sources discussed above. The levels of I/I observed during the 2009 and 2010 studies are shown in Table 3.4, and are defined as Rain Dependent Inflow and Infiltration (RDII). RDII is a measurement of the wastewater flow in the collection system in excess of the average dry weather flow. The data is normalized using units of gallons per linear foot per inch of rainfall (Gal/LF/in).

Table 3-4

<table>
<thead>
<tr>
<th>Basin</th>
<th>2009 Max Net RDII - Normalized (Gal/LF/in)</th>
<th>2010 Max Net RDII - Normalized (Gal/LF/in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A01</td>
<td>3.26</td>
<td>4.0</td>
</tr>
<tr>
<td>A02</td>
<td>0.51</td>
<td>-</td>
</tr>
<tr>
<td>A03</td>
<td>-</td>
<td>5.6</td>
</tr>
<tr>
<td>A04</td>
<td>2.31</td>
<td>5.6</td>
</tr>
<tr>
<td>A05</td>
<td>0.43</td>
<td>-</td>
</tr>
<tr>
<td>A06</td>
<td>7.61</td>
<td>22.5</td>
</tr>
<tr>
<td>A07</td>
<td>2.76</td>
<td>-</td>
</tr>
<tr>
<td>A08</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>A09</td>
<td>10.42</td>
<td>-</td>
</tr>
<tr>
<td>A10</td>
<td>5.40</td>
<td>-</td>
</tr>
<tr>
<td>B01</td>
<td>2.44</td>
<td>-</td>
</tr>
<tr>
<td>B02</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>B03</td>
<td>1.27</td>
<td>-</td>
</tr>
<tr>
<td>B04</td>
<td>1.90</td>
<td>-</td>
</tr>
<tr>
<td>B05</td>
<td>2.37</td>
<td>-</td>
</tr>
<tr>
<td>B06</td>
<td>0.79</td>
<td>-</td>
</tr>
<tr>
<td>B07</td>
<td>0.50</td>
<td>-</td>
</tr>
<tr>
<td>C01</td>
<td>1.24</td>
<td>3.1</td>
</tr>
<tr>
<td>C02</td>
<td>-</td>
<td>6.2</td>
</tr>
<tr>
<td>C03</td>
<td>4.15</td>
<td>-</td>
</tr>
<tr>
<td>C04</td>
<td>8.64</td>
<td>-</td>
</tr>
<tr>
<td>C05</td>
<td>1.95</td>
<td>-</td>
</tr>
<tr>
<td>C06</td>
<td>0.32</td>
<td>-</td>
</tr>
<tr>
<td>C07</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>D01</td>
<td>2.91</td>
<td>-</td>
</tr>
</tbody>
</table>
Based on this information, the basins with the highest levels of rain dependent I/I are Basins A06, A09, A10, CO2, C03, and C04.

The known problem areas and issues in the collection system are summarized on the basin maps included in Appendix A.

### 3.4 Quantifying the I/I Issues

A survey of industry standard I/I rates shows that I/I in a collection system reaches an “excessive” amount when peak wet weather flow exceeds 275 gallons per capita per day. For a community of 23,000 people, the wet weather threshold for “excessive” I/I would be 6.3 MGD. During the most recent major storm in 2011, plant influent flow exceeded 8 MGD. This indicates the District has excessive I/I. At a total flow rate of 6.3 MGD, each linear foot of gravity collection system would contribute 10.7 gallons of wastewater per day.

Average dry weather flow without I/I in the District is approximately 1.5 MGD, or 2.6 gallons per linear foot of collection system per day. To surpass the “excessive” threshold during a storm event, there would need to be an average of 8.1 gallons of I/I per linear foot per day.

The District has a history of major storm events in which daily total rainfall exceeded 3 inches. As shown in Section 3.3, some basins within the District have significantly higher rates of I/I than others. An estimate of the RDII required to create an “excessive” condition was determined for a 3-inch storm. Subtracting average dry weather flows (2.6 Gal/LF/day) from the “excessive” I/I criteria (10.7 Gal/LF/day), the amount of I/I that would be deemed excessive would be 8.1 Gal/LF/day. For a storm event with a daily rainfall of 3 inches, RDII of 2.7 Gal/LF/in or higher would be considered “excessive”, as the total flow rates per linear foot would be expected to exceed a total of 10.7 Gal/LF/day (2.7 Gal/LF/in x 3 inches/day = 8.1 Gal/LF/day).

By comparing the “excessive” threshold RDII criteria of 2.73 Gal/LF/in shown in Table 3.4, it is clear that many of the basins exceed these criteria. Basins with more than twice this level RDII (5.46 Gal/LF/in or higher) are considered to be areas of “extreme” I/I. A graphical representation of the areas with their respective levels of infiltration is included in Appendix A.

Data on RDII is unavailable for three basins, including basins A08, B02, and C07. I/I exists in these basins, but is not specifically quantified. The amount of I/I in these basins is assumed to be similar to the surrounding basins with similar groundwater levels, lateral connections, and construction age and materials.
3.5 Rehabilitation Completed

In the late 1990s, the District started a program to address I/I in the system, including replacement of manholes, main lines, coating of manholes, and lining of sewer lines. As part of the City’s and County’s street overlay program, the District has replaced many manhole cones, frames and covers throughout the system. A review of available information indicates rehabilitation of gravity sewer mains has been completed in several subbasins throughout the District.

In 1994/95, the District replaced a majority of the gravity sewer system that was originally installed in 1927. Between 2001 and 2013, the District has made a variety of other sewer improvements including CIPP lining and main replacements. A photo of a typical CIPP lining installation is included as Photo 3-3.

Photo 3-3: Typical CIPP Installation
4.0 Rehabilitation Technologies

Rehabilitation technologies for pipelines, laterals and manholes are described in the following subsections.

4.1 Pipeline Rehabilitation Technologies

Pipeline rehabilitation technologies to reduce I/I include a number of trenchless methods as well as the traditional open cut replacement. The following subsections provide an overview of the most commonly used technologies.

4.1.1 Smoke Testing

While not a rehabilitation technology, smoke testing is an effective strategy for locating where I/I may be entering the collection system. During smoke testing, and artificially created smoke is forced into a manhole or other sewer opening, under slight pressure. Locations where smoke exits the system can be visually observed by a plume of smoke above grade, and are indications of areas where I/I may be entering the system. These identified locations can then be repaired. A photo of a smoke test indicating potential sources of I/I is shown in Photo 4-1.

![Photo 4-1: Smoke Testing](image)

4.1.2 Open Cut Replacement

Replacement of existing deteriorated sewer mains by the open cut method is a proven method for reducing the I/I into the sewer system. By excavating the sewer, and replacing with modern materials, the vast majority of infiltration into the main can be eliminated. Open trench replacement also allows for relatively easy upsizing of the size of the main.

Costs for replacement by open cut replacement are typically higher than other alternative rehabilitation technologies due to the increase in excavation and surface repair required. High groundwater in the area increases the complexity of this method of rehabilitation, requiring dewatering and further increasing installation costs. The existing flow may also need to be bypassed to perform the replacement, requiring bypass pumps and above grade piping.
4.1.3 Point Repairs

In locations where isolated infiltration has been identified in a sewer main, and the overall condition of the main is good, point repairs can be completed. Point repairs can be completed by the open cut method, or a variety of trenchless point repair products are available, including cured-in-place point repairs, pull-in-place liners, and stainless steel mechanical liners.

The District recently purchased a PipePatch Cured-in-Place Pipe (CIPP) point repair system. Bypass pumping is not required using this system, as wastewater is allowed to flow through the liner during installation. Installation using this technology can provide a significant cost savings over traditional open cut point repairs. Before and after photos of a typical point repair are shown in Photo 4-2.

Photo 4-2: Before and After Point Repair

![Before and After Point Repair](image)

4.1.4 Pipe Bursting

Pipe bursting is a trenchless technology rehabilitation method that utilizes a bursting head pulled through the existing host pipe to break the existing pipe while simultaneously pulling a new PVC, HDPE, or other material pipe into the same alignment as the host pipe. The nominal diameter of the pipe can be upsized by up to two nominal pipe sizes larger than the host pipe. The cost for pipe bursting is approximately equal to that of other trenchless pipe rehabilitation technologies.

The District has used pipe bursting in the past. In areas with unstable soils, they have observed sags in the new pipe, caused during installation. As a result of settling in the trench section under the weight of the pipe bursting head. They have also observed the issue of sags and humps being formed if the fused pipe material is inserted into the entry pit at too steep an angle. Pipe bursting requires bypass pumping for the section being replaced. A conceptual image of replacement by pipe bursting is included as Photo 4-3.

![Photo 4-3: Conceptual Image of Replacement by Pipe Bursting](image)
4.1.5 Cured in Place Pipe

Cured-in-place pipe (CIPP) is a trenchless technology rehabilitation method that utilizes a liner material either directly inverted or pulled-in-place in the existing pipe. It is one of the most popular methods of pipe rehabilitation currently being utilized. Prior to installation, the inside of the pipe must be cleaned and cleared of any obstructions, debris, and any joints with major offsets. CIPP installation must meet ASTM F1216 and ASTM F1743 for installation specifications and tube and material as specified by ASTM D5813. Once the liner is installed, circulating heated water, steam, or ultraviolet (UV) light is used for the curing process. After the liner is cured, the laterals are reinstated through a remotely operated cutting machine. Photo 4-4 shows a conceptual rendering of CIPP.

There are a range of products that are included in the category of CIPP, including Glass Reinforced Polymer (GRP) liners and cured resin liners. Bypass pumping is required for the duration of the installation process, and the installed product will reduce the interior diameter of the pipe. The installation of CIPP product requires curing time, which extends the duration of bypass pumping compared to a modified cross section liner. The finished product will be a structurally sound pipe within a pipe, with smooth interiors. A net increase in overall carrying
capacity is anticipated with a CIPP product even with a decrease in the pipe inside diameter, there is an incremental increase in pipe capacity (due to the smooth interior of the pipe).

There have been reports of CIPP being ineffective at reducing I/I in sewer collection systems. If the CIPP liner doesn’t adhere to the interior of the host pipe, water can infiltrate behind the liner, and enter the collection system at manholes or lateral connection points. In order to mitigate this issue, end seals, O-rings and sealing top hats can be installed at manhole and lateral connections, which can prevent water from entering the sewer main at these locations. A typical sewer top hat is shown in Photo 4-5. Bypass pumping is typically required for installation of CIPP.

![Photo 4-5: Sewer Top Hat](image)

### 4.1.6 Spiral Wound Liner

The spiral wound liner method is a trenchless rehabilitation technology that uses a polyvinyl chloride (PVC) liner formed inside of the pipe to be rehabilitated. A winding machine constructs the pipe liner from strips of PVC, and inserts the spiral wound pipe into the existing pipe. The annular space between the liner and host pipe can be filled with grout, or, once the PVC is fully installed in the pipeline, the spirally wounded PVC can be radially expanded to fit tightly against the wall of the host pipe. A fixed diameter spiral wound liner is also available which does not expand to the diameter of the host pipe; the annular space is filled with grout. Laterals are immediately reinstated with top hats (short liners in each lateral connection that are sealed to the new liner) to provide a seal between the new liner and the lateral.

Spiral wound linings are typically used in larger diameter pipes and can be constructed while the existing pipe is in service, during low flow conditions, which can eliminate the need for bypass pumping. A net increase in overall carrying capacity is anticipated due to the smooth interior of the pipe if the spiral wound liner is expanded to the diameter of the host pipe. Photo 4-6 shows a typical spiral wound liner after installation.
4.1.7 *Spray on Linings*

Rehabilitation of sewer mains using a spray on lining system requires entry into the sanitary sewer pipeline for application and inspection. The industry standard for sewer lines with sufficient diameter for entry is typically 36 inches, and as a result, is unlikely to be applicable for the District. Spray on liners can be a range of products, including epoxy, polymer, or cementitious materials. Product selection typically varies depending on the level of deterioration of the host pipe, and the desired wall smoothness of the rehabilitated pipe. Depending on the type of spray on lining, some liners are more effective at reducing I/I. Pressure grouting may be required in location of known I/I prior to installation of the spray on liner. Bypass piping is necessary using this method if rehabilitation.

4.1.8 *Modified Cross Section Lining*

A modified cross section lining rehabilitation system is a trenchless rehabilitation technology that uses a PVC or HDPE pipe, which is deformed prior to installation, and pulled into place within the existing pipe. It is then expanded within the host pipe using pressure and heat. This process is commonly called U-lining, or sewage lining.

Sewage lining is completed by reducing the diameter of HDPE pipe with heat and stress, pulling the compressed pipe into the existing sewer, and allowing the pipe to cool and expand. When the pipe expands, it fits tightly within the host pipe.

A U-liner style rehabilitation is completed by deforming a specialized HDPE or PVC pipe into a U shape, and pulling the pipe into the host pipe before expanding and curing the pipe. In some applications, the deformed pipe can be inserted into the pipe via existing manholes, otherwise excavation can be required for larger diameter pipe rehabilitations.

Typically, grouting, or curing of a resin between the liner and interior of the host pipe does not occur. As a result, this method of rehabilitation is less effective at stopping I/I. Also, liners have been known to deform after installation. They also reduce the interior pipe diameter more than other rehabilitation technologies.

4.1.9 *Sliplining*

Sliplining is one of the oldest trenchless technology methods and utilizes a smaller pipe inserted in the host pipe. The annular space between the new pipe and the host pipe is then filled with grout. For this method, the laterals
are reconnected via excavation. The most common materials used to slipline are HDPE, fiberglass, and PVC pipe. The method of sliplining installation depends on the type of material used to slipline. With HDPE pipe or fusible PVC, a continuous installation is feasible, since both materials can be welded into continuous pieces of any length. For PVC or fiberglass pipe, the segmental sliplining installation method is required, where the individual pieces of pipe are lowered into place, pushed together, and pushed inside the host pipe. Bypass pumping is typically required for sliplining.

4.2 Sewer Lateral Rehabilitation Technologies

Many of the technologies available for sewer mainline rehabilitation can also be used on sewer laterals. This includes open cut replacement, pipe bursting, point repairs, and cured in place liners. Additional information or strategies for encouraging individual homeowners to repair or replace sewer laterals are included in Section 4.6. A photo of a typical sewer lateral replacement, installed using the open cut method is included as Photo 4-7.

![Photo 4-7: Open Cut Sewer Lateral Replacement](image)

4.3 Manhole Rehabilitation Technologies

Alternative manhole rehabilitation technologies to reduce I/I are described in the following subsections.

4.3.1 Replace Manhole Frames and Covers

Replacing manhole frames and covers can significantly reduce Inflow and Infiltration at manholes. By installing machined tight fitting manhole covers with sealed pick holes, in place of existing manhole covers, inflow could be reduced. In addition, while installing new frames and covers, any deficiencies in manhole construction near the top of the manhole can be addressed simultaneously.

When manholes frames and covers are being raised or replaced, a permanent chimney seal can also be installed to reduce future I/I. With a permanent chimney seal, an internal cap and seal can also be provided specifically for areas that are low lying, or areas that see ponding to prevent surface runoff from entering the collection system. One example of a chimney seal is the I/I barrier manufactured by AP/M Permaform.
4.3.2 Pressure Grouting

Pressure grouting in locations of known I/I is an effective method of reducing I/I. Pressure grouting is typically used to stop visible leaks in manholes, main lines and wet wells. Pressure grouting stops I/I only in the immediate location of application. It may take several re-applications as the groundwater rises and new points of I/I are identified.

4.3.3 Internal Structural Coating

Structural coatings for manhole rehabilitation include epoxy fiberglass composites, polymeric coatings, cementitious linings, and insitu-structural replacement. All of these technologies will effectively line and protect the interior of the manhole from future degradation.

Cured-in-place epoxy fiberglass composites are typically custom mixed for each specific structure and intended service. Therefore, the strength and thickness varies.

Polymeric coatings are installed using a multi-layered spray-on method. Polymeric coatings can be epoxy based, or polyurethane based. Internal coating thickness varies between 0.5 to 1.0 inches. Polymeric coatings have been found to be particularly effective at reducing corrosion and stopping I/I in manholes. A polymeric coating is shown in Photo 4-8.

Photo 4-8: Polymeric Coating on Sewer Manhole

Reinforced cementitious liner material, when mixed with appropriate amount of water, develops as a paste-like material which may be sprayed, cast, pumped, or gravity flowed. Reinforced cement-based liners are highly dense and impermeable. These liners can be combined with antibacterial additives and coatings to increase the longevity of the rehabilitation. A cement liner application is shown in Photo 4-9.
4.3.4 **Insitu Structural Replacement**

If manholes are highly defective and severely degraded, an insitu replacement and structurally independent manhole within a manhole can be installed. This concrete-based procedure places a minimum 3-inch thick reinforced concrete wall within the existing structure without interrupting flows. The new wall is designed to completely fill voids in the existing structure and provide sufficient strength to withstand vertical and axisymmetric loading. In highly corrosive environments, a top coat of a polymeric coating may be used as an impermeable barrier. The plastic protective liner is capable of resisting typical wastewater acids and chemical byproducts. The disadvantage to this method is the decrease in manhole circumference.

4.4 **Challenges during Rehabilitation**

The process of sewer main, lateral, and manhole rehabilitation includes many ancillary processes and procedures in addition to the basic requirements of performing the rehabilitation. These additional steps in the rehabilitation process add significant costs to the end project.

Prior to the start of any rehabilitation project, there are several steps that need to be completed to streamline a project. This includes identifying areas in need of rehabilitation: engineering, including the selection of appropriate rehabilitation methods and design and specification of the rehabilitation project; geotechnical investigation, if required by the selected rehabilitation method; and contracting with a knowledgeable contractor to complete the work. Pre- and post-construction closed circuit television inspections are also highly recommended.

Another key consideration in any sewer rehabilitation project is the handling and managing of wastewater flows. Depending on the rehabilitation technology used, bypass pumping may be required. Typically, rehabilitation can last for hours, or days, depending on the rehabilitation technology used. If bypassing is required, a fully redundant bypassing system is typically required to reduce the likelihood of a wastewater spills in the event of a pump failure. Photo 4-10 shows a bypass pumping setup with a noise barrier.
In addition to the planning and coordination requirements and the monetary costs of completing sewer rehabilitations, there are many challenges associated with impacts to the public. The public may be impacted by many aspects of a sewer rehabilitation project, including noises associated with construction and bypass pumping, traffic disruptions associated with increased construction traffic and road closures or other traffic controls, or other impacts from the construction including odors produced from some of the available rehabilitation technologies. These impacts can be somewhat mitigated through public education and notifications, but do increase the costs of a project.

4.5 Current Usage of Rehabilitation Technologies

A survey was conducted of local municipalities to determine which strategies are currently being actively implemented to reduce I/I. The survey respondents included Los Angeles County Sanitation District and the City of Simi Valley Sanitation Department.

The primary technologies implemented to stop I/I at manholes include:

- Plug manhole cover pick holes
- Raising low structures
- Stop infiltration at connection points by hydrophobic pressure grouting
- Lining manholes with a polymeric coating or FRP liner

The primary technologies implemented to stop I/I on sewer mains include:

- Smoke test to locate illegal connections and storm drain cross connections
- Line or replace gravity sewers
- Install CIPP point repairs at known infiltration points
- Pressure grouting

4.6 Methods to Reduce Sewer Lateral Infiltration

Infiltration from sewer laterals has become a significant issue for many agencies as this is a source which does not fall directly under their control, yet can contribute greatly to infiltration into the system. Many communities have addressed the need to replace aging and leaking sewer laterals to reduce I/I using several approaches:
Incentive-based approaches

1. Enforcement-based approaches
   - time of sale requirement to obtain a sewer lateral certificate before transfer of title
   - Fines on monthly utility bills for non-compliance
   - termination of water or sewer service for non-compliance

2. Agency driven approaches

4.6.1 Incentive Based Approaches

To assist property owners with replacement of sewer laterals, some communities offer grants and no interest or low-interest loans to fund the inspection and repair/replacement. The Sewerage Agency of Southern Marin, north of the San Francisco Bay, is one of the agencies offering such a program. The grant program is based on income while the loan program provides low-interest financing over a 1 to 3-year period with no income threshold.

The City of San Luis Obispo has a voluntary service lateral rehabilitation program. The homeowner benefits by receiving construction permits, technical advice and a rebate of one-half the cost of replacement or repair up to a maximum of $1,000 per property from the City.

The City of Santa Barbara combines multiple incentive programs by offering an inspection incentive of $150 per property, providing a repair incentive of half of lateral replacement costs up to $2,000 per property, providing low interest loans to qualified homeowners, and waiving fees associated with City permits. The City of Santa Barbara also requires inspections when spills have occurred related to laterals, or the City has identified issues with a lateral through CCTV or smoke testing. Sewer lateral certifications are also required to be obtained for homeowners applying for building permits for the addition of 400 square feet or more of dwelling space or 2 or more plumbing fixtures.

The Town of Hillsborough, California offers to repair/replace sewer laterals in conjunction with work on the main sewer system, still at the property owner’s cost but significantly reduced. They also offer low-interest loans to customers.

4.6.2 Enforcement Based Approaches

Several communities, particularly in the San Francisco Bay area, have passed ordinances to address the problem of leaking private sewer laterals. East Bay Municipal Utility District (EBMUD) recently passed the Private Sewer Lateral (PSL) Ordinance that requires property owners to obtain a Compliance Certificate when buying or selling property, applying for a building permit or changing water meter size. The sewer lateral must be inspected by a contractor using CCTV in the presence of an agency inspector to verify it is free of leaks. An exemption can be granted if the property owner can provide verification the sewer lateral was replaced in the last ten years. Details of EBMUD’s program can be found here: http://www.eastbaypsl.com/eastbaypsl/index.html.

The City of Ventura's Private Lateral Program was adopted in January 2012 and became effective February 3, 2014. The ordinance includes provisions for inspection of private sewer laterals prior to the close of escrow at the point of sale of a property. A Private Sewer Lateral Inspection Report must be submitted to the City. Compliance can also be triggered by the City's inspection via CCTV that root buildup or grease/rags or other problems exist which must be corrected.
Commercial and common interest properties are required to submit a PSL Inspection Report to the City every ten years. The City of Ventura’s program can be found here: http://www.cityofventura.net/water/privatelateral.

Other agencies have implemented requirements for certifying or rehabilitating sewer laterals prior to issuing building permits.

4.6.3 Agency Driven Approaches

Agency driven approaches require the collection system owner or manager to take a more proactive role in the lateral replacement. Typically, the agency identifies problems with laterals through Sewer System Evaluations, including smoke testing, and CCTV. The agency may fund and/or undertake work to repair identified problems. If the agency undertakes the work, an ordinance could be imposed to require the homeowner to cover the cost of the repair, or the cost could be added to the customer’s bill.
5.0 Development of Future Projects

One of the primary strategies for reducing I/I in the collection system, is to replace or rehabilitate collection system components, including manholes, main lines, and sewer laterals. A detailed discussion of the methods used for these rehabilitations is included in Section 4.

In order to determine specific sewer rehabilitation project scopes, the District will need to conduct a preliminary design for each potential project. For each project, project specific designs and budgetary cost estimates will need to be prepared.

5.1 Prioritization

To achieve the maximum reduction in I/I, it is recommended future projects be prioritized based on the known issues in each basin. These known issues are discussed in Section 3.3, and are shown on the basin maps included in Appendix A.

5.2 Point Repair System

The District recently purchased a PipePatch Cured-in-Place Pipe (CIPP) point repair system. This is a cost-effective technology for completing rehabilitations on pipe segments that are in overall good condition, but have minor isolated defects. This provides a solid section of pipe inside the damaged host pipe. These point repairs will be effective at reducing I/I.
6.0 Conclusions & Rehabilitation Costs

6.1 Rehabilitation Costs

Budgetary costs for a variety of rehabilitation and replacement tasks have been developed to aid the District in budgeting for future projects to reduce I/I. When developing budgetary cost estimates, adjustments will need to be made according to the current market, inflation, and project specific factors.

A mark-up has been included in the unit costs for replacement and rehabilitation developed for this study. The low budgetary estimates have been increased by 50%, and the high budgetary estimates have been increased by 100% to cover the costs of the following:

- Engineering
- Taxes
- Bonds
- Mobilization
- By-pass pumping
- Traffic control
- Contingencies.

6.1.1 Pipeline Replacement by Open Cut Replacement

Pipeline replacement costs for pipeline replacements using traditional open cut methods vary significantly, depending on the depth of cover, type of surface repair, pipe size and material, location, and other project specific factors. It is assumed that all new replacement piping will be PVC DR 26. Table 6-1 shows budgetary cost for various size piping.

<table>
<thead>
<tr>
<th>Size</th>
<th>Low Budgetary Cost ($/LF)</th>
<th>High Budgetary Cost ($/LF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-Inch</td>
<td>$150</td>
<td>$300</td>
</tr>
<tr>
<td>10-Inch</td>
<td>$173</td>
<td>$340</td>
</tr>
<tr>
<td>12-Inch</td>
<td>$195</td>
<td>$380</td>
</tr>
<tr>
<td>15-Inch</td>
<td>$218</td>
<td>$440</td>
</tr>
<tr>
<td>18-Inch</td>
<td>$240</td>
<td>$480</td>
</tr>
<tr>
<td>21-Inch</td>
<td>$270</td>
<td>$540</td>
</tr>
<tr>
<td>24-Inch</td>
<td>$300</td>
<td>$600</td>
</tr>
</tbody>
</table>

6.1.2 Pipeline lining

It is assumed that lining existing sewer lines will be completed by the CIPP method. Table 6-2 shows the budgetary range of costs for various size piping rehabilitated with CIPP.
Table 6-2: Pipeline Lining Costs

<table>
<thead>
<tr>
<th>Size</th>
<th>Low Budgetary Cost ($/LF)</th>
<th>High Budgetary Cost ($/LF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-Inch</td>
<td>$45</td>
<td>$100</td>
</tr>
<tr>
<td>10-Inch</td>
<td>$53</td>
<td>$160</td>
</tr>
<tr>
<td>12-Inch</td>
<td>$60</td>
<td>$220</td>
</tr>
<tr>
<td>15-Inch</td>
<td>$90</td>
<td>$240</td>
</tr>
<tr>
<td>18-Inch</td>
<td>$105</td>
<td>$280</td>
</tr>
<tr>
<td>21-Inch</td>
<td>$120</td>
<td>$320</td>
</tr>
<tr>
<td>24-Inch</td>
<td>$150</td>
<td>$360</td>
</tr>
</tbody>
</table>

6.1.3 Sewer Laterals

It is assumed that sewer laterals will be lined using the CIPP method. Table 6-3 shows the budgetary range of costs for various size sewer laterals rehabilitated with CIPP.

Table 6-3: Sewer Lateral Rehabilitation Costs

<table>
<thead>
<tr>
<th></th>
<th>Low Budgetary Cost ($/EA)</th>
<th>High Budgetary Cost ($/EA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sewer Lateral Replacement</td>
<td>$3,750</td>
<td>$10,000</td>
</tr>
<tr>
<td>Sewer Lateral Lining</td>
<td>$3,000</td>
<td>$6,000</td>
</tr>
</tbody>
</table>

6.1.4 Manholes

Table 6-4 shows preliminary budgetary cost estimates for sewer manhole replacement and sewer manhole lining.

Table 6-4: Manhole Rehabilitation Costs

<table>
<thead>
<tr>
<th></th>
<th>Low Budgetary Cost ($/EA)</th>
<th>High Budgetary Cost ($/EA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sewer Manhole Replacement</td>
<td>$9,000</td>
<td>$30,000</td>
</tr>
<tr>
<td>Sewer Manhole Lining</td>
<td>$3,000</td>
<td>$10,000</td>
</tr>
</tbody>
</table>

6.1.3 Total System Rehabilitation Costs

An estimate of the total costs to rehabilitate the entire system to reduce the majority of the I/I entering the system has been developed, and are included in Table 6-5.
Table 6-5: Total System Rehabilitation Costs

<table>
<thead>
<tr>
<th>Pipe Type</th>
<th>Linear Feet Installed</th>
<th>Percentage to be Replaced or Rehabilitated</th>
<th>Quantity</th>
<th>Units</th>
<th>Low Unit Price</th>
<th>Low Total Cost</th>
<th>High Unit Price</th>
<th>High Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rehabilitate Asbestos Cement Pipe</td>
<td>11,831</td>
<td>50%</td>
<td>5,915</td>
<td>LF</td>
<td>$53</td>
<td>$313,511</td>
<td>$160</td>
<td>$946,448</td>
</tr>
<tr>
<td>Replace Cast Iron Pipe</td>
<td>3,038</td>
<td>100%</td>
<td>3,038</td>
<td>LF</td>
<td>$173</td>
<td>$525,574</td>
<td>$340</td>
<td>$1,032,920</td>
</tr>
<tr>
<td>Ductile Iron Pipe</td>
<td>728</td>
<td>0%</td>
<td>-</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Replace Techite Pipe</td>
<td>2,415</td>
<td>100%</td>
<td>2,415</td>
<td>LF</td>
<td>$173</td>
<td>$417,797</td>
<td>$340</td>
<td>$821,103</td>
</tr>
<tr>
<td>Rehabilitate Vitrified Clay Pipe</td>
<td>419,541</td>
<td>50%</td>
<td>209,771</td>
<td>LF</td>
<td>$53</td>
<td>$11,117,848</td>
<td>$160</td>
<td>$33,563,315</td>
</tr>
<tr>
<td>Rehabilitate Manholes</td>
<td>2400</td>
<td>20%</td>
<td>480</td>
<td>EA</td>
<td>$3,000</td>
<td>$1,440,000</td>
<td>$6,000</td>
<td>$2,880,000</td>
</tr>
<tr>
<td>Replace Manholes</td>
<td>2400</td>
<td>5%</td>
<td>120</td>
<td>EA</td>
<td>$9,000</td>
<td>$1,080,000</td>
<td>$30,000</td>
<td>$3,600,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$14,894,730</td>
<td>$42,843,787</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$15,000,000</td>
<td>$43,000,000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The following assumptions have been made in the development of these costs:

- 50% of all VCP Pipes need to be rehabilitated using CIPP lining
- All Techite Pipe needs to be replaced by open cut replacement method
- All Cast Iron Pipe needs to be replaced by open cut replacement method
- All open cut pipe replacements are 10” diameter pipe
- 25% of all Asbestos Cement Pipe needs to be rehabilitated using CIPP lining
- 5% of all manholes need to be replaced
- 25% of all manholes need to be lined
- No sewer lateral replacements are included
6.2 Conclusions

Controlling I/I within the collection system is a significant issue for the District. It will require a significant investment on the part of the District to reduce I/I to reasonable levels.

The primary recommended strategies for reducing I/I include:

- Conduct smoke testing in areas with the highest levels of I/I, and eliminate all identified cross connections.
- Conduct inspections to identify manholes experiencing I/I, and rehabilitate or replace these manholes.
- Conduct inspections to identify sewer mains experiencing I/I, and rehabilitate or replace these mains.
- Implement a lateral replacement program to encourage residents to replace deteriorated laterals.
- Focus improvements on basins with the highest levels of I/I.

To complete the necessary system rehabilitations, the District should budget between $15 and $43 million.
Appendix A

Basin Maps
### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPM</td>
<td>Gallons Per Minute</td>
</tr>
<tr>
<td>GAL/LF/IN</td>
<td>Gallons of I/I Per Linear Foot Per Inch of Rainfall</td>
</tr>
<tr>
<td>I/I</td>
<td>Inflow and Infiltration</td>
</tr>
<tr>
<td>PDWF</td>
<td>Peak Dry Weather Flow</td>
</tr>
<tr>
<td>PWWF</td>
<td>Peak Wet Weather Flow</td>
</tr>
<tr>
<td>PSEF</td>
<td>Peak Storm Event Flow</td>
</tr>
<tr>
<td>RDII</td>
<td>Rain Dependent Inflow and Infiltration</td>
</tr>
<tr>
<td>PVC</td>
<td>Polyvinyl Chloride</td>
</tr>
<tr>
<td>VCP</td>
<td>Vitrified Clay Pipe</td>
</tr>
</tbody>
</table>

### Legend

- **Basin Boundary**
- **Property Boundary**
- **Sanitary Sewer**
- **Sewer Mains with Known I/I**
- **Manholes with Known I/I**
- **High Ground Water**
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Flow (SPM)</th>
<th>Date</th>
<th>% of PDWF</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDWF</td>
<td>90</td>
<td>1/7/2006</td>
<td>100%</td>
</tr>
<tr>
<td>PWWF</td>
<td>160</td>
<td>4/14/2006</td>
<td>178%</td>
</tr>
<tr>
<td>PSEF</td>
<td>245</td>
<td>4/4/2006</td>
<td>272%</td>
</tr>
<tr>
<td>Maximum RDI</td>
<td>2.76</td>
<td>2009</td>
<td>Year = 2009</td>
</tr>
</tbody>
</table>

Initial Construction Decade: 1950s

Majority of Mains Installed Decade: 1950s

Predominant Pipe Material: VCP