Utilizing Asset Management to Achieve Sustainable Stormwater Systems

Tom Iseley, Director of Trenchless Technology Center (TTC), Louisiana Tech University, Ruston LA, USA
Ken Eyre, PE, PACP, Senior Associate, Greeley and Hansen, USA
Paul D. Huston, PACP, Project Manager, Greeley and Hansen, USA
Urso Campos, MST Student, Purdue School of Engineering & Technology, IUPUI, USA
Hamed Zamenian, Ph.D. Student, Lyles School of Civil Engineering, Purdue University, USA
Seyed Saleh Behbahani, Ph.D. Student, Department of Civil Engineering, Louisiana Tech University, Ruston LA, USA

ABSTRACT

Not only do managers of buried infrastructure systems need to have physical condition assessments (PCAs) as part of their asset management efforts, one of the primary challenges facing pipe renewal decision makers is - What asset defect coding system best suits each agency? Shallower utilities have slightly different yet critical concerns and needs than deeper utilities, such as the influence of third party intrusions (much more frequent in shallower utilities). To help put PCAs in context, we need to first examine infrastructure asset management components. Typical asset management elements for a buried conveyance system such as a municipal stormwater system include:

- ✓ What is owned (Asset inventory, supported by GIS and other enterprise database systems)
- ✓ Where are the assets
- ✓ What is the asset condition (Physical condition data)
- ✓ What are assets worth (Financial – Fluctuating funds - Budget and GASB reporting)
- ✓ What is the level of service (Minimum performance and service expectations)
- ✓ Is “overland relief” designed and provided to reduce flooding risk?
- ✓ What is remaining service life
- ✓ What are the renewal and maintenance strategies and related practices
- ✓ Are there near-term influences associated with performance demands

Having a sound and established pipeline condition assessment (PCA) process supports agencies infrastructure re-investment programs and provides a defensible mechanism regarding capital project identification, prioritization and managing operation and maintenance (O&M) practices. With the advent of stormwater-type utility fees, which help fund some of the increasing stormwater management program elements, local citizens and elected officials will rely on the appropriate justification provided by implementing and maintaining a PCA process. Examples of PCAs for stormwater systems, along with implementation challenges, will be shared with this presentation.

1. INTRODUCTION

In the United States, the majority of the underground infrastructure pipeline network system was built more than 100 years ago. The D rating of drinking water and wastewater/stormwater infrastructure in the American Society of Civil Engineering (ASCE) report card of 2013 demonstrates the fact that the majority of this complex infrastructure is deteriorated and needs emergency response. “Capital investment needs for the nation’s wastewater and stormwater systems are estimated to total $298 billion over the next twenty years”. The urban stormwater system is among valuable and cost-intensive structures in the urban environment representing a considerable national capital asset for most countries. The urban stormwater collection systems have been developed primarily to convey the stormwater in order to reduce the flooding in urban communities; however, like other buried infrastructure, stormwater pipes deteriorate with time and cause reduction of both structural integrity and hydraulic or discharge capacity of pipes. Moreover, the environmental impact of stormwater discharges both on quantity and quality factors because of the population growth and urbanization in recent years, have attracted the attention of the decision makers on the importance of stormwater asset management program. The advantage of implementing the comprehensive asset management may include, but are not limited to (CDM, 2006):

- Increased knowledge of the location of the assets;
- Increased knowledge of which assets are critical;
- Capital improvement projects that meet the true needs of the system;
- Better operational decisions;
- More efficient operation;
- Improved emergency response;
- Greater ability to plan and pay for future repairs and replacements;
- Better communication with customers;
- Rates based on sound operational information; and
- Increased acceptance of rates.

The Certification of Training in Asset Management (CTAM)-200 manual on Developing Buried Asset Management Programs (BAMI-I, 2013) envisions a “Total Asset Management Plan” (TAMP) consisting of three levels: strategic plan, tactical plan, and operational plan. Key elements for each level of a TAMP are shown in Figure 1.

TOTAL ASSET MANAGEMENT PLAN (TAMP)
Level 1 - Strategic Planning
Long-range 10 to 30 year timeline
1. Define Utility's Mission 2. Define Organizational Functions 3. Establish Level of Service Commitment 4. Establish and Maintain Best Practices 5. Set Benchmarks to Monitor Performance 6. Perform Periodic Updates-Revisions
Level 2 - Tactical Planning
Establish and Maintain Best Practices
1. Organization Structure - Functions 2. Staff Evaluation 3. Level of Service Commitment 4. Assets - Adequacy & Utilization
Level 3 - Operations Planning
Evaluate Assets
1. WHAT do we have? 2. WHERE is it located? 3. WHAT is its condition? 4. WHAT is it worth? 5. WHAT action is required? 6. WHEN is action required? 7. HOW much will it cost? 8. HOW will it be funded?

Figure 1: Key elements for each level of a TAMP (CTAM-200)

2. LITERATURE REVIEW ANALYSIS

Review of the current state of practice and research in stormwater asset management has revealed the lack of comprehensive asset management program on this topic. In addition, because of the similarity of stormwater collection and wastewater collection system, the concentration was given to the wastewater asset management. This section will review the existing stormwater management in the United States and outside the United States to explore the best asset management practice.

2.1 City of Grand Rapids, United States

City of Grand Rapids, MI established a proactive long-term plan for its stormwater infrastructure system through developing an effective and sustainable asset management program for next 20 years (City of Grand Rapids, 2013). The general scope established that an asset management plan consists of three major items:

- Assessment of the existing stormwater assets;
- Evaluation of levels of service the stormwater asset will meet; and
- Summary of efforts necessary to meet the desired level of service.

The defined asset management includes the planning, design, construction, operation and maintenance of infrastructure that performs a function for the City of Grand Rapids. This function for the stormwater system includes drainage and stormwater quality management (City of Grand Rapids, 2013). Also, City of Grand Rapids has defined a process approach toward stormwater asset management through identifying the following points:

- What are the assets? (Inventory)
- What are the assets worth? (Valuation)
- Where are the assets located? (Geographic Information System)
- How is the system operated? (Level of Service)
- What is the condition? (Probability and Consequence of Failure)
- What is needed to be done? (Construct, Maintain or Replace)
- How much will it cost? (Financial Plan)

In addition, as a part of stormwater asset management plan, the business risk exposure (BRE) was developed in order to identify the criticality of the asset components. The BRE formulation has been defined as below:

$$\text{Business Risk Exposure (BRE)} = \text{Probability of Failure (POF)} \times \text{Consequence of Failure (COF)} \qquad (1)$$

The probability that an asset will fail (POF) is a function of various attributes such as the asset's condition, performance, reliability and maintenance history. The COF includes economic, environmental and social impact. Definitions of COF categories are summerized in Table 1.

Table 1 Definitions of COF categories (City of San Diego 2013)

Category	Subcategory	Description
Social	Public Perception	Public perception of City's performance declines. This includes external or non-quantifiable potential economic costs associated with a decline in public perception of City performance.
	Public Health and Safety	Injuries, death, or property damage occurs. This includes external or non-quantifiable potential economic costs associated with increased health or safety risks to citizens.
Environmental	Regulatory	Regulators take action. This includes external or non-quantifiable economic costs associated with deterioration in trust of the regulators for which the City is taking appropriate actions to achieve compliance with a permit that is not explicit.
	Environmental Quality	Measurements of environmental quality show declines (e.g. ecosystem health declines, standards are no longer met). This includes external or non-quantifiable economic costs associated with a degrading or degraded environmental quality or condition. Such economic costs could include reduction in property values, reductions in tourism, loss of jobs, and resulting reductions in tax revenues.
Economic	Short-term Financial	Fines, settlements.
	Long-term Financial	Increased regulatory compliance costs, increased City of San Diego Storm Water Division requirements, increased costs to rebuild public trust, capital outlays, and for other reasons.

In order to prioritize the renewal plan, the business risk exposure (BRE) was adopted for the stormwater system similar to the City of Grand Rapids, MI. BRE is the product of the probability of failure (POF) and the consequence of failure (COF). The POF is basically from the condition assessment of stormwater collection system components; however, the city developed a reference table to quantify the COF for its stormwater system based on social, economic, and environmental factor as shown in Table 2.

Table 2 Consequence of Failure Categories and Weight (City of San Diego, 2013)

Category	Sub-Category	Weight		% Overall Weight
Social	Public Perception	1	0.2	6.67
	Public Health and Safety		0.8	26.67
Environment	Regulatory	1	0.7	23.33
	Environmental Quality		0.3	10.0
Economic	Short-term Financial	1	0.6	20.0
	Long-term Financial		0.4	13.33
Sum of Weight		3	3	100

2.2 City of San Diego, United States

Another case is the City of San Diego stormwater asset management program. The City of San Diego storm water division developed the Watershed Asset Management Plan (WAMP) in order to document the current state of assets (e.g., asset inventory, valuation, condition, risk) and to project the long-range asset renewal (rehabilitation and replacement) requirements (City of San Diego, 2013). The city also adopted the Water Environment Research Foundation recommendation on a seven core asset management plans as shown in Figure 2 and Table 3.

Figure 2: Seven Core Elements of Asset Management (City of San Diego, 2013)

Table 3 Core Elements and Goals of Asset Management (City of San Diego, 2013)

Core Asset Management Elements	Goals
Lifecycle Processes and Practices	Enhance the efficiency, transparency, and consistency of the business decision-making process.
Information Systems	Increase the system integration, functionality, and support capabilities.
Data and Knowledge	Capture, organize, and document asset information.
People	Provide a platform for managing and sharing information and knowledge.
Commercial Tactics	Focus on effective delivery of projects and services.
Organization	Establish sound, strategic support for asset management practices.
Asset Management Plan	Document the current state of the City of San Diego Storm Water Division’s assets and future requirements.

These seven core asset management elements (Figure 2) have been classified into 10 steps in order to reach sustainable stormwater management system. These 10 steps are shown in Figure 3.

Figure 3: 10 Steps process to reach stormwater asset management program (City of San Diego, 2013)

The risk-based condition assessment has been applied to all the physical assets and it includes three level of inspection: 1) basic, 2) intermediate, and 3) advanced based on the level of sophistication as shown in Figure 4. The City of San Diego has utilized several types of condition assessment technologies specifically for storm drain pipes, outfalls, and pump stations. The condition assessment program ranged from field inspections such as CCTV to conducting 'Delphi' workshops with key members of the O&M staff (City of San Diego, 2013).

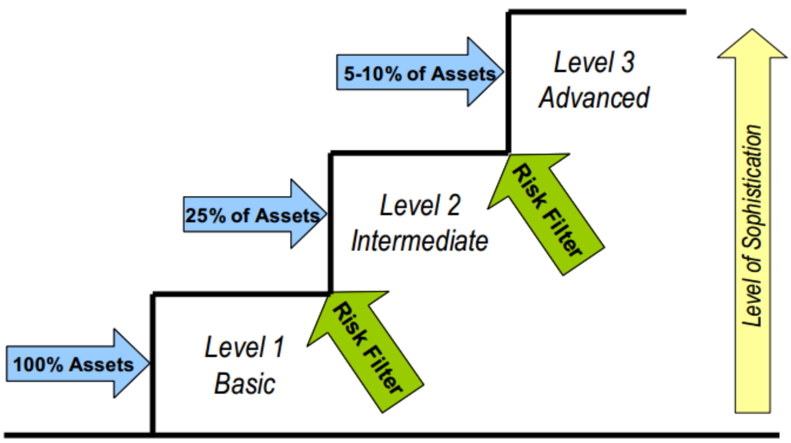

Figure 4: Risk-Based Condition Assessment Approach (City of San Diego, 2013)

The unique section of this asset management manual is the funding strategies, which provide recommendations on how it will be paid. According to the manual the process can be used to fund elements of the stormwater program are summarized below:

- Transferring payments from water enterprise funds for water captured and used beneficially that offsets the demand for potable water.
- Developing a parcel assessment based on the pollutant discharge potential for City parcels.
- Developing a general or sales tax to fund water quality program elements.
- Including water quality improvement requirements in transportation bond funds or transportation revenue initiatives promoted by the City, County, or San Diego County Association of Governments. This would allow for road improvement projects to incorporate green street features or other stormwater BMPs.
- Increasing penalties for illegal discharges identified through the City's inspection and enforcement program.
- Increasing the restrictions on pollutant discharges per City ordinances so that there are greater numbers of citations and fines issued.
- Developing a gasoline tax that funds water quality improvements.
- Expanding grants for capital projects as applicable.

3. PIPE CONDITION ASSESSMENT (PCA) OBJECTIVES

Municipal stormwater management programs in the U.S. are essentially the same and differ by their extent and magnitude. In the U.S., the Federal Environmental Protection Agency (US EPA) uses the 1972 Clean Water Act (CWA) and its amendments to impose regulatory controls on wet weather programs. Whether or not a community is defined under Phase I or II of the CWA's Municipal Separate Stormwater System (MS4) regulations, conveyance systems can be composed of:

- "Open" system –drainage inlets, storm drainage ditches, infiltration ditches and swales, detention and retention ponds
- "Closed" system – pipes, manholes, junction boxes/chambers, storm outfalls, end-walls, head-walls

This section focuses on the piped conveyance system with a discussion regarding physical condition assessments (PCAs). PCAs for "open" systems is beyond the scope of this paper.

The basic pipe PCA framework:

- Supports maintenance and infrastructure reinvestment initiatives
- Includes prioritization for a scalable program when funding levels fluctuate
- Uses inspection and physical condition assessment results to:
    - Guide pipe renewal selection (Capital Improvement Program -CIP- Planning)
    - Prioritize infrastructure reinvestment efforts
    - Identify maintenance needs
- Uses a pipe condition rating method to match agency needs

The following sections address elements associated with the importance of establishing a pipe condition rating framework. The subject matter topics include:

- Historical perspective
    - US Clean Water Act
- Increasing Federal and State NPDES regulatory scrutiny
- Pipe condition methodology
- Differences between Storm and Sanitary Systems
- Physical Condition Assessments (PCAs)
    - Need
    - Criteria/Drivers
- Example Pipe Condition Rating Practices
- Lessons Learned
- Summary / Closing

4. HISTORICAL PERSPECTIVE: Federal Requirements

For many decades, water and wastewater agencies have been actively implementing formal asset management plans which have at their core physical condition assessments. The advent of the 1972 US Clean Water Act – PL 92-500 (CWA) set out the need to improve water quality principally by controlling biochemical oxygen demand (BOD) and Total Suspended Solids (TSS) discharges from wastewater treatment plants (WWTPs). In the 1980s the U.S. Environmental Protection Agency (US EPA) began the wet weather control effort to make communities with combined sewer systems (CSS) comply with long term control plan (LTCP) requirements. LTCP requirements featured a combination of sewer system separation (creating separate sanitary and stormwater systems), combined sewer overflow (CSO) consolidation and elimination and other off-line and on-line storage and disinfection features, as some of the demonstrated means and measures to reduce untreated, mixed sewage overflow discharges (primarily consisting of stormwater) to waters of the U.S. (WOTUS).

In the 1980s, the US EPA turned its attention to examining the condition of the municipal collection and conveyance systems. The US EPA began to develop the framework to require communities to reduce and eliminate municipal sanitary sewer overflows (SSOs). In some regions of the country, due to aging infrastructure and its condition, the US EPA began a number of SSO enforcement actions against many communities, which continues to present day. Consent orders have become the primary enforcement mechanism by which the US EPA and the corresponding state regulatory agencies have imposed these unfunded mandates upon wastewater conveyance system operators.

In the late 1980s the US EPA began to develop the National Pollutant Discharge Elimination Survey (NPDES) requirements, under the CWA, to again impose another unfunded mandate on urbanized communities, with the launch of the Municipal Separate Stormwater System (MS4) Phase I regulations. The Phase I MS4 regulations were intended to impose urban stormwater runoff controls on the more densely populated and developed communities. The Phase I MS4 regulations impacted communities with urban populations in excess of 100,000. Communities such as Greensboro, NC, were allowed three years to compile and assess the water quality and system inventory information needed to accompany the Phase I permit application. The Phase I water quality provisions were quite extensive in that many storm outfalls had to be monitored for a wide range of pollutants of concern (POC). The POC sampling, analytical chemical testing and reporting had to be provided by each Phase I MS4 community, at great costs. For example, Greensboro, NC MS4 permit application and related costs exceeded three million dollars (Treadway, 2014). The Phase I communities also had, and continue to, document, report and assess their routine practices running the gamut from outfall monitoring, street sweeping, inlet cleaning and material disposal, to good housekeeping at all municipally-owned facilities.

The US EPA recognized that companion stormwater runoff regulations for smaller urbanized MS4 communities were needed, and followed the Phase I implementation. In the late 1990s, the Phase II MS4 regulations became effective, impacting more than 37,000 communities nation-wide. The US EPA also recognized at the outset, imposing extensive POC monitoring, testing and reporting could financially impair some communities' ability to comply. The US EPA required the Phase II MS4 communities to essentially provide the same requirements that had been developed for the Phase I MS4 agencies and, excluded the POC monitoring, chemical testing and reporting requirements. The Phase II MS4 communities are required to comply with the six minimum control measures (MCMs) prescribed in the Phase II regulation.

5. PIPE CONDITION METHODOLOGY: History and Application

One of the most widely used defect coding systems regarding "scoring" pipe condition based on collection system inspection observations (defects) was developed in the United Kingdom by the Water Research Centre (WRc) and adopted by the National Association of Sewer Service Companies (NASSCO) for use in the United States. WRc's defect coding approach is based on decades of forensic and empirical data collection, complete with failure mode analyses for a host of pipe materials and soil conditions. NASSCO modified the pipe defect coding system to address the differences between the United States' collection system characteristics and the characteristics of the collection systems in Europe. NASSCO created the Pipeline Assessment and Certification Program (PACP©) to train U.S. inspection contractors, consultants, municipalities, and related manufacturers on the details of the defect coding system and to standardize defect codification.

NASSCO also provides a “Certification” program for the software utilized on the CCTV equipment for pipeline inspection, so as to provide another means to standardize codification of pipe inspection. This software can assign the numerical ranking based on the default PACP defect codes and generates a scoring related to the entered observations. The resultant “scoring” is reliant on the accurate data entry by the technician/operator performing the pipe inspections.

NASSCO has primarily focused on the pipe defect coding for sanitary and combined sewer systems, with little attention to stormwater system needs. With the onslaught of regulatory consent decrees focused on eliminating sanitary sewer overflows in the U.S., NASSCO’s focus in adapting the WRc pipe defect coding methodology targeted sanitary and combined sewer systems. Only recently, has NASSCO begun to consider the unique differentiators that stormwater systems have as compared with sanitary and combined sewer systems. We understand that the next issue of the PACP training guidance should begin to show differences between storm and sanitary pipe condition observations.

Figure 5 represents a simplified flow path associated with collecting and processing the observed internal pipe defects, followed by an evaluation step where the NASSCO PACP defect codes are used to characterize the extent and nature of the defects. Once the NASSCO PACP defect codes are applied, the NASSCO PACP “QuickScore” is executed and compiles and assembles the defect codes into the four-digit value representing the pipe’s condition. The “QuickScore” pipe condition rating results can then be assessed and prioritized for structural and O&M scheduling.

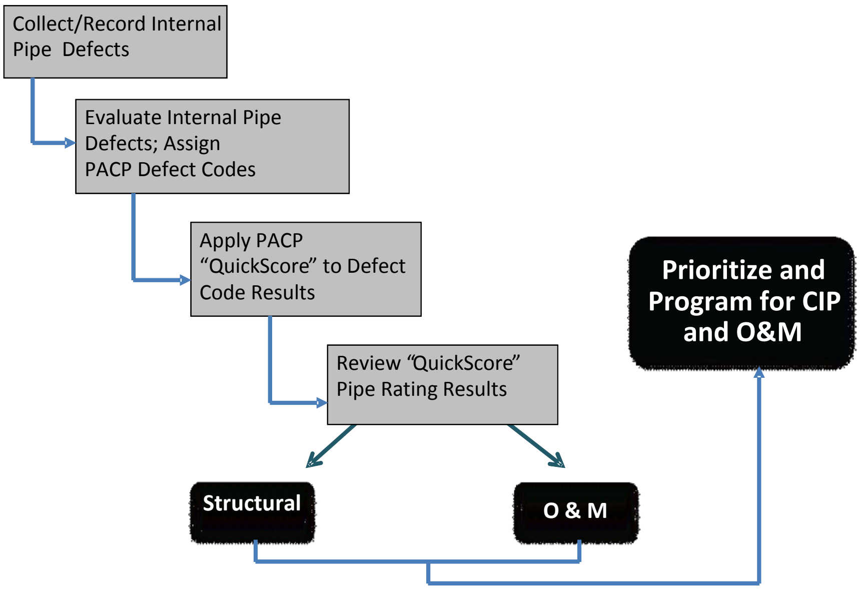

Figure 5: Simple Flow Path

The NASSCO PACP coding system is widely used in the U.S. with CCTV inspections and incorporates four “Families” of defects: “Structural”, “Operational and Maintenance” (O&M), “Construction”, and “Miscellaneous” (NASSCO, 2001). The “Structural”, “O&M”, and “Construction” Families of defects and observations, are further broken down into the Groups shown in Table 4. Typically, infrastructure managers use this data for planning and renewal efforts. Utility managers may wish to only consider the ”Structural” aspects for determining which assets need resources dedicated for the renewal (repair, rehabilitation or replacement) because the reported observations indicate imminent, or near-term, failure (potential for diminished or blocked flow). Defects related to operation and maintenance activities are scored separate from “Structural” observations, since O&M results help direct the maintenance groups’ practices. Such practices may include line cleaning, blockage removal, surface repairs (cave-ins), velocity regulator installation, access covers replaced and other activities. Other municipal agencies may wish to utilize the overall rating (combined structural and O&M) so that assets with high scores may be subjected to further review, to confirm the need for structural renewal, or if O&M activities need to be modified, and scheduled.

Table 4 NASSCO Pipe Defect “Families” (NASSCO, 2001)

<table>
<tr><th colspan="2">Structural</th><th>O&M</th><th>Construction</th></tr>
<tr><td>Crack</td><td>Joint</td><td>Deposits</td><td>Tap</td></tr>
<tr><td>Fracture</td><td>Surface Damage</td><td>Roots</td><td>Intruding Seal Material</td></tr>
<tr><td>Broken</td><td>Weld Failure</td><td>Infiltration</td><td>Line</td></tr>
<tr><td>Hole</td><td>Point Repair</td><td>Obstacles/Obstructions</td><td rowspan="3">Access Points</td></tr>
<tr><td>Deformed</td><td>Brickwork</td><td rowspan="2">Vermin</td></tr>
<tr><td>Collapsed</td><td>Lining Failure</td></tr>
</table>

A final “Miscellaneous” Family contains defects that are not included in the other three Families and include such inspection observations as the camera being underwater, pipe joint length change, lining change, water level change, or survey abandoned, among others. The “Group” within each Family includes a coding system with an additional level of detail in an attempt to describe as many defects found within a sewer as possible. For example, the “Structural” Family – “Fracture” Group includes five descriptions to provide additional detail to the category: Fracture Longitudinal (FL), Fracture Circumferential (FC), Fracture Multiple (FM), Fracture Spiral (FS) and Fracture Hinge (FH). Altogether, there are 90 “Structural” Family defect codes, 47 “O&M” defect codes, 44 “Construction” defect codes and 13 “Miscellaneous” defect codes, for a total of 194 individual codes in 22 Groups.

These families and groups provide varying degrees of descriptive inspection details and drive the numerical rating of the defects. Having the observations assist in establishing the internal condition and eventually lead to decisions regarding pipe renewal or modify maintenance practices, or simply provide a benchmark for later inspections and comparison provides a means for documenting and justifying infrastructure renewal projects. By having an observation description, future severity rating results may be utilized to compare changes in the defect or observation. Benchmark comparisons may also help with estimating remaining useful pipe segment service life.

Use is made of a severity rating scale to gauge the defect results of the Structural and O&M Families, which reflects the extent and number of occurrences of each pipe condition grade. The severity rating scale for each defect can be described as 1 (excellent), 2 (good), 3 (fair), 4 (poor), or 5 (immediate attention).

NASSCO’s severity rating scale is defined as:

1. Failure is unlikely in the foreseeable future,
2. Pipe unlikely to fail for at least 20 years,
3. Pipe may fail in 10 to 20 years,
4. Pipe will probably fail in 5 to 10 years, or
5. Pipe has failed or will likely fail within the next five years (NASSCO, 2001).

Where more than 9 defects occur within given pipe inspections, and to account for these occurrences, NASSCO has established an alpha-numeric pairing, essentially in groups of five, from “A” to “Z”. In this way, the NASSCO PACP QuickScore application can be used as a first screening tool for reporting the results. Table 5 represents the corresponding characters assigned to the defect count.

Table 5 NASSCO PACP “QuickScore” Defect Count and Corresponding Characters (NASSCO, 2001)

Defect Count	Corresponding Character	Defect Count	Corresponding Character
1	1	55 – 59	J
2	2	60 – 64	K
3	3	65 – 69	L
4	4	70 – 74	M
5	5	75 – 79	N
6	6	80 – 84	O
7	7	85 - 89	P
8	8	90 - 94	Q
9	9	95 - 99	R
10 - 14	A	100 - 104	S
15 - 19	B	105 - 109	T
20 - 24	C	110 - 114	U
25 – 29	D	115 - 119	V
30 – 34	E	120 - 124	W
35 – 39	F	125 - 129	X
40 – 44	G	130 - 134	Y
45 – 49	H	>= 135	Z
50 – 54	I		

A pipe segment with no defects will have a QuickScore of “0000”. A pipe segment which only has defects of one grade will have for its QuickScore a first character of the defect grade, a second character of the occurrences of the defect and the last two characters as “00”. Figure 6 (Eyre, Fortin, 2014) shows an example NASSCO PACP QuickScore and some representative pairing.

A four digit result representing:

Digit 1 – Greatest defect score found in that pipe = 5 (on a 1-5 scale)

Digit 2 – The frequency of the greatest defect score = 2

Digit 3 – The second greatest score found in that pipe = 2 (on a 1-5 scale)

Digit 4 – The frequency of the second greatest score = 6

Example, for structural assessment, a segment with 2 grade 5’s, 0 grade 4’s, 0 grade 3’s and 6 grade 2’s, result would be:

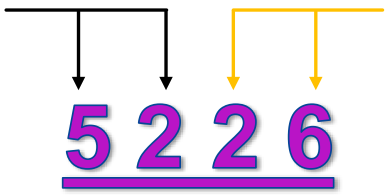

Figure 6: PACP “QuickScore” Example (Eyre, Fortin, 2014)

6. DIFFERENCES BETWEEN STORM AND SANITARY SYSTEMS are Summarized in Tables 8 to 10.

Table 6 Structural Differences between Storm and Sanitary Pipe Systems (Eyre, Fortin, 2014)

Feature	Wastewater Collection System	Stormwater Conveyance System
Construction Quality	High	Limited inspection monitoring staff, reliance on contractor
Pipe section lengths	Longer (10', 12', 20') pipe sections have fewer joints	Shorter (4', 6' & 8') pipe sections have many joints
Lateral connections	Essential	Not usually permitted, treated as unauthorized connection
Lift holes	None, use slings or pipe hooks	18" dia. and above may have them; if not properly sealed, may leak and allow root intrusion. May lead to pipe crack/fracture.
System depth	Deeper, below storm, force main may be shallower than gravity lines	Shallower, oftentimes located higher elevation than sanitary exposed to vehicular point live loads.
Acceptance Tests	Mandatory to protect health, welfare and water quality, leaks not tolerated	Not required, might have visual inspection
Chemical breakdown	Constant flows (diurnal) with chemicals and gaseous exposure and possible corrosive attack on pipe walls.	Episodic flows with storm events. Water usually free of contaminants and not contributing to deterioration.
Gravity flow	Yes	Yes
Other utility intrusions	Susceptible. Not included under programs to locate underground utilities prior to digging.	Susceptible, higher occurrence due to shallower nature. Not included under programs to locate underground utilities prior to digging.
Infiltration type	Groundwater infiltration is more likely as system is deeper in the ground; Stormwater from defects or deterioration in system	Shallower pipe is subjected to saturating water infiltration, less soil overburden so voids surface quicker and easier
Infiltration leaks	Impacts capacity and increases treatment costs	Carries soil from pipe envelope, creating or causing voids, sink holes and safety concerns to citizens. Increased standards for mastic, gaskets
Abrasive flow	Turbulence associated with pumping and elevation and directional changes	Debris in flow may scour pipe walls; debris particles are generally larger, more dense
Pressure flow	Yes	Not usually; prevalent more in coastal areas
Destination	Treatment plant	Stream (Waters of the U.S.); other structural BMPs

Table 7 O&M Differences between Storm and Sanitary Pipe Systems (Eyre, Fortin, 2014)

Feature	Wastewater Collection System	Stormwater Conveyance System
Capacity	Critical; overflows are regulatory violations	Overland relief can be incorporated into design
Joints	Watertight, minimizes root intrusion, joints are subject to acceptance tests	Lack of joint seals may result in root intrusion, especially in shallow installations
Line Maintenance and Monitoring	Fat, oil and grease accumulation requires frequent cleaning. Cleaning can damage pipe walls.	Heavy debris and deposition can clog system resulting in flooding. Debris is generally larger which can clog pipes easier.
Surface Impacts	Force mains typically shallower than gravity sewers	Shallower pipe systems are susceptible to damage from vehicular loads and other utility intrusions
Flow pattern	Stable with diurnal swings.	Episodic. Supplemented with overland relief. Usually free of contaminants. Usually does not contribute to pipe deterioration.
Vermin	Roaches, spiders, snakes	Nocturnal mammals, crickets, frogs, critters …. Alligators are not unheard of.
Closed and Open Characteristics	Closed system, may have lift stations	Open and transitional system, open channels to pipe then to open channel. Some submerged outlets to impoundments
Security	Intrusion alarms typically installed on critical assets; SCADA, telemetry	Difficult to keep secure and free of vandalism, critters and person entries

Table 8 Trenchless Technology (Pipe Rehabilitation) Differences between Storm and Sanitary Pipe Systems (Eyre, Fortin, 2014)

Feature	Wastewater Collection System	Stormwater Conveyance System
Lateral connections	Many	None too few
Bypass flows	Requires on-site pump operations during installation; may need a pipe de-commissioning and sanitizing step prior to disassembly	Rehab installation can be scheduled during 'dry' days, eliminating need for pump and bypass
Styrene	Curing and contaminated flows are treated at POTW	Not permitted in discharge to stream; requires new liner to be flushed and contact flows are pumped into sanitary sewer, treated at POTW

7. Pipe Condition Rating Approach - Implementation Challenges

Table 9 (Eyre, Fortin, 2014) summarizes some of the related implementation challenges associated with establishing a formal storm pipe condition rating approach. This listing is by no means complete and represents a snapshot of current issues which a municipality may consider when starting up or re-vamping a storm pipe condition assessment program.

Table 9 Storm Pipe Condition Rating Implementation Challenges (Eyre, Fortin, 2014)

Need to:

- ✓ Transform from “reactive” to “proactive” mode
- ✓ Maintain current inventory while inheriting additional facilities (School districts; Home owner associations; State DOT, Parks Dept., conveyance system give-backs)
    - o Proposed federal rule may also add more inventory and related reporting and assessments of “ditches” connected to tributary waters of the U.S.
- ✓ Confirm boundaries and pipe/structure ownership where others connect to system
- ✓ Fund capital and O&M when funding levels fluctuate
- ✓ Provide adequate MS4 program management resources (internal and external)
- ✓ Anticipate that future MS4 permit language may require development of an asset management plan
- ✓ Provide technically based, defensible approaches to expedite processing of inspection backlog
- ✓ Educate/require pipe inspection and utility contractors and ensure:
    - o Software function, reliability, consistency and compatibility
    - o Agency acceptance of installations
    - o QA / QC procedures are in place for renewal installations (independent testing laboratory)
- ✓ Recognize different procurement may exist for sanitary /storm systems including:
- ✓ Trenchless technologies (especially using felt cured-in-place liner - CIPPL)
        - ▪ Styrene controls – environmental discharge requirements (Discharges to WOTUS no longer accepted)
- ✓ Sanitary sewer rehabilitation contract pricing is geared toward lateral re-instatement
        - ▪ Some trenchless procedures may not be suited to larger sized pipe
        - ▪ Some agencies pre-determine CIPP liner thicknesses

Table 10 (Eyre, Fortin, 2014) represents what we are finding related to the pipe condition assessment implementation issues and serves, again, as a sampling and can be a guide for municipalities.

Table 10 Summery of Findings (Eyre, Fortin, 2014)

- ✓ Most stormwater system management programs operate in “reactive” mode
- ✓ Agencies have expressed desire to shift from “reactive” to “proactive” mode
- ✓ Threat of more MS4 permit requirements is driving physical condition assessments (PCAs)
    - o "Open" system –curb and yard inlets, storm drainage and infiltration ditches and swales, detention and retention ponds
    - o “Closed” system – pipes, manholes, junction boxes/chambers, storm outfalls, end-walls, headwalls
    - o On addition to monitoring and reporting private storm treatment and storage systems connected to MS4s, municipalities are now wrestling with how to meet Federal proposed rule adding “ditches” to an expanding inventory where monitoring, reporting and performance assessment may be needed.
- ✓ Agencies recognize the importance of physical condition assessments especially stormwater conveyance
    - o PCA results provide infrastructure re-investment decision support
- ✓ Maintenance agreements between local municipality and state DOTs attempt to address inter-connections and shared resource responsibilities
- ✓ Few agencies are utilizing a structured pipe condition rating approach such as NASSCO PACP / MACP
- ✓ Pipe condition data management is overwhelming public agencies
- ✓ Subtle yet important differences between storm and sanitary piped conveyance
- ✓ Wide range of agency staff skill sets
- ✓ Agency staff lack training, awareness and understanding of significance of pipe condition defects
    - o Severity
    - o Extent
- ✓ Agency practices and procedures related to acceptance of new or rehabilitated stormwater systems need to be enforced
    - o Development projects released from bond
    - o Internal inspection requirements

- ✓ DOTs concerned with use of laser scanning technology, post-construction inspections, and reporting of findings
    - Plastic pipe materials subject to stretching, deformation, rebound
    - Issue of ovality and deformation

8. LESSONS LEARNED

Recognizing that use of a formal storm pipe condition rating methodology in the U.S. is slowly gaining traction, and as with so many related applications, it takes time for the public works culture to adapt and integrate this specific practice into existing asset management programs. Public works agencies world-wide all provide some level of asset management regardless if it is for transportation and transit, facilities, buildings and grounds, buried infrastructure, or fleet operations. Building upon the experiences from the wastewater sector, which was the main thrust behind the development of the NASSCO PACP, stormwater agencies will greatly benefit from the adaptation of the defect code applications to storm pipe. Meanwhile, lessons learned from those agencies already at the forefront using such a structured storm pipe condition methodology, where the results lead to informed decisions, includes:

- Recognize the many differences between storm and sanitary systems
- Pipe condition assessment application is an Iterative pipe defect coding process, for storm systems, still evolving from NASSCO aspect
- Pipe inspection database management is crucial - avoid data "sitting on shelf" with no review and related action
- Need to establish cultural change incorporating system condition assessment practices and infrastructure re-investment justification
- Be flexible, responsive and adaptive:
    - Changed direction (accommodate citizen expectations)
    - Fluctuating and scalable funding/budgets
- Don't be afraid to customize defect codes for your system
- Seek a simple, defensible and ease of implementation (pipe defect coding method)
- There is an on-going need to invest in staff training and technology
- Pipe installation, inspection and acceptance method is critical
- System interconnections with other agencies and private systems need to be identified

9. Example Pipe Condition Rating Practices - Virginia Phase I MS4 Communities and District of Columbia

Several of the total of eleven Phase I MS4 communities in Virginia use some form of storm pipe condition rating assessment process. Fairfax County and City of Chesapeake are using the NASSCO PACP QuickScore approach. The cities of Virginia Beach and Newport News are using other scoring and pipe rating indexes available with the NASSCO PACP. DC Water had as its base the NASSCO PACP defect coding approach (Greeley and Hansen - EPMC-3 - Technical Memorandum No. 5, 2005) where a scale of 1 to 5 was used, with five being the worst condition, and an additional classification of "5.1" was added for collapsed pipe. Figure 7 (Eyre, Fortin, 2014) represents the DC Water sewer pipe condition scoring and classification.

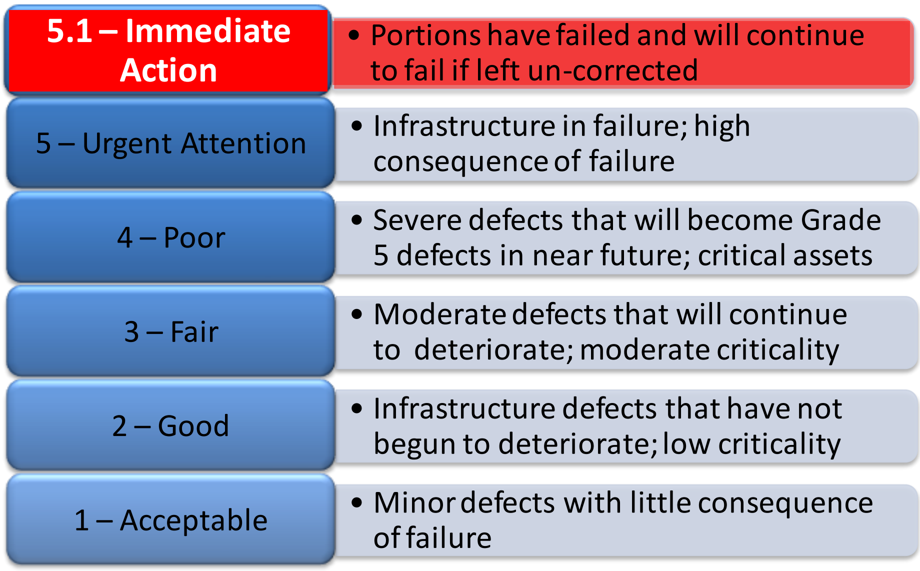

Figure 7: DC Water pipe defect condition rating - based on NASSCO PACP Defect Coding and Rating Approach (Eyre, Fortin, 2014)

Table 11 (Eyre, Fortin, 2014) is an example of results using the NASSCO PACP QuickScore approach. Figure 8 represents a sample spatial distribution of QuickScore results (using GIS), where the QuickScore results can be related to a "priority needs" scale using 1 to 3, and allow for a maintenance placeholder. "Priority One" can be defined by each agency, and for example could be defined as "Urgent corrective action required". "Priority Two" might represent the need for "Near-term corrective action required within 2-3 years". Lastly, "Priority Three" could include "Rehabilitation or repair is recommended, with possible failure or interruption within 5 years". "Maintenance" means there are no observed structural conditions and the pipe could be inspected within the next 20-years.

Table 11 Sampling of NASSCO PACP "QuickScore" Results (Eyre, Fortin, 2014)

Location	PACP QuickScore Overall Rating
1335 Lindale Dr	5221
4001 Grant Ct	5121
565 Saddlehorn Dr	4131
1204 Woodstream	4121
3021 Oak Dr	3228
2901 Sir Thomas crossing Sir Thomas	3111
3241 Bruin Dr	3111
Shadyside @ Wisteria Ct	3111
4224 Foxxglen Run	2400
Grant Ct to 3108 Tyre Neck	231A
Grant Ct	2312
Oak Dr E.	2300
905 Saddleback Trail Ct	2211
Meadowbrook to Pineridge	2211
Wythe Ln	2200
2505 Foreman Lndg	2112

Location	PACP QuickScore Overall Rating
3500 Avondale Ct	2111
3117 Dean	2100
102 American Legion Rd	2100
Mapleton Cres at Shadyside	1500
Foxgrove Ln	1500
Woodcroft Ln	1500
Western Branch Blvd at Dunedin Dr	1400
2017 Phyllis Dr	1300
3537 Kentucky Trl	1200
Hawksley	1200
Poplar Hill /Kenley Ct	1200
3221 Pineridgen Dr	1100
713 Sparrow Rd	1100
Helensburgh Dr	1100
853 Woodstream Way	1100
608 Guisborne Ct	0000
816 Dawson Cir	0000

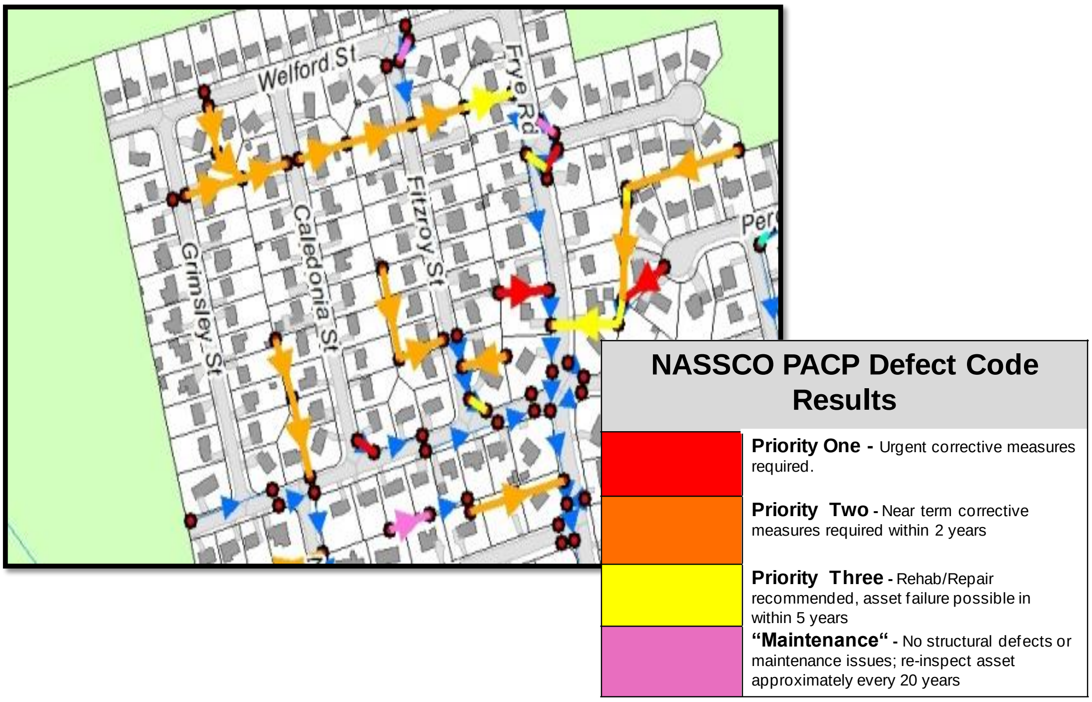

Figure 8: Example of Spatial Distribution of Priority Pipes (based on NASSCO PACP "QuickScore" (Eyre, Fortin, 2014)

10. SUMMARY/CLOSING

Municipal owners/operators responsible for stormwater conveyance systems, especially the piped portion, have at their disposal reasonable, established practices and procedures to assess the physical condition (internal) of these important assets. "Out of sit and out of mind" is no longer an acceptable reason for ignoring the condition of storm conveyance systems. Establishing priorities, and using available resources to implement or improve system condition and operation, are among the first steps toward fully knowing the extent and configuration of the storm system inventory. Once the system inventory is mapped, then efforts can begin to inspect the system and determine its condition, where the inspection observation results can be managed using established guidance as that offered with the NASSCO PACP approach. Some agencies, such as DC Water, use external engineering expertise (Engineering Program Management Consultants - EPMCs) to help augment their own staff. The EPMCs generate sewer system inspection task orders providing for the internal inspection and condition data collection. Once the data is collected, it is processed (similar to that as shown in Figure 8), and then the high priority CIP projects are scheduled in DC Water's CIP and keyed into their KPI. In this way the asset is tracked and when renewal is complete, scheduled for routine inspection and maintenance checks. Storm pipe condition rating applications are the gateway to asset management. Protecting the buried storm infrastructure and having a structured asset management plan that is flexible as funding sources fluctuate, has at its core the need for a proven physical condition assessment approach. The physical condition assessment approach should include provision for pipe condition rating and scoring so that data does not overwhelm system operators. Interpreting the data can take advantage of established methods modeled after the NASSCO PACP approach and the results used to make informed infrastructure re0investment and O & M decisions.

References

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- [5] Eyre, K., and Fortin, P, More on Things that Go Bump in the Pipe: Implementing municipal storm sewer pipe condition rating systems, 2014 International APWA Congress, Toronto, CN.
- [6] NASSCO PACP version 6.01, November 2010.