FAILURE, ASSESSMENT & DESIGN OF SEWER FORCE MAINS

Webinar

March 3rd, 2021

ENVIRONMENTAL PARTNERS

WELCOME

PRESENTERS

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ABOUT EP

Environmental Partners (EP) is an award-winning multidisciplinary engineering and consulting firm celebrating its 24th year in business. With a team of over 70 professionals, EP proudly serves New England.

LOCATIONS

[HQ] Quincy, MA

Woburn, MA

Hyannis, MA

Middletown, CT

ABOUT EP

EP provides a broad range of services to municipal, commercial, industrial, and institutional clients

SERVICES INCLUDE

Civil Engineering
Construction Management
Drinking Water
Emergency Management Services
Owner's Project Management (OPM)
Environmental
GIS & Asset Management
Planning
Stormwater
Traffic & Transportation
Wastewater
Geotechnical

AGENDA

- Introductions
- Force Mains Background
- Common Causes of Force Main Failure
- Recent Force Main Failure Case Studies
- Force Main Condition Assessment Approach
- Design Considerations & Planning for New Sewer Force Mains
- Questions

FORCE MAINS BACKGROUND

Definition| Materials | Failures | Prevention

FORCE MAINS BACKGROUND

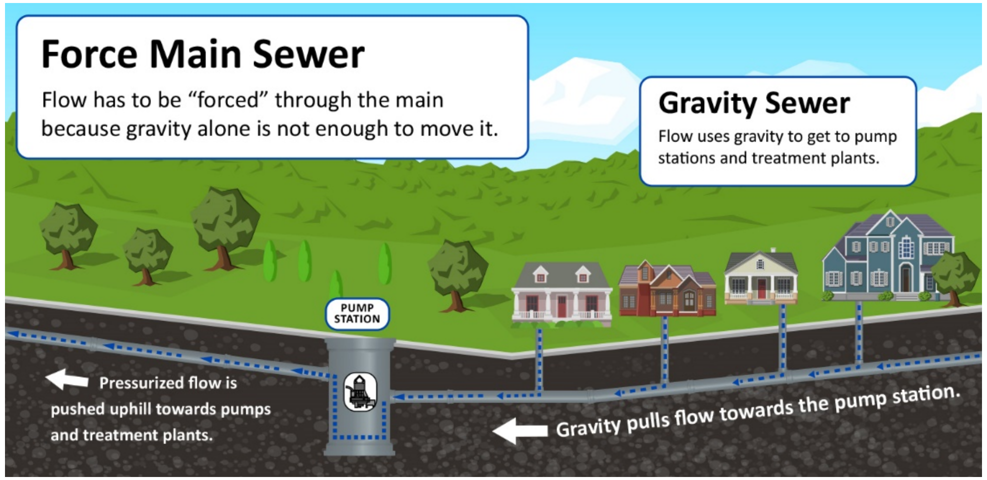
SEWER FORCE MAINS

What are they?

- Pipelines that convey wastewater under pressure from the discharge side of a pump to a discharge point

- Convey wastewater from lower to higher elevation where a gravity sewer system is not feasible or cost effective

- Key Elements of Force Main:
  - Pipe
  - Plug/Gate Valves
  - Pressure Surge Control Devices
  - Manholes - Access, ARV, and Clean Out/Blow-off
  - Pig Launching Stations, etc.
  - Air Injection Stations



Sewer Force Main Diagram

SOURCE: METROPOLITAN ST. LOUIS SEWER DISTRICT

SEWER FORCE MAIN PIPE MATERIAL

- Ductile Iron (DI)
- Polyvinyl Chloride (PVC)
- Cast Iron (CI)
- Polyethylene (PE)
- High Density Polyethylene (HDPE)
- PE/HDPE-lined DI/CI
- Asbestos Cement (AC)

Most frequently used materials for sewer force mains

HDPE Force Main For Slip-Lining

CASE STUDY NO.1

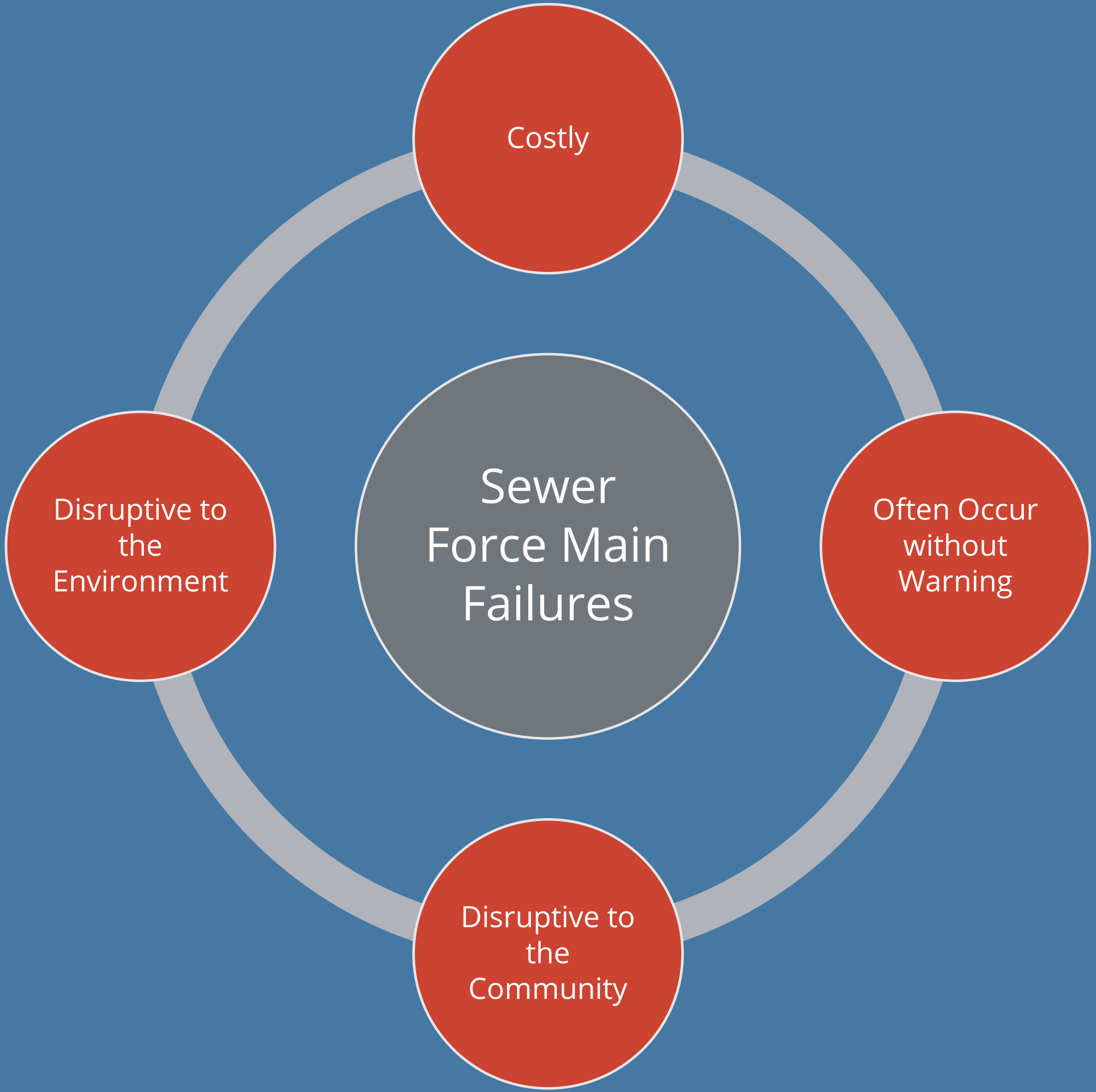
PVC Force Main Installation

CASE STUDY NO.1

SEWER FORCE MAIN PIPE MATERIAL – ADVANTAGES & DISADVANTAGES

Material	Advantages	Disadvantages
Ductile Iron & Cast Iron	• Can withstand high pressures (Typically more than PVC/HDPE for large pipe sizes)	• Less Favorable Hydraulics than HDPE or PVC • More susceptible to chemical attack and corrosion via hydrogen sulfide gas than HDPE or PVC
PVC	• Can withstand high pressures • Superior Hydraulics • Chemical and Corrosion resistant • Lightweight	• Less flexible than HDPE Pipe • Less resistant to Abrasion than HDPE • Pipe bedding more critical for PVC pipe than DI pipe
HDPE & PE	• Can withstand high pressures • Highly Flexible and Lightweight • Superior Hydraulics • Chemical and Corrosion resistant • High resistance to Abrasion (Superior to PVC)	• Typically more suitable for trenchless applications
Asbestos Cement	• Can withstand high pressures • Lightweight • Chemical and Corrosion resistant	• Less Favorable Hydraulics than HDPE or PVC • Relatively brittle

SEWER FORCE MAIN FAILURES



Emergency Response to FM Break
CASE STUDY NO.2

Emergency Response to FM Break
CASE STUDY NO.3

PROACTIVE VS. REACTIVE COSTS

- Average emergency repair cost for 20-inch or larger: $750k
- Structural rehab is approximately 200% of lining rehab
- Condition assessment cost is approximately 2% of replacement value
- Proactive Costs:
    - Condition assessment; Phased rehab
- Reactive Costs:
    - Emergency response, rehab and possible fines

SEWER FORCE MAIN FAILURE PREVENTION

- Sewer force mains constructed between the 1970s – 1990s may be nearing their end of life
- Preventative measures include:

1. Understanding the vulnerability of the force main to common failure causes based on its age, use, and material
2. Perform routine maintenance on the force main
3. Consideration for Force Main Condition Assessment
4. Assess vulnerability and risk

Failed Force Main Section

CASE STUDY NO.1

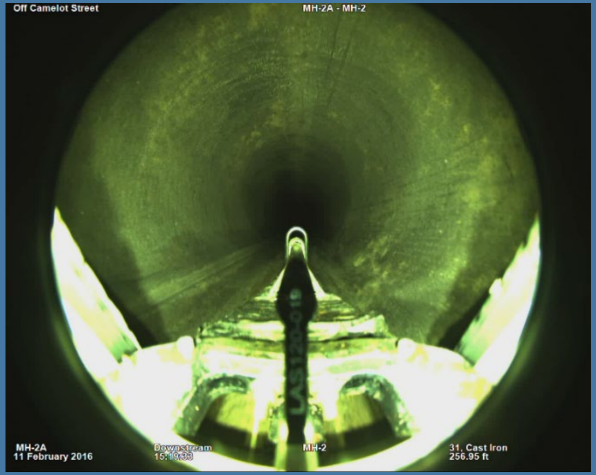
COMMON CAUSES OF FORCE MAIN FAILURE

Internal Corrosion | External Corrosion

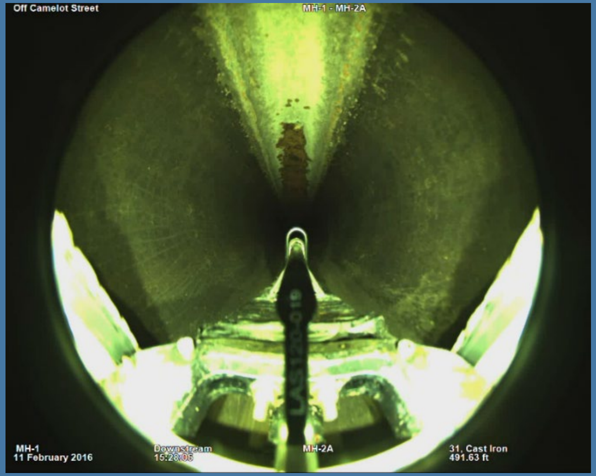
Workmanship Error | Lack of Routine Maintenance

COMMON CAUSES OF FORCE MAIN FAILURE

INTERNAL CORROSION



- H_2S Attack
- Microbial Attack
- Calcium Leaching (Conc. Pipe)
- Abrasion/Scour



WHICH SEWER FORCE MAINS ARE AT HIGH RISK?

Ductile Iron Pipe

Cast Iron Pipe

COMMON CAUSES OF FORCE MAIN FAILURE

EXTERNAL CORROSION

- Corrosive Soils
- Loss of Coating
- High Chloride and Sulfate environments
- Damage of ferrous pipe during installation

WHICH SEWER FORCE MAINS ARE AT HIGH RISK?

Ductile Iron Pipe

Cast Iron Pipe

Asbestos Cement Pipe

COMMON CAUSES OF FORCE MAIN FAILURE

STRUCTURAL FAILURE

- Point Load Failure
- Cyclic Fatigue
- Bell Failure
- Pipe deflection to external loads
- Third party damage
- Joint leakage
- Surge and transient pressures

WHICH SEWER FORCE MAINS ARE AT HIGH RISK?

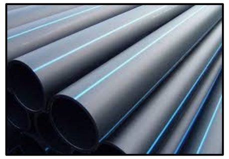
Ductile Iron Pipe

Cast Iron Pipe

Asbestos Cement Pipe

PVC Pipe

Polyethylene Pipe

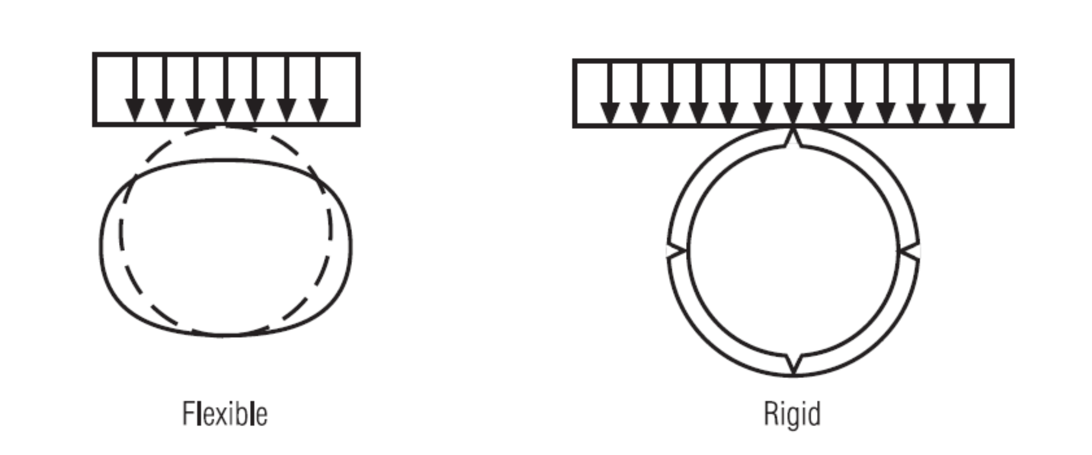


HDPE Pipe

COMMON CAUSES OF FORCE MAIN FAILURE

WORKMANSHIP ERROR

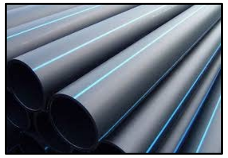
- Joint Fusion (HDPE Pipe)
- Pipe Bedding
- Excessive Push (Plastic Pipe)



WHICH SEWER FORCE MAINS ARE AT HIGH RISK?

Ductile Iron Pipe

PVC Pipe



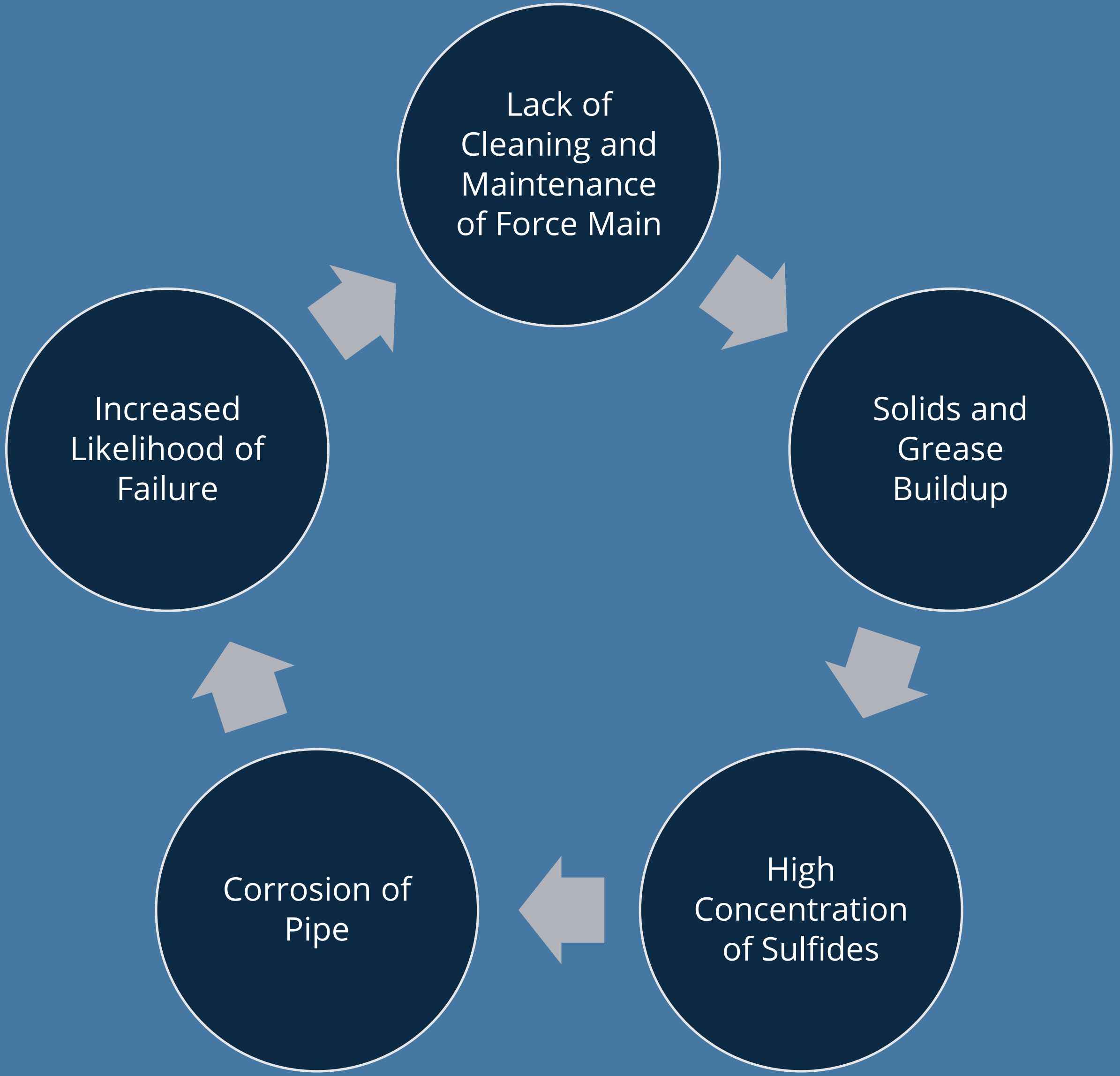
HDPE Pipe

Asbestos Cement Pipe

Cast Iron Pipe

COMMON CAUSES OF FORCE MAIN FAILURE

LACK OF ROUTINE MAINTENANCE



WHICH SEWER FORCE MAINS ARE AT HIGH RISK?

Ductile Iron Pipe

Cast Iron Pipe

Asbestos Cement Pipe

PVC Pipe

Polyethylene Pipe

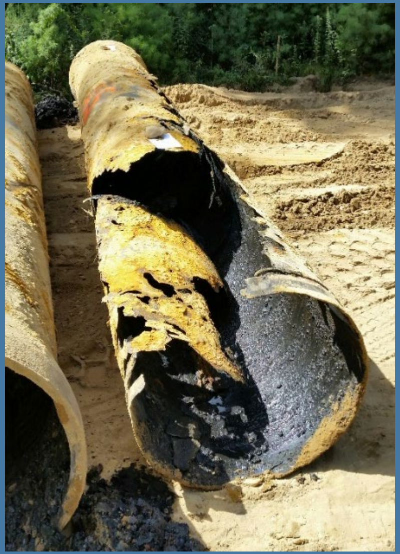
HDPE Pipe

RECENT FORCE MAIN FAILURE CASE STUDIES

Five Case Studies

RECENT FORCE MAIN FAILURE CASE STUDIES

CASE STUDY NO.1



KEY FACTS:

Date of Failure(s): 12/19/2015, 1/27/2016, and 1/31/2016

Pipe Age: 14 years

Pipe Size: 30-inch

Pipe Length: 25,000 feet

Pipe Material: Cement-lined Class 52 DI

Cause of Failure: H_2S Corrosion

Unique Features: Portion of FM installed within cross-country easement. Undulating elevation profile. Highway crossing.

Cost to Repair: ~$48.2 Million

RECENT FORCE MAIN FAILURE CASE STUDIES

CASE STUDY NO.2

KEY FACTS:

Date of Failure(s): 9/2016 and 10/2017

Pipe Age: 32 Years

Pipe Size: 20-inch

Pipe Length: 16,000 feet

Pipe Material: Cement-lined Class 52 DI

Cause of Failure: Corrosive Soils

Unique Features: Force main installed below junkyard, landfill, and wetlands

Cost to Repair: ~$500,000 per break

RECENT FORCE MAIN FAILURE CASE STUDIES

CASE STUDY NO.3

KEY FACTS:

Date of Failure(s): 1/4/2018

Pipe Age: 32 Years

Pipe Size: 16-inch inside 20-inch

Pipe Length: 17,900 feet

Pipe Material: PE inside CI

Cause of Failure: Workmanship Error

Unique Features: Portion of FM installed within cross-country easement. Shallow cover. No grout in annular space.

Cost to Repair: ~$2.7 Million

RECENT FORCE MAIN FAILURE CASE STUDIES

CASE STUDY NO.4

KEY FACTS:

Date of Failure(s): No Failure

Pipe Age: 1979

Pipe Size: 12", 14" and 20"

Pipe Length: 20 feet

Pipe Material: CI & DI

Cause of Failure: No Failure

Unique Features: Located in wetwell subject to sewer surcharge

Cost to Repair: $350,000

RECENT FORCE MAIN FAILURE CASE STUDIES

CASE STUDY NO.5

KEY FACTS:

Date of Failure(s): May 2020 (3 breaks)

Pipe Age: 1981

Pipe Size: 16”

Pipe Length: 7.8 Miles

Pipe Material: Cement-Lined DI

Cause of Failure: **Internal** Corrosion

Unique Features: Length of pipe; easement and exposure

Cost to Repair: TBD

FORCE MAIN CONDITION ASSESSMENT APPROACH

Site Reconnaissance | Desktop Study

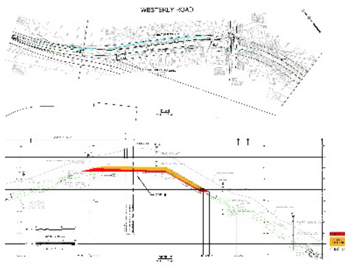
Assess Extent of Failure and Condition

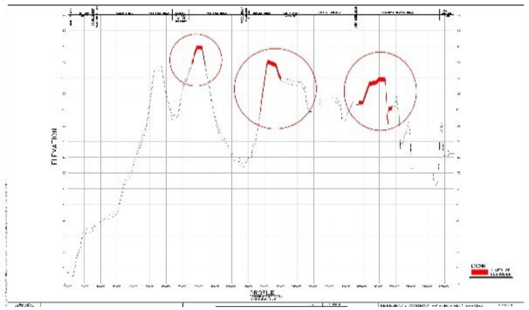
Assess Rehabilitation Options

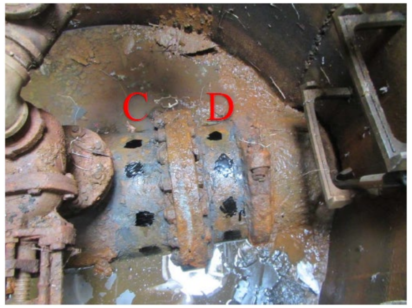
Identify Permanent Solution

FORCE MAIN CONDITION ASSESSMENT APPROACH

1. Tier 1: Desktop study; Surface Inspection; Hydraulic profile and modeling
2. Tier 2: Geoprobes; test pits; soil testing; UT Scans
3. Tier 3: CCTV; HD Scans; Specialty tools







FORCE MAIN CONDITION ASSESSMENT APPROACH

TIER 1 : PERFORM SITE RECONNAISSANCE

- Conduct Site Visit to relevant areas including Pump Stations and/or Treatment Plants
- Obtain records, operation and maintenance manuals, and pump station data
- Coordinate with Town staff
- Walk the entirety of the force main alignment. Gather notes and note any concerns

Force Main Alignment Walk Through

CASE STUDY NO.2

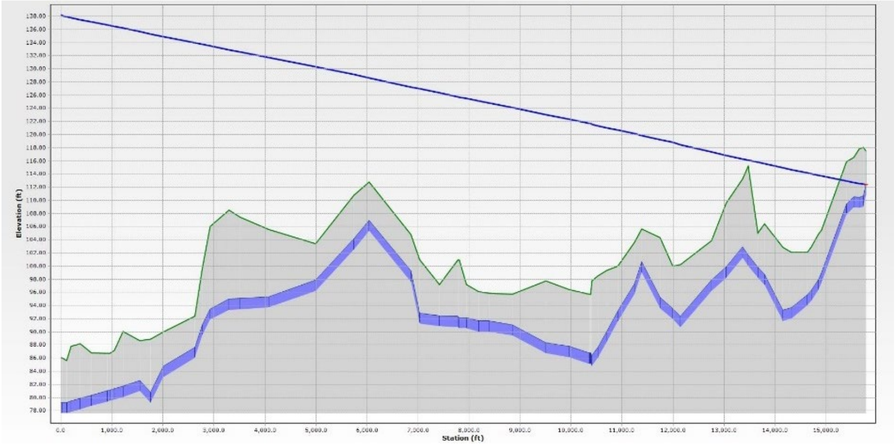
Site Visit to Pump Station

CASE STUDY NO.2

FORCE MAIN CONDITION ASSESSMENT APPROACH

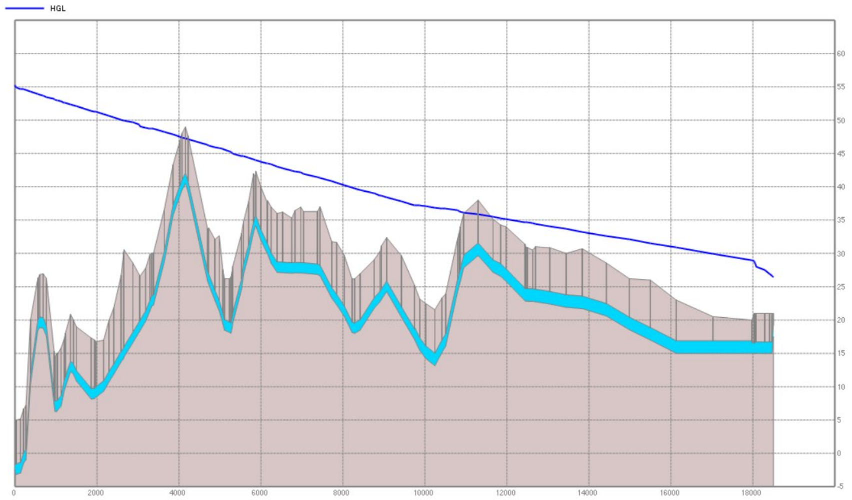
TIER 1(Cont'd): PERFORM DESKTOP STUDY

- Gather and Review As-Built/Record Plans
- Gather and Review Flow Data
- Gather and Review Pump Station Data (Pump Cycles, Operation Data, Pressures)
- Construct Hydraulic Model of Force Main



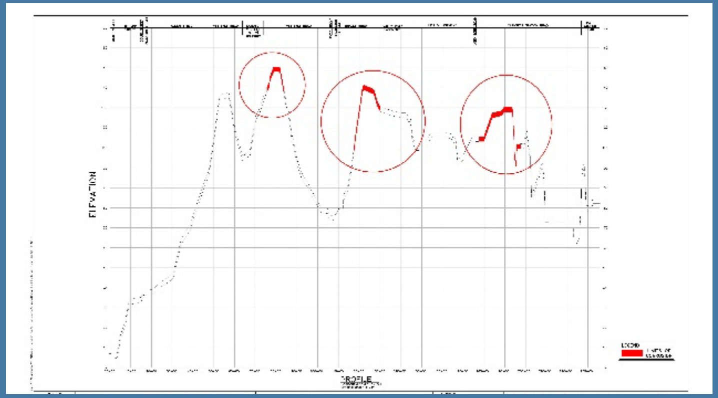
SewerGEMS Hydraulic FM Model

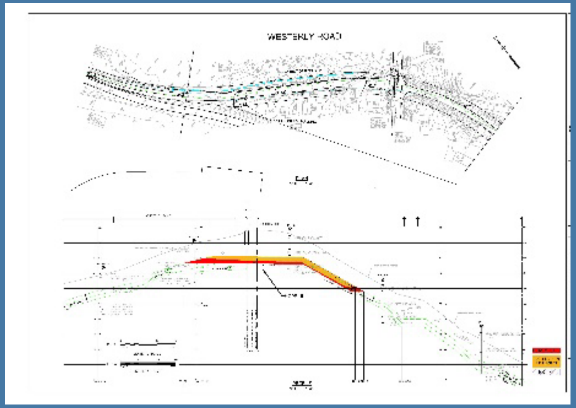
CASE STUDY NO.2



PCSWMM Hydraulic FM Model

CASE STUDY NO.3

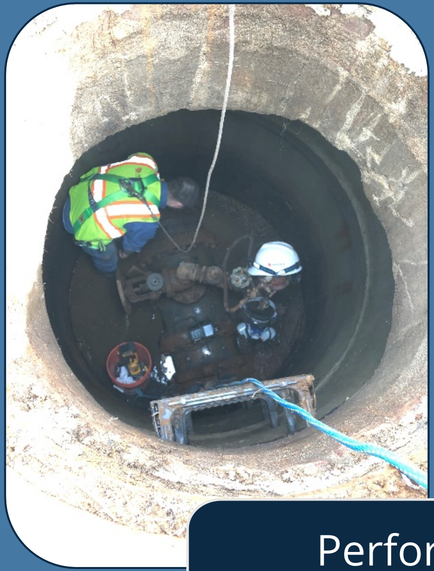




TIER 2: EXTERIOR CONDITION ASSESSMENT

Gain Access to Force Main

- Via Existing Access Manholes (if present)
- Via Excavated Access Pits



Perform Exterior Condition Assessment

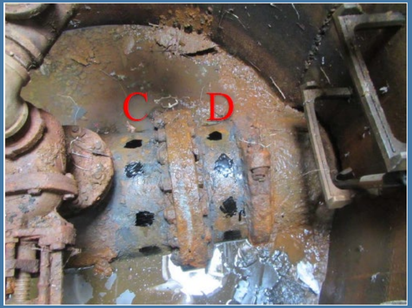
- Multiple Methods Available

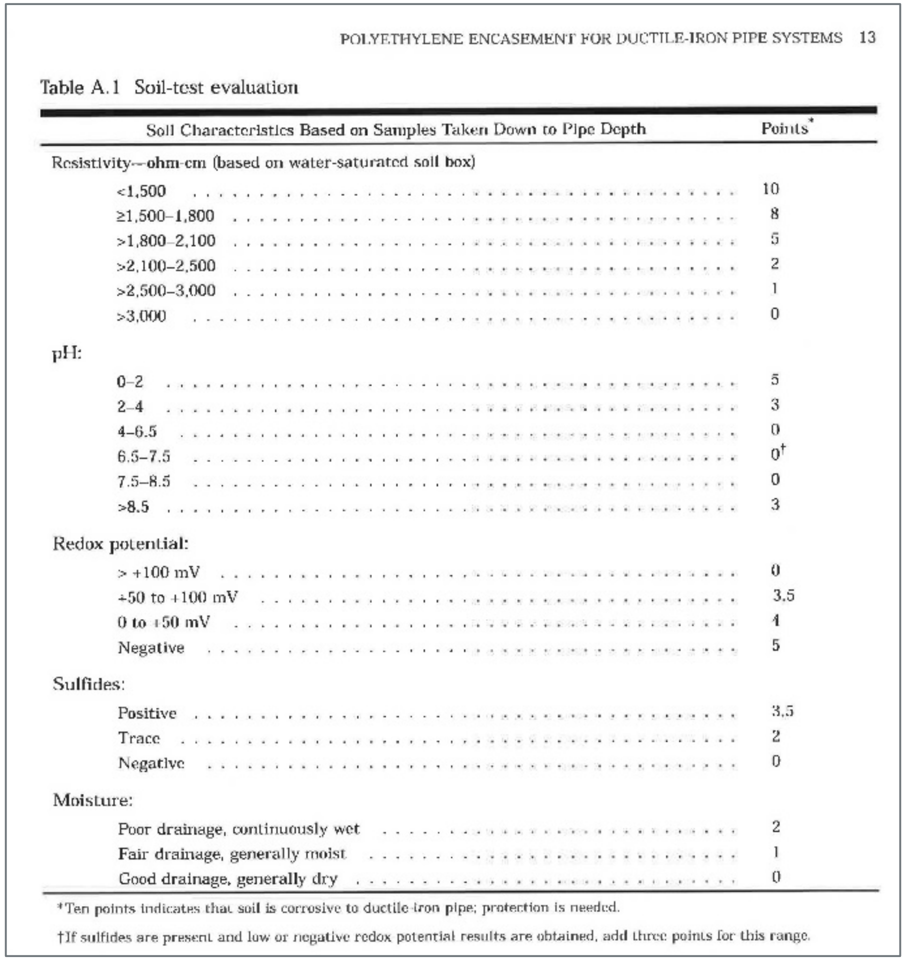
FORCE MAIN CONDITION ASSESSMENT APPROACH

TIER 2: EXTERIOR CONDITION ASSESSMENT

METHODS AND TECHNOLOGIES:

- Ultrasonic Thickness Scan
  - Determine if a loss of wall thickness has occurred in the pipe using a non-destructive, non-invasive method
- Geoprobe/Boring Drilling and Sampling
  - Determine if corrosive soils are present and whether the force main is at risk of external corrosion (AWWA 10-Point System)





POLYETHYLENE ENCASEMENT FOR DUCTILE-IRON PIPE SYSTEMS 13

Table A.1 Soil-test evaluation

Soil Characteristics Based on Samples Taken Down to Pipe Depth	Points*
Resistivity—ohm-cm (based on water-saturated soil box)	
<1,500	10
≥1,500–1,800	8
>1,800–2,100	5
>2,100–2,500	2
>2,500–3,000	1
>3,000	0
pH:	
0–2	5
2–4	3
4–6.5	0
6.5–7.5	0†
7.5–8.5	0
>8.5	3
Redox potential:	
> +100 mV	0
+50 to +100 mV	3.5
0 to +50 mV	4
Negative	5
Sulfides:	
Positive	3.5
Trace	2
Negative	0
Moisture:	
Poor drainage, continuously wet	2
Fair drainage, generally moist	1
Good drainage, generally dry	0

*Ten points indicates that soil is corrosive to ductile-iron pipe; protection is needed.

†If sulfides are present and low or negative redox potential results are obtained, add three points for this range.

AWWA 10-Point System for Soil Corrosivity

CASE STUDY NO.2

FORCE MAIN CONDITION ASSESSMENT APPROACH

TIER 3: ASSESS EXTENT OF FAILURE & CONDITION OF FORCE MAIN

FOR INTERIOR CONDITION ASSESSMENT:

Bypass Force Main

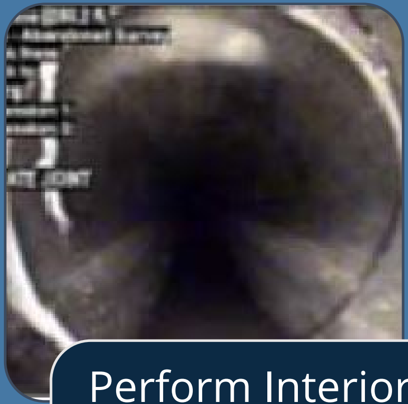
- Via Existing Standby FM (if present)
- Via Constructed Bypass

Gain Access to Force Main

- Via Existing Access Manholes (if present)
- Via Excavated Access Pits

Clean/Jet Force Main

- Via Existing Access Manholes (if present)
- Via cut and entry into force main



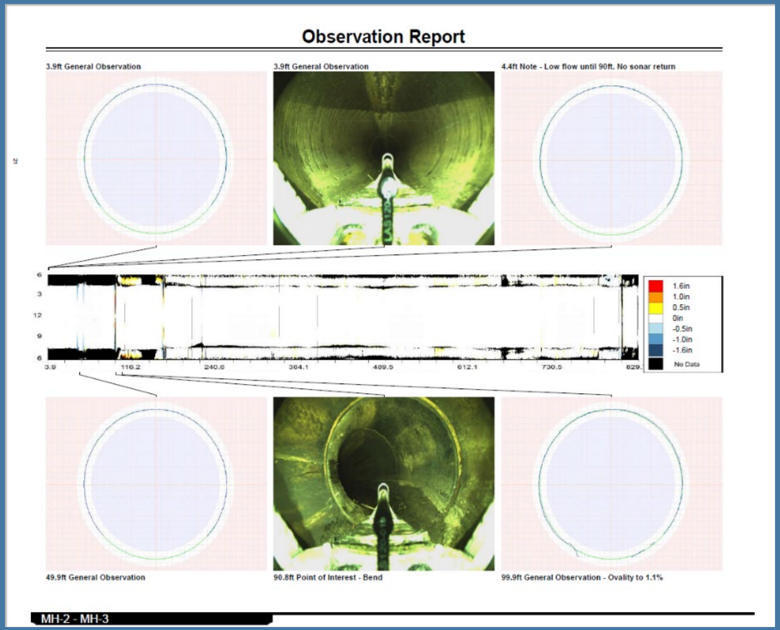
Perform Interior Condition Assessment

- Multiple Methods Available

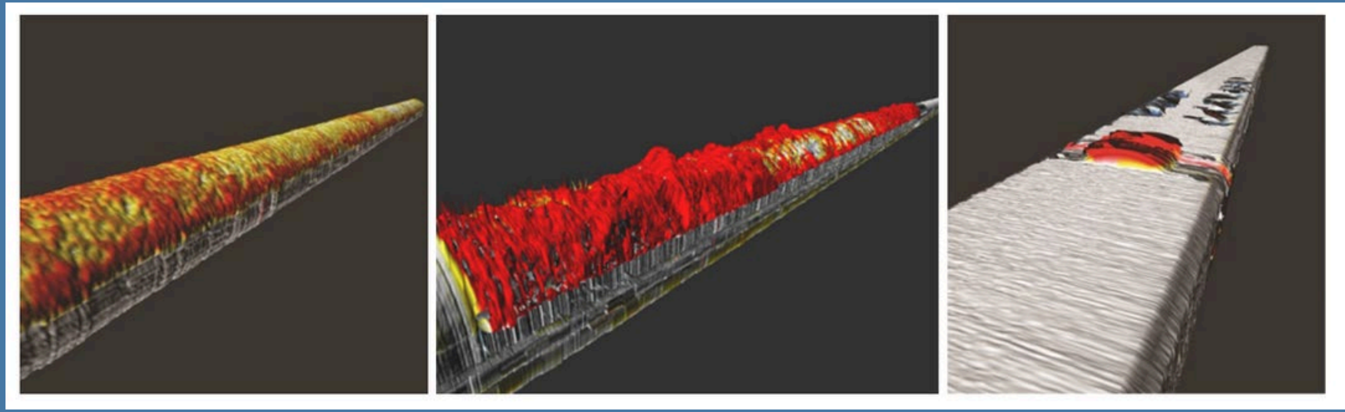
FORCE MAIN CONDITION ASSESSMENT APPROACH

INTERIOR CONDITION ASSESSMENT METHODS & TECHNOLOGIES
(PIPE OFFLINE)

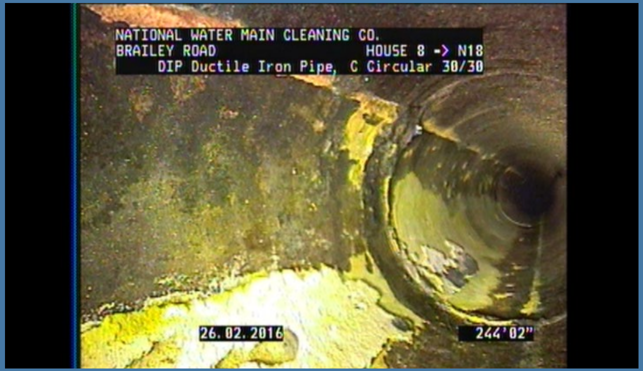
- Closed-Circuit Television (CCTV) Inspection
  - Visual of pipeline condition
- Multi-Sensor Condition Assessment
  - 2-D laser scan, sonar data, traditional HD CCTV Inspection to determine levels of corrosion and deformation
  - Helps determine if CIPP or Sliplining is a viable option
  - Only functions above water level
  - Can be influenced by buildup on pipe or tuberculation



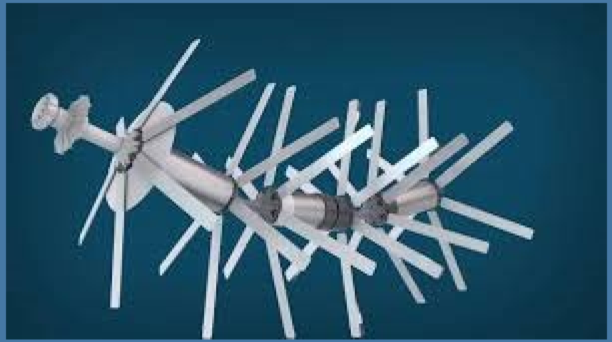
Sample Multi-Sensor Scan Report
CASE STUDY NO.1



Courtesy of RedZone Robotics

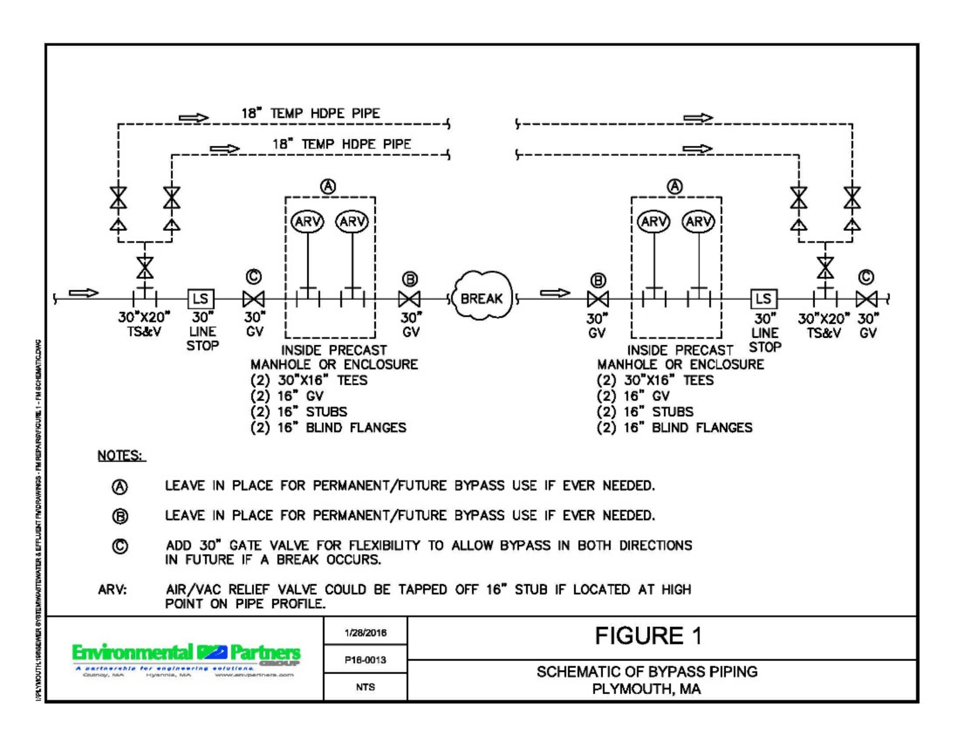


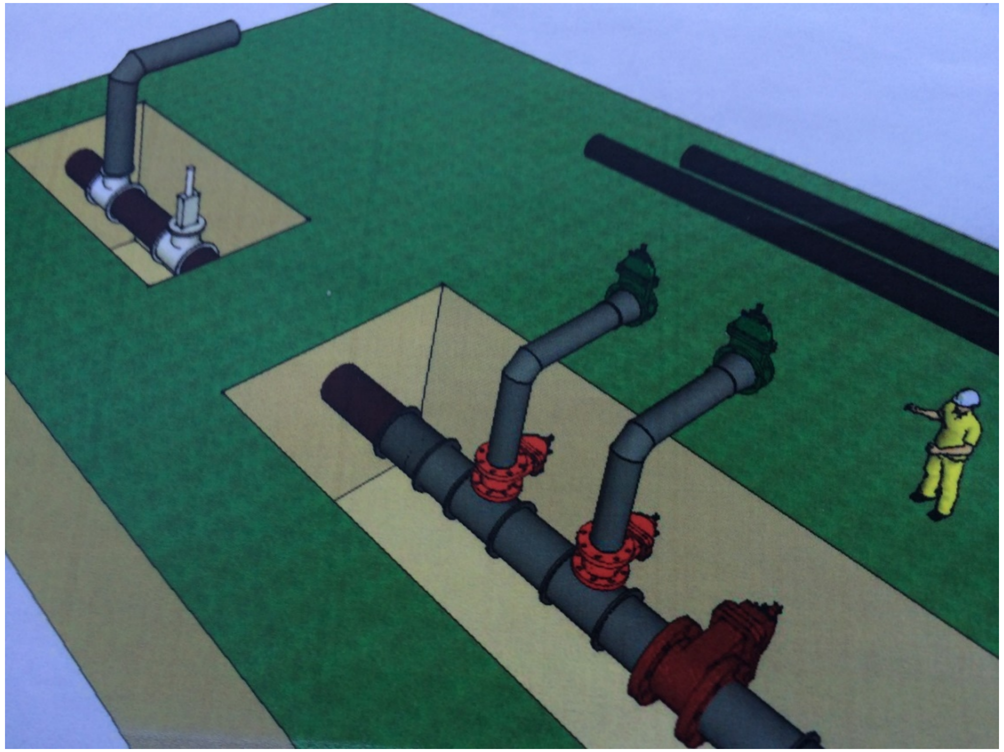
INTERIOR CONDITION ASSESSMENT METHODS AND TECHNOLOGIES
(PIPE ONLINE)



- Smart Ball: Leaks and gas pockets detections
- Pipe Diver: Free swimming tool to locate broken prestressed wires
- Broadband Electromagnetic: Measures wall thickness of exposed pipe
- Ultrasonic Pig: Measures localized wall thickness- Extensive cleaning is required

BYPASS OF A LIVE FORCEMAIN





DESTRUCTIVE TESTING

- Test pits and coupons
- Ultrasonic pigging
- Others

DEVELOPMENT OF EMERGENCY ACTION PLAN

- Risks and Vulnerabilities
- Emergency Notification
- Vendor Contact Information
- Equipment and Materials on standby
- Plan for Funding

FORCE MAIN CONDITION ASSESSMENT APPROACH

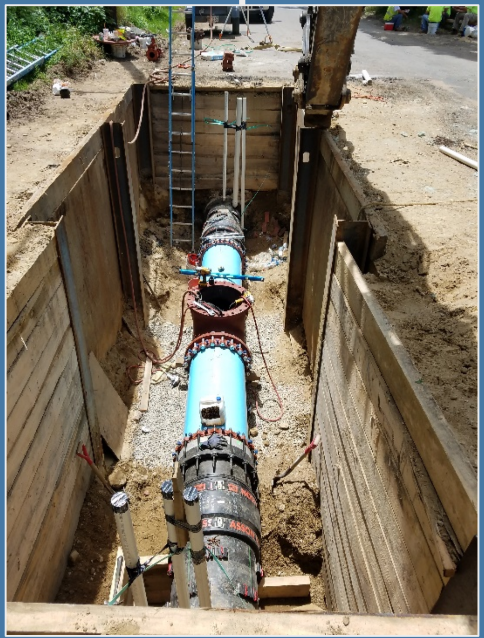
EVALUATE ALTERNATIVE REHABILITATION OPTIONS

Repair?

Replace?

Re-Use?

Combination?



DESIGN CONSIDERATIONS & PLANNING FOR NEW SEWER FORCE MAINS

DESIGN CONSIDERATIONS & PLANNING

1. Alignment Selection
2. Integration with Pump Station Design
3. Pipe Material Selection
4. Pipe Sizing
5. Construction Considerations
6. Special Considerations
7. Permitting Considerations
8. Cost and Funding Considerations

1. ALIGNMENT SELECTION

- Conduct an Alternative Force Main Alignments Assessment
  - Implementation Feasibility Study
  - Cost Estimates for all Alternatives
- Coordinate with the other potential upgrades along the Alignment

Alignment	Length of Pipe (ft)	Environmental Disruption (ft)	Use of Town Property (ft)	Use of Bike Path/Sidewalk (ft)	Vital Areas (#)	Flood Zones (ft)	Residential Areas (ft)	Historic District (ft)	High Points + Low Points (#)	Peak Elevation (ft)	Narrow Roadways (ft)	Commercial Areas (ft)	Length of Potential Gravity Sewer Replacement (ft)	Length of Potential Water Main Replacement (ft)
Option 1A	18,760	0	2451	11600	3	190	9529	5801	11	59	2966	2151	3860	3550
Option 1B	20,420	0	2506	11680	3	190	10097	5801	7	59	1966	2602	3860	3550
Option 2A	18,260	0	1784	10932	3	190	8023	5790	11	41	2954	2151	2750	5150
Option 2B	19,920	0	1839	11012	3	190	8591	5790	9	41	2954	1813	2750	5150

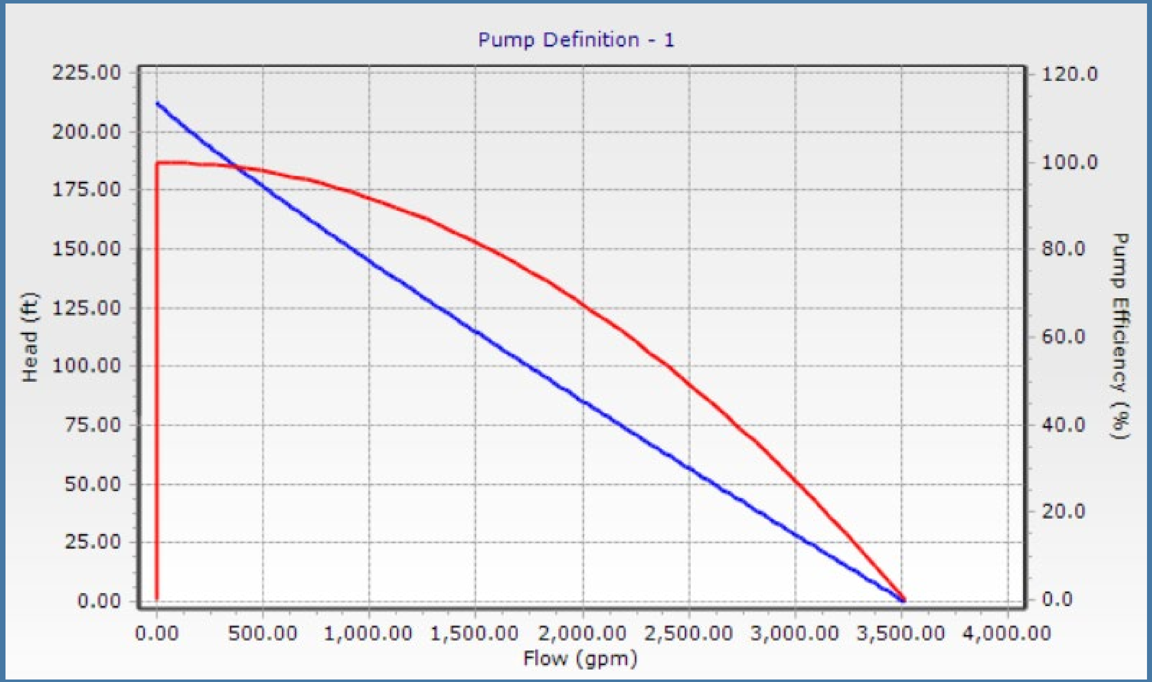
Example Summarized Implementation Feasibility Study

CASE STUDY NO.3

2. INTEGRATION WITH PUMP STATION DESIGN

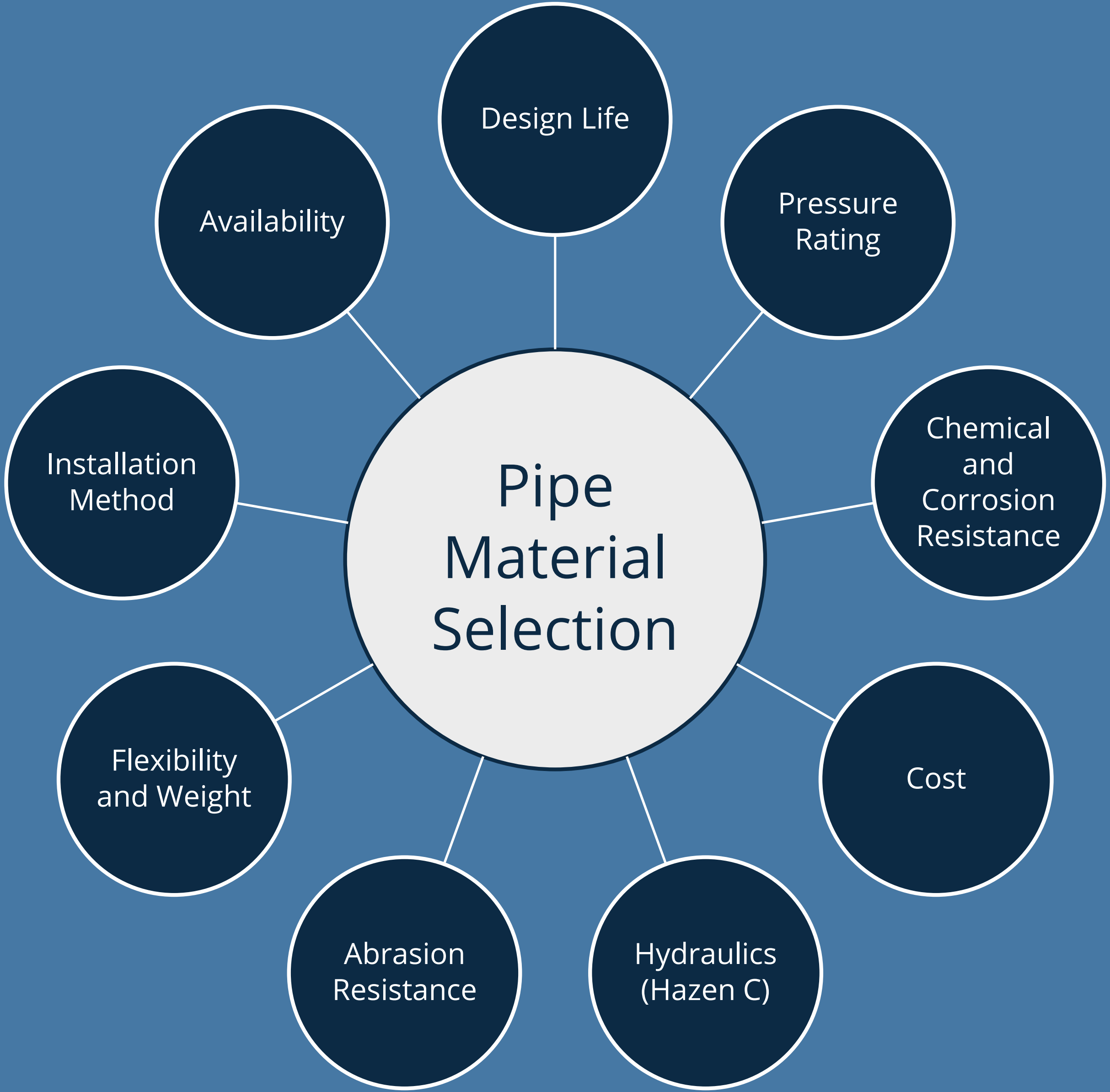
Design Must Consider:

- Pump Station Characteristics
  - Configuration, type, and number of pumps
  - Operation restrictions
  - Size of wet well
  - Size of internal piping
  - Key elevations
  - Treatment and screening
- Pump Performance Curves
- Existing Average Daily and Peak Flows
- Projected Average Daily and Peak Flows



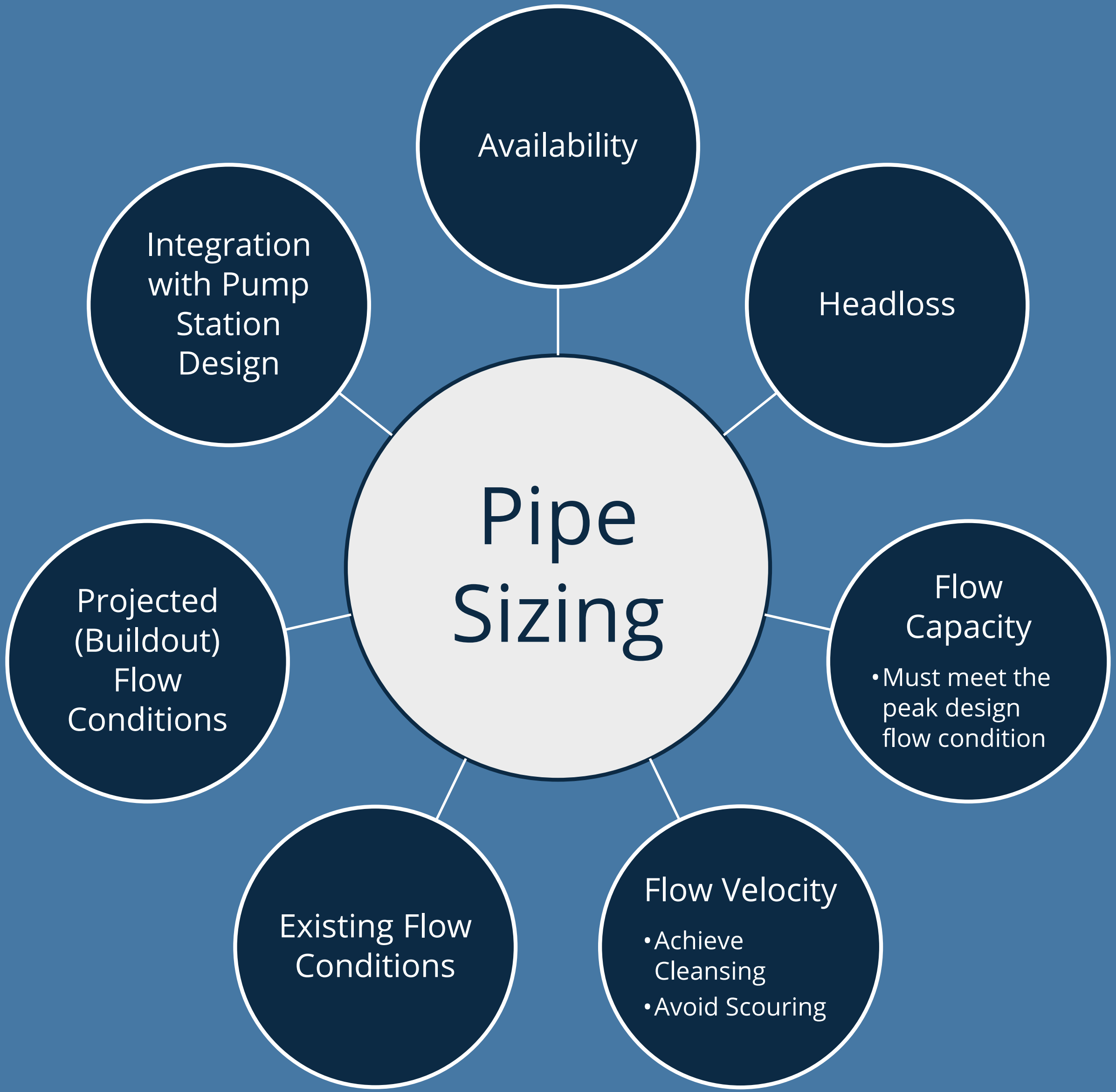
Example Pump Performance Curve used for Modeling
CASE STUDY NO.3

3. PIPE MATERIAL SELECTION



DESIGN CONSIDERATIONS & PLANNING FOR NEW SEWER FORCE MAINS

4. PIPE SIZING



	Existing Flow Conditions			Projected Flow Conditions		
Pipe Option	Flow Capacity(1)	Can Meet Peak Flow?	Can Achieve 3 fps?	Flow Capacity(1)	Can Meet Peak Flow?	Can Achieve 3 fps?
24” C905 PVC (DR18)	↑ - 1 pump ↑ - 2 pumps	Yes	Yes	↑ - 1 pump ↑ - 2 pumps	Yes	No
20” C905 PVC (DR18)	= - 1 pump ↑ - 2 pumps	Yes	Yes	↑ - 1 pump ↑ - 2 pumps	No	No
18” C905 PVC (DR18)	↓- 1 pump ↓- 2 pumps	No	Yes	↓- 1 pump ↓- 2 pumps	No	No

(1) – ↑ indicates an increase in flow capacity when compared to the current system
↓ indicates a decrease in flow capacity when compared to the current system
= indicates an comparable flow capacity when compared to the current system

Example Pipe Sizing Analysis
CASE STUDY NO.3

DESIGN CONSIDERATIONS & PLANNING FOR NEW SEWER FORCE MAINS

5. CONSTRUCTION CONSIDERATIONS

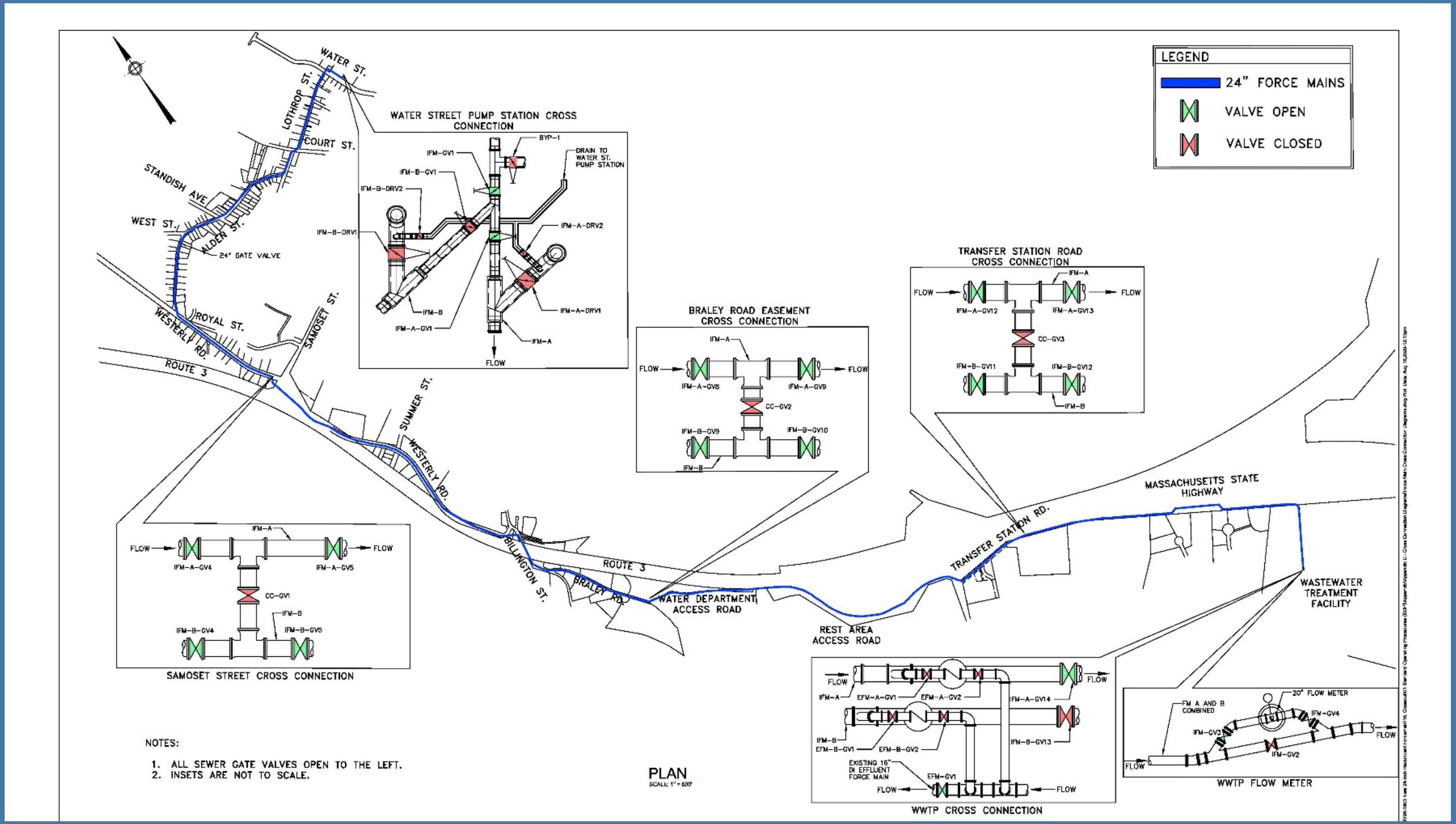
Design Must Consider:

- Traffic Management
- Geotechnical Considerations
- Roadway and Surface Restoration
- Dewatering and Stormwater Management
- Utility Impacts
- Construction Sequencing
- Coordination with other Town Projects

Sampling During Geotechnical Investigation
CASE STUDY NO.2

Complex Utility Coordination
CASE STUDY NO.3

5. SPECIAL CONSIDERATIONS



7. PERMITTING CONSIDERATIONS

Force Main Construction May Require Several Permits:

- DEP (MA)
- DEEP(CT)
- DES (NH)
- DOT
- USARMY
- Local Conservation Commissions
- State Procurement Laws (for emergency bidding)
- FEMA Notifications
- State Management Agencies

8. COST & FUNDING CONSIDERATIONS

Major Factors Affecting Cost:

- Project Location and Complexity
- Pipe Installation Method
- Pipe Size and Material
- Force Main Length & Depth
- Force Main Appurtenances
- Connections and Tie-Ins
- Bypass Requirements
- Surface Restoration
- Geotechnical Conditions
- Unknown Conditions

Funding Opportunities:

- Clean Water State Revolving Fund (CWSRF Program)

Q&A

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THANK YOU

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