



Expanded Case Study: Sewer Pipe Defect Analysis Of El Paso Water Area 3

1. Introduction

This case study provides a comprehensive engineering analysis of sewer condition assessment data based on the NASSCO Pipeline Assessment Certification Program (PACP) framework. The dataset, derived from Impact Pipe Inspection's InREACH Process using EdgeAI's Pipe Dream Camera System, includes over 3,280 unique pipe segment references and focuses on evaluating defects by pipe material, diameter, defect type, and severity grading. The purpose of this analysis is to identify recurring structural and operational issues that pose risks to serviceability and structural integrity, while also aligning with national best practices for sewer asset management.

Key findings indicate that Vitrified Clay Pipe (VCP), a legacy material widely used in mid-20th century sewer construction, exhibits the highest concentration of structural defects—particularly longitudinal fractures (FL) and cracks (CL). These defects are primarily concentrated in 8-inch diameter pipes, which not only constitute the majority of the inspected inventory but also display elevated defect frequency and severity. In fact, VCP 8-inch segments consistently lead in Grade 4 and 5 structural defects, indicating an urgent need for rehabilitation or replacement in many areas.

Operational and Maintenance (O&M) defects—especially Debris Not Flowing (DNF)—were also prevalent in misaligned or deteriorated joints, suggesting aging infrastructure and inadequate slope or hydraulic performance. PVC pipes, while present in smaller quantities, exhibited fewer structural issues but did show isolated joint-related concerns, particularly in medium and larger diameters. Cast iron and concrete pipes showed intermediate defect volumes, often influenced by age, location, or installation conditions.

Trend analysis revealed:

- **Pipe Material Trend:** VCP pipes are most vulnerable to structural failure, particularly due to their brittleness and susceptibility to root intrusion, ground movement, and joint separation.



- **Pipe Diameter Trend:** 8-inch pipes represent the most defect-prone diameter, both due to their high frequency in the system and their age.
- **Defect Type Trend:** Structural defects, especially fractures and cracks, dominate in VCP. O&M defects like DNF tend to occur where joint degradation is observed.
- **Severity Trend:** Structural defects dominate high-severity grades (4–5), while O&M defects are more commonly graded 1–3, though some show elevated grades requiring short-term reinspection.

This analysis supports a targeted rehabilitation strategy that prioritizes Grade 4–5 structural defects in VCP 8-inch segments and systematic maintenance of flow-blocking O&M conditions. By correlating defect codes with pipe material and geometry, the utility can more effectively allocate resources, schedule repairs, and develop a proactive asset management plan.

2. Joint Defects by Pipe Material

A significant portion of joint-related defects were identified in Vitrified Clay Pipe (VCP), confirming the known limitations of this material in legacy sewer systems. VCP exhibited high counts of longitudinal fractures (FL) and cracks (CL), often aggravated by ground movement or root intrusion. Among the top structural joint defect codes recorded:

- **FL (Fracture Longitudinal):** Indicates extensive linear cracking, commonly observed at pipe joints.
- **CL (Cracks Longitudinal):** Precursor to more severe structural failures.
- **FM (Fracture Multiple):** Advanced degradation signifying imminent structural compromise.
- **FS (Fracture Spiral):** Suggestive of torsional stress or pipe shifting.
- **DNF (Debris Not Flowing):** An O&M issue, often occurring at poorly aligned or damaged joints.

The majority of these defects are concentrated in 8-inch diameter VCP segments, a common size in older infrastructure. PVC and Cast Iron pipes also showed joint-related defects, but at a much lower frequency. PVC, in particular, was more often affected by O&M issues like DNF or infiltration-related concerns at joints.

Understanding the distribution of joint defects by material allows utilities to direct maintenance and rehabilitation toward the highest-risk combinations. Specifically, medium-diameter VCP segments require immediate structural assessment and prioritized repair planning.

3. Severity Trends for Top Defect Codes



An evaluation of severity grading, as defined by PACP standards, provides insight into the urgency and magnitude of each defect type. Grades range from 1 (minor, monitor) to 5 (critical, imminent failure). In this dataset, high-severity defects were consistently associated with structural issues rather than O&M concerns.

- **Structural Defects:** Defects such as FL (Fracture Longitudinal), FM (Fracture Multiple), and FS (Fracture Spiral) commonly appeared with Grades 4 and 5, indicating significant loss of structural integrity. These defects are typically found in aging VCP infrastructure and suggest that portions of the system are approaching or have exceeded their design life.
- **Operational & Maintenance (O&M) Defects:** Conditions such as DNF (Debris Not Flowing), GRE (Grease), and INF (Infiltration) generally appeared in Grades 1–3. These issues, while not immediately structurally compromising, can evolve into more serious conditions if not addressed through routine cleaning and inspection.

The prevalence of high-grade structural defects highlights the need for urgent intervention in specific segments of the network. Prioritizing Grade 4–5 structural defects for rehabilitation or replacement is essential for risk mitigation. Meanwhile, recurring O&M defects, particularly those with a Grade 3 rating, should be tracked in a proactive maintenance schedule to prevent escalation.

This severity-based prioritization strategy aligns with NASSCO's risk-based asset management principles and helps utilities effectively deploy capital resources where they will have the greatest impact on system reliability and public health.

4. Defect Classification: O&M vs Structural

Defects observed in this analysis were grouped according to the NASSCO PACP categories of Operational & Maintenance (O&M) and Structural. Each class carries distinct implications for asset management, inspection frequency, and rehabilitation response.

Operational & Maintenance (O&M) Defects: These defects affect flow performance but do not necessarily compromise the structural integrity of the pipe. Common examples include:

- **DNF (Debris Not Flowing):** Obstruction of hydraulic flow due to sediment, debris, or root intrusion.
- **GRE (Grease):** Accumulations that may impede flow or contribute to blockages.
- **INF (Infiltration):** Minor leaks at joints or connections allowing groundwater entry.

While not structurally critical, recurring O&M defects can increase the risk of backups, surcharge, and eventual deterioration if left unaddressed. These defects are best managed



through routine cleaning, root cutting, and scheduled maintenance programs. Defects with Grade 3 or higher severity should be prioritized for follow-up inspection within 3–5 years.

Structural Defects: These defects represent physical compromises in the pipe wall or joints and pose a direct risk to system integrity. Common examples include:

- **FL (Fracture Longitudinal)**
- **FM (Fracture Multiple)**
- **FS (Fracture Spiral)**
- **CL (Crack Longitudinal)**

Such defects are typically indicative of advanced material degradation, improper bedding, or external loading stress. When found with severity Grades 4 or 5, immediate engineering evaluation and rehabilitation design are warranted. Options may include trenchless lining (e.g., CIPP), segmental replacement, or point repairs, depending on the defect extent and location.

Understanding this classification supports a dual strategy: proactive maintenance for O&M issues and capital improvement planning for structural risks. This alignment ensures the utility addresses both immediate service concerns and long-term infrastructure resilience.

5. Visual Analysis of Defects

A set of visualizations were prepared to illustrate the trends discovered in the inspection dataset. These visuals help communicate key findings effectively and serve as decision-support tools for engineering and operations teams. Below is a narrative summary of the key charts included:

a. Defect Severity Distribution: This chart categorizes all recorded PACP defects by severity grade (1–5). It shows a pronounced concentration of Grades 4 and 5 among structural defects such as FL, FM, and FS, particularly in VCP pipes. In contrast, most O&M defects fall within Grades 1–3, though a portion of DNF entries reach Grade 4, signaling localized hydraulic concerns.

b. Joint Defects by Pipe Material and Diameter: This matrix-style bar chart displays the distribution of joint-related defects by both material and diameter. The most notable cluster is 8-inch VCP segments, accounting for the highest frequency of joint failures. These results reinforce the urgency of inspecting and prioritizing rehabilitation in these pipe groups.

c. Total Defects by Pipe Material: This comparative bar graph summarizes the total number of defects identified across different pipe materials. VCP ranks highest, followed by PVC and Cast Iron (CT). This reflects the historical reliance on VCP in legacy systems and its greater vulnerability to mechanical and environmental stress.



d. Defects by Pipe Diameter: This chart demonstrates the frequency of defects by pipe diameter. The highest concentration occurs in 8-inch pipes, a common diameter in many systems. The chart also reflects a secondary peak in 12-inch VCP pipes, indicating that larger-diameter legacy assets are also at elevated risk.

These visual representations align with PACP-based scoring and industry expectations. They can be integrated into GIS platforms or asset management dashboards to further enhance proactive inspection planning, budget forecasting, and risk-based prioritization.

6. Conclusion & Recommendations

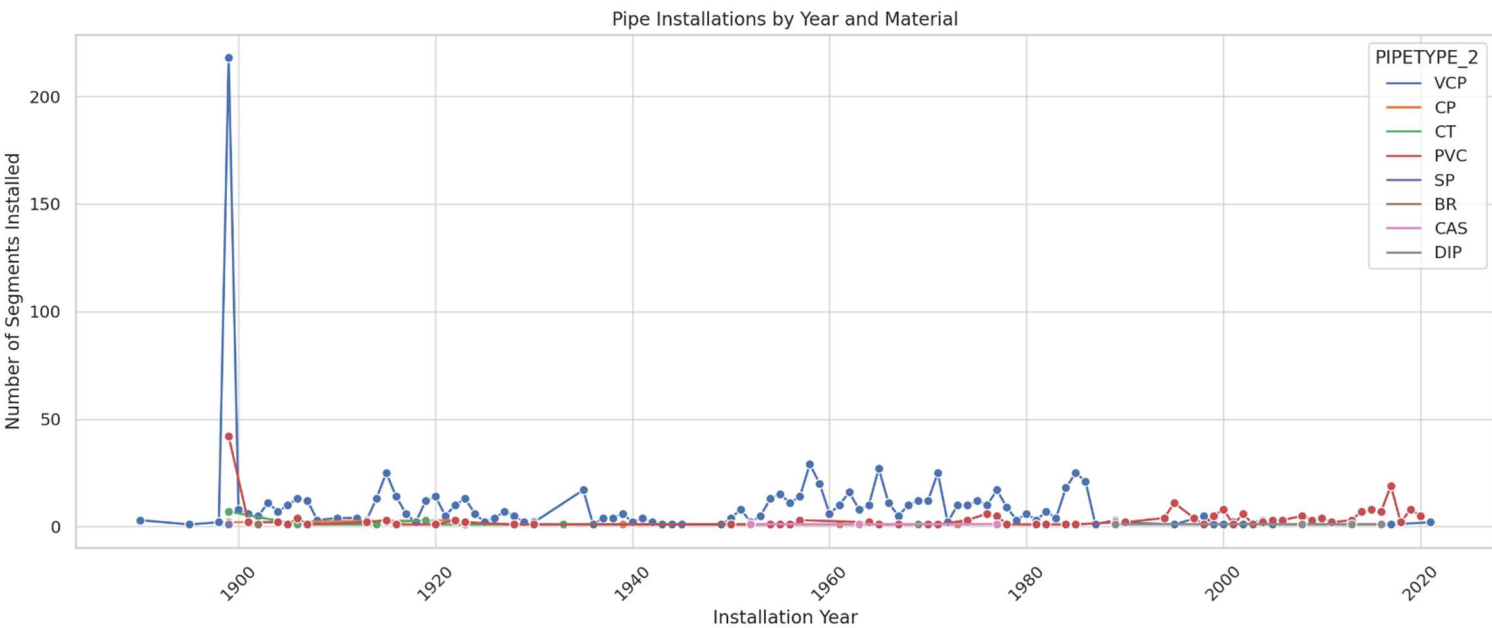
The findings from this case study demonstrate a clear pattern of structural deterioration and flow-related issues concentrated within legacy segments of the sewer system, particularly among 8-inch Vitrified Clay Pipe (VCP). This material, though historically common, now represents a significant vulnerability due to its high incidence of longitudinal fractures, cracks, and joint separations.

7. Construction Date Analysis

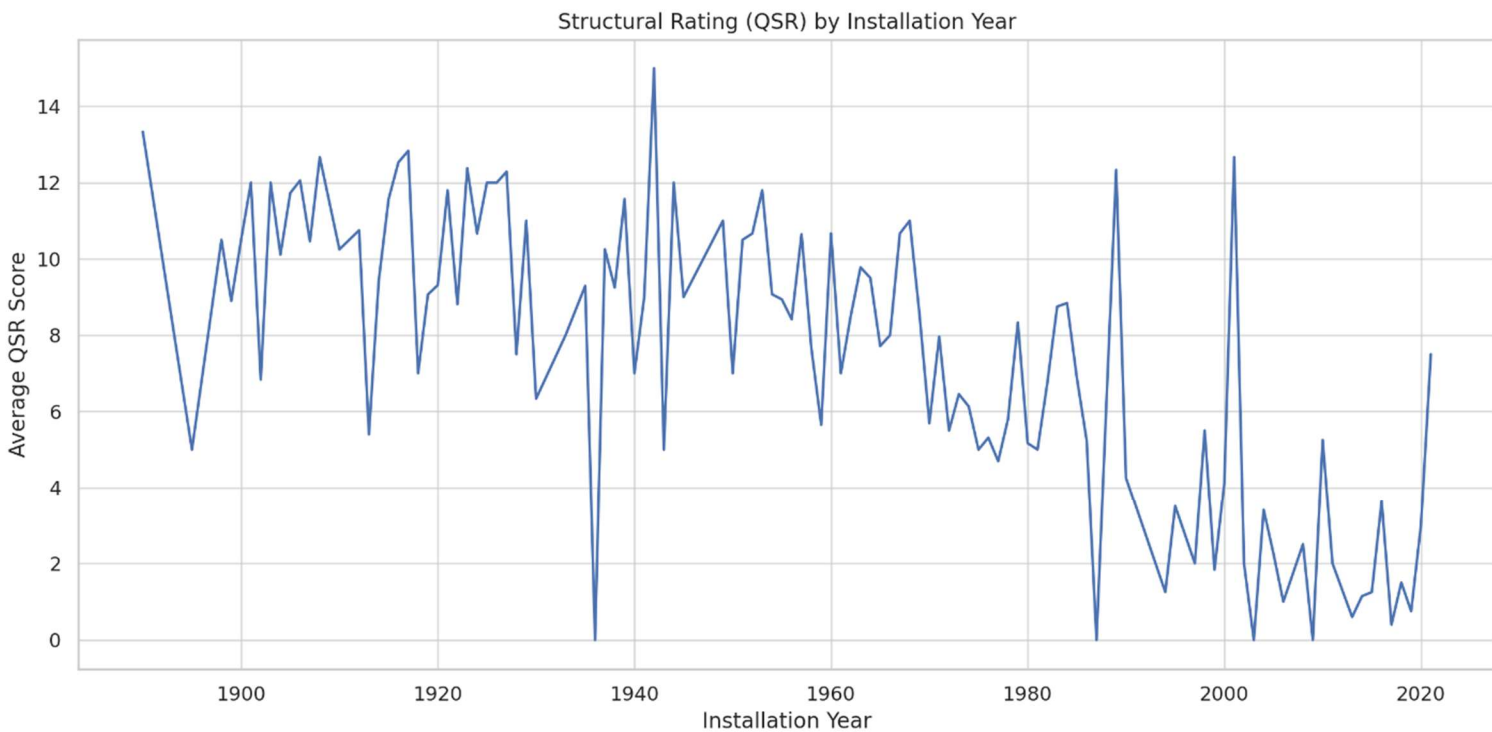
- The following is a summary of the asset data extracted from the PACP inspection dataset:
 1. Total pipe segments analyzed: 1212
 1. Installation years range from 1890 to 2021
 2. Average Quick Maintenance Rating (QMR): 6.31
 3. Average Quick Structural Rating (QSR): 8.03
- Pipe material distribution:
 1. VCP: 951 segments
 2. PVC: 224 segments
 3. CT: 19 segments
 4. CP: 9 segments
 5. DIP: 4 segments
 6. CAS: 3 segments
 7. SP: 1 segment
 8. BR: 1 segment



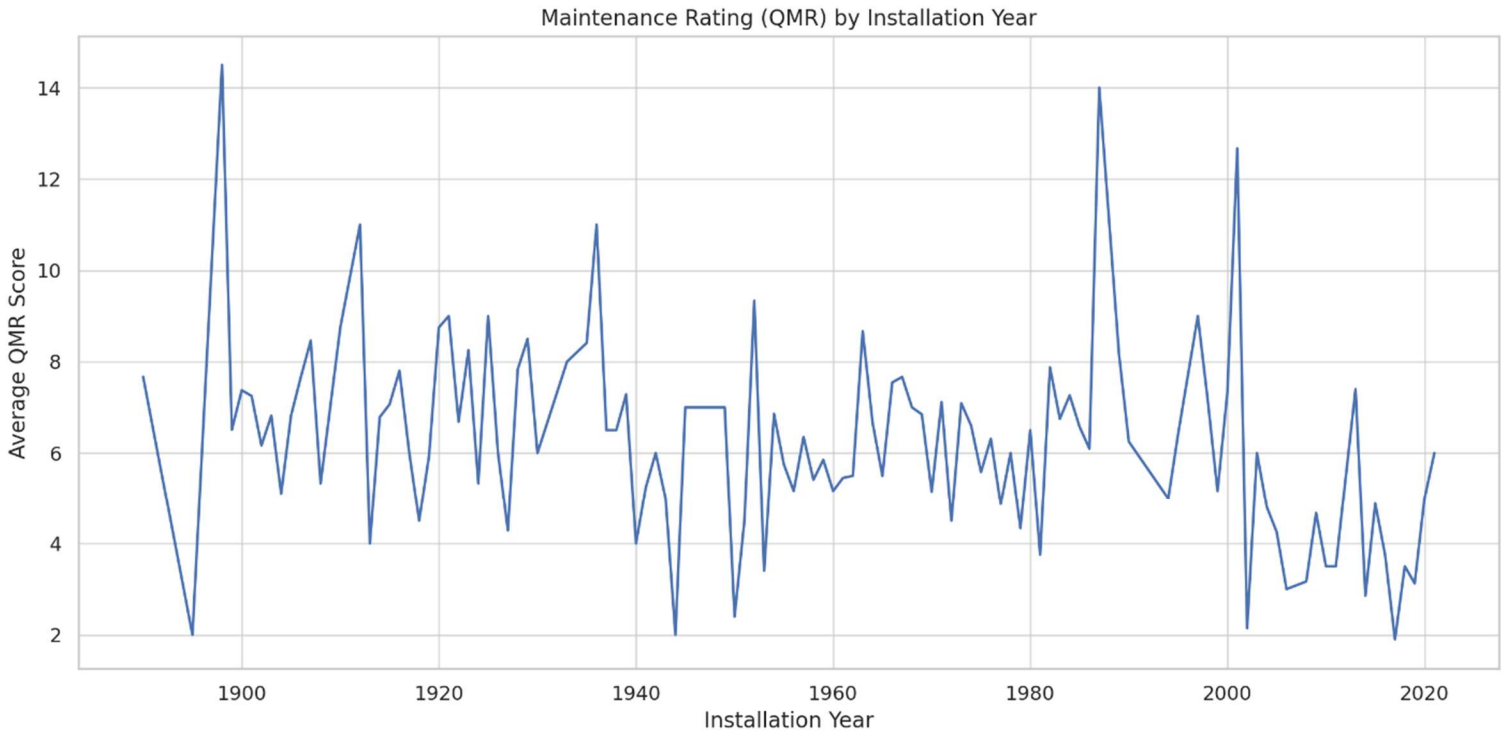
8. Pipe Material Usage Over Time



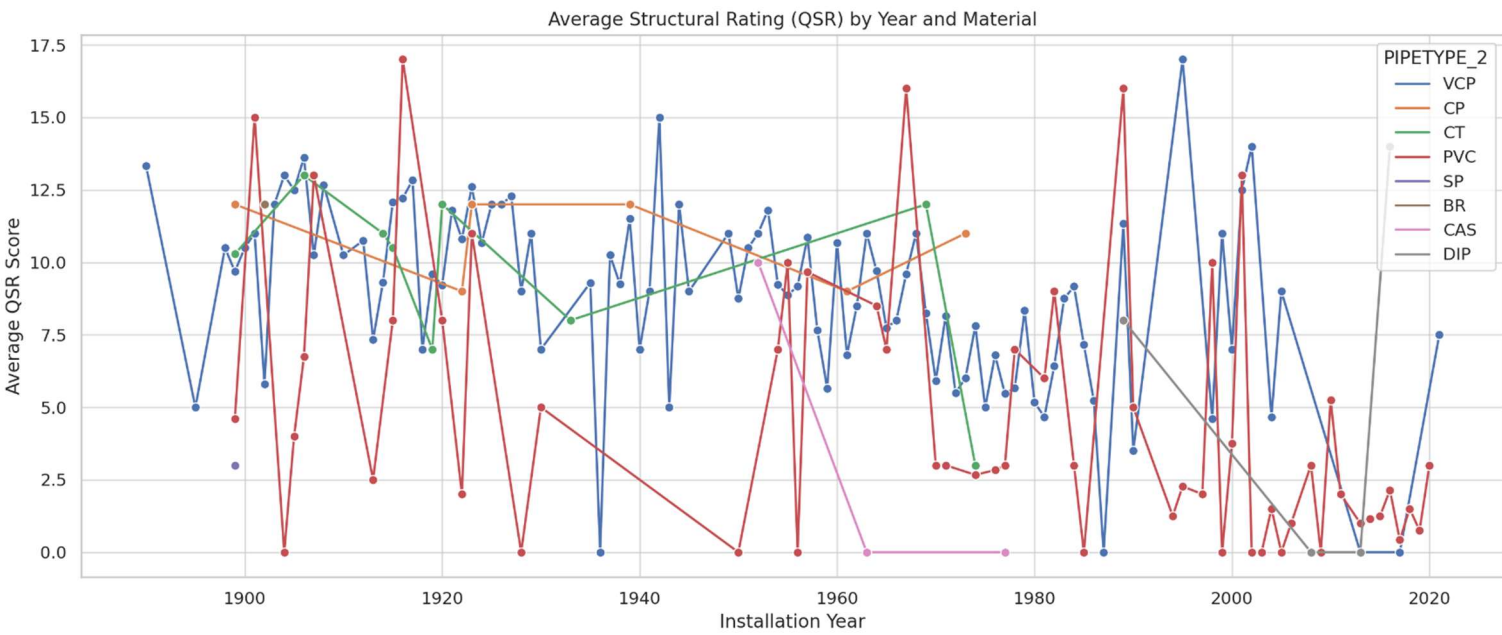
9. Structural Rating (QSR) Over Time



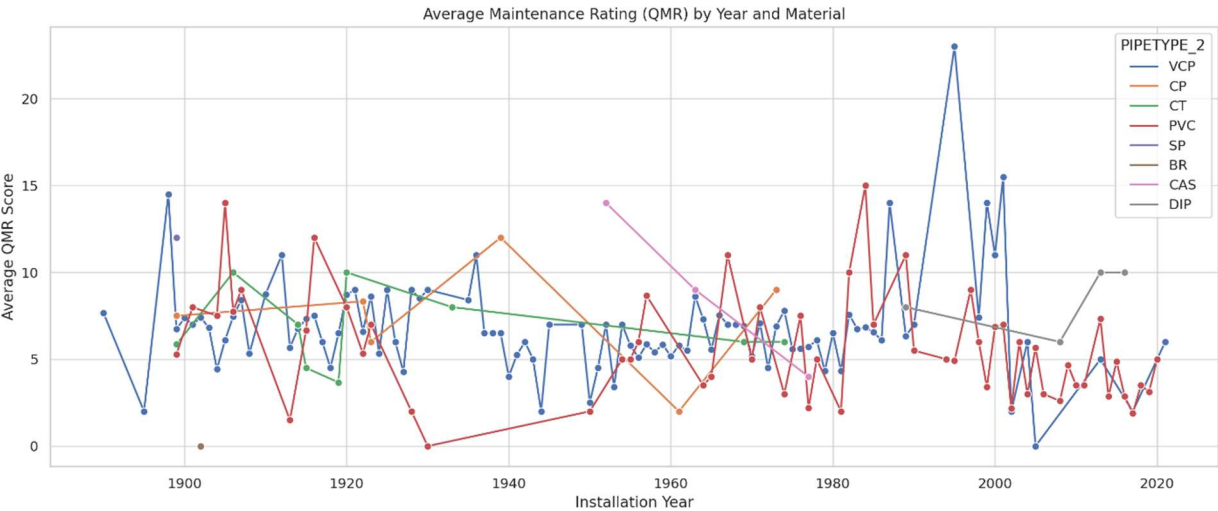
10. Maintenance Rating (QMR) Over Time



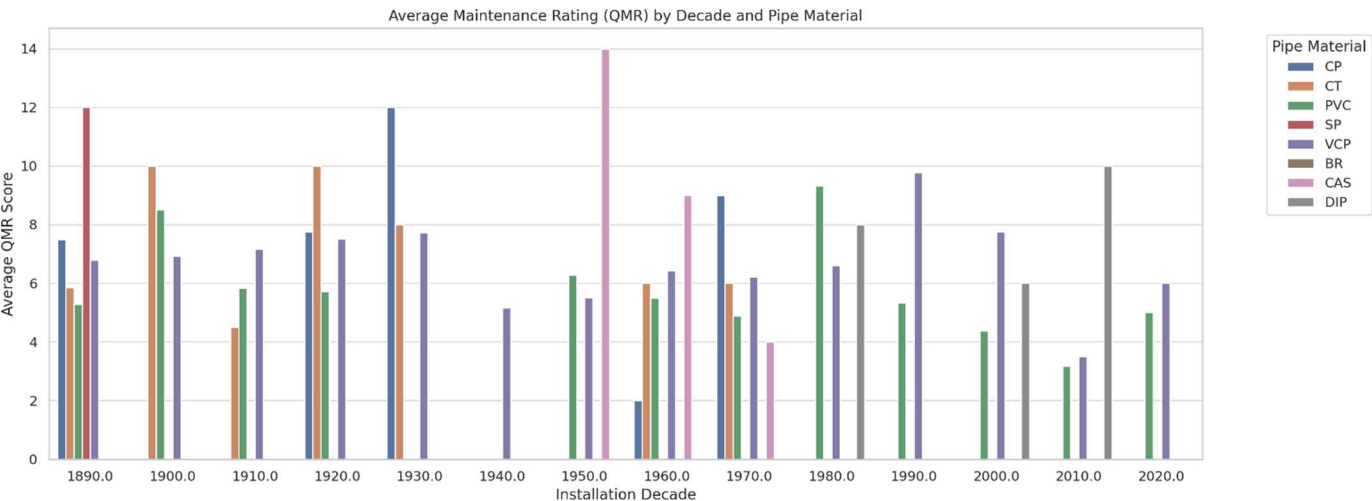
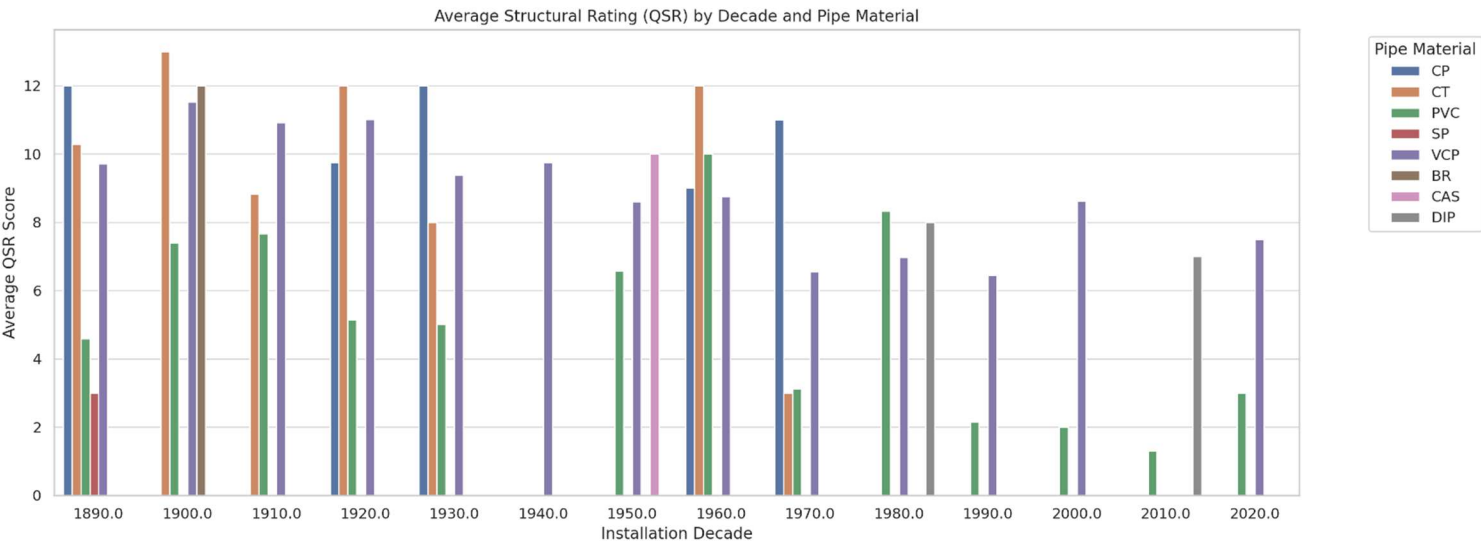
11. Structural Condition by Year and Material



12. Maintenance Condition by Year and Material



13. Comparison by Decade and Material



Key takeaways include:

- Structural defects such as FL, FM, and FS are highly correlated with older VCP segments, most notably in 8-inch pipes.
- High-severity (Grades 4–5) structural issues should be prioritized for rehabilitation through trenchless or open-cut repair programs.
- DNF and other O&M defects are frequent but typically lower in severity. These should be managed through scheduled cleaning, inspection cycles, and hydraulic performance monitoring.

Based on these findings, the following actions are recommended:

1. **Immediate Prioritization of High-Severity Structural Defects (Grades 4–5):** Focus on VCP segments with multiple occurrences of FL, FM, and FS. Conduct engineering evaluations and initiate rehabilitation design.
2. **Routine Cleaning and Maintenance for O&M Issues:** Segments with recurring DNF, INF, or GRE codes should be placed on high-frequency jetting and inspection schedules.
3. **Condition-Based Asset Management Strategy:** Use PACP scoring, material profiles, and diameter trends to inform capital planning and optimize inspection investments.
4. **GIS Integration and Dashboarding:** Incorporate this data into an asset management system to support visual prioritization, maintenance tracking, and capital budgeting.
5. **Update Reinspection Cycles:** Adjust reinspection intervals based on defect severity and material—e.g., inspect high-risk segments within 12–24 months, and lower-risk ones within 4–10 years depending on grade and defect type.

These targeted actions support a proactive, data-driven approach to sewer infrastructure management that reduces system risk, optimizes public investment, and supports regulatory compliance.

Appendix A: Industry Standards by Pipe Material

- **Vitrified Clay Pipe (VCP):**
 - Highly brittle and prone to fractures and joint separation.
 - Common defects: FL, CL, FM, FS, ISJ.



- Recommendations: Caution with mechanical cleaning. Relining or replacement advised.
- **Concrete Pipe (RCP/Non-RCP):**
 - Vulnerable to corrosion (e.g., hydrogen sulfide) and cracking.
 - Common defects: FL, CL, CRB, FSP.
 - Recommendations: Monitor for spalling and offset joints; consider geopolymer lining.
- **PVC Pipe:**
 - Generally chemically resistant, but vulnerable to joint separation.
 - Common defects: ISJ, MJS, DEB.
 - Recommendations: Inspect joints routinely; structurally sound otherwise.
- **HDPE Pipe:**
 - Strong fusion joints, but may exhibit deformation (ovalities) or poor welds.
 - Common defects: DEF, SAP, ISJ.
 - Recommendations: Quality control during installation is critical.
- **Brick or Stone Pipe (BR):**
 - Found in historical systems; subject to collapse or infiltration.
 - Common defects: B, H, FS, ISJ.
 - Recommendations: Full replacement or structural relining typically required.

Appendix B: O&M and Structural Reinspection Guidelines

Operational & Maintenance (O&M) Defects:

- **Grades 1–2:** Reinspect every 8–10 years.
- **Grade 3:** Reinspect every 4–5 years.
- **Grades 4–5:** Reinspect every 1–2 years or after next major cleaning.

Structural Defects:

- **Grades 1–2:** Reinspect in 8–10 years.
- **Grade 3:** Reinspect in 3–5 years.
- **Grades 4–5:** Reinspect in 12–24 months or sooner if high-risk area.



Appendix C: Severity Grading Summary (PACP)

Grade Description		Action Recommendation
1	Minor – superficial	Monitor during routine cycles
2	Fair – slight deterioration	Schedule future reinspection
3	Moderate – early signs of risk	Inspect every 3–5 years
4	Poor – significant defects	Evaluate for rehabilitation
5	Critical – imminent failure	Immediate repair or replacement

This concludes the technical appendices supporting the sewer defect analysis and rehabilitation planning strategy.



Defect Severity Distribution

