Depth Perception

Tracking Sewer Performance Using Design Guidelines & Regulatory Expectations

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ABSTRACT From 2004 to 2015, the United States Environmental Protection Agency (EPA) issued 10 Consent Decrees to sewer utilities located in seven states within Region 4. Provisions within 50% of these agreements reveal an emerging regulatory expectation for sewer system performance, where the EPA has incorporated flow depths as leading indicators to highlight sewers that are at higher risk for sanitary sewer overflows (SSOs).

When coupled with sewer design guidance from the American Society of Civil Engineers (ASCE), the Water Environment Federation (WEF), and/or local sewer design requirements, these emerging regulatory expectations provide an effective framework in which to track, characterize, and manage system performance. Although these provisions were limited to EPA Region 4 during this period, they have broader implications for future enforcement initiatives in other EPA Regions and should be of general interest to sewer utilities across the United States. This paper provides an overview of these performance benchmarks as well as examples to illustrate their application.

KEY WORDS Flow Depth, d/D Ratio, Capacity Assurance, Sanitary Sewer Overflow

Introduction

Today's sanitary sewer system managers, engineers, and operators face a daunting challenge: transport wastewater in a cost-effective manner from point-of-generation through aging infrastructure to point-of-treatment with no sanitary sewer overflows (SSOs). To meet this objective, *depth perception* is required. In general terms, *depth perception* is the ability to determine the relative distance between objects. However, within a sanitary sewer system a deeper connotation is invoked and represents the relationship between the flow depth in a sewer and the capacity of that sewer to convey it. This concept is presented and discussed in this paper, where actual flow depths are measured or modeled and are evaluated in the context of sewer design guidelines and emerging regulatory expectations.

Background

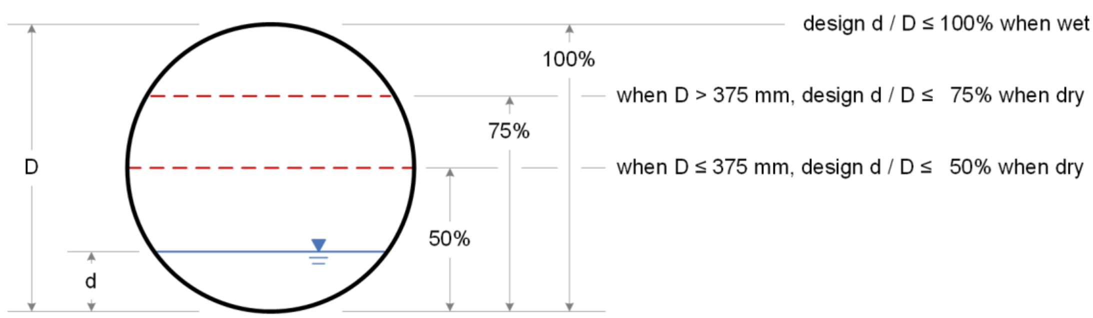
The concept of using flow depth as a key performance indicator (KPI) is not new. The flow depth-to-diameter (d/D) ratio has long been incorporated into sewer design guidelines, and is defined as shown in Equation (1).

$$\text{Flow Depth-to-Diameter Ratio} = \frac{d}{D} \qquad (1)$$

where: d = flow depth, mm
D = sewer diameter, mm

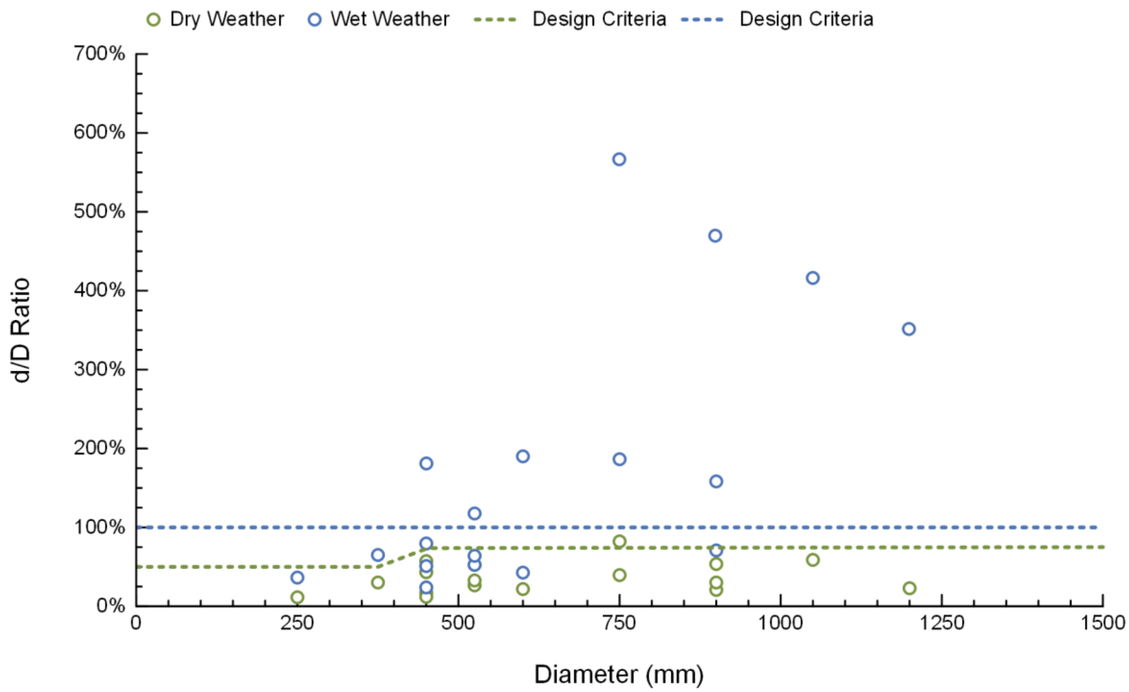
Sewers are often designed to flow under gravity flow conditions with some reserve capacity. For example, the American Society of Civil Engineers (ASCE) and the Water Environment Federation (WEF) recommend that sewers with diameters up to 375 mm be designed to flow with dry weather d/D ratios no more than 50%, and larger diameter sewers be designed to flow with dry weather d/D ratios no more than 75%. Sewers are not generally designed to operate under surcharge conditions. Therefore, it is recommended that wet weather d/D ratios should not exceed 100%.[1] The concept of flow depth within the context of ASCE and WEF sewer design guidance is illustrated in Figure 1. Similar comparisons can also be made using local sewer design requirements, as needed.

FIGURE 1: Flow Depth-to-Diameter Ratio in the Context of Sewer Design Criteria



The authors have used such guidelines as KPIs for a number of years to evaluate existing sewer systems under actual operating conditions, and the results can be presented and explored in graphical form as shown in Figure 2. This graphical method evaluates observed maximum hourly average flow depth data within existing sewers in the context of sewer design guidance.

FIGURE 2: Evaluating Sewer Performance in Context of Sewer Design Guidance

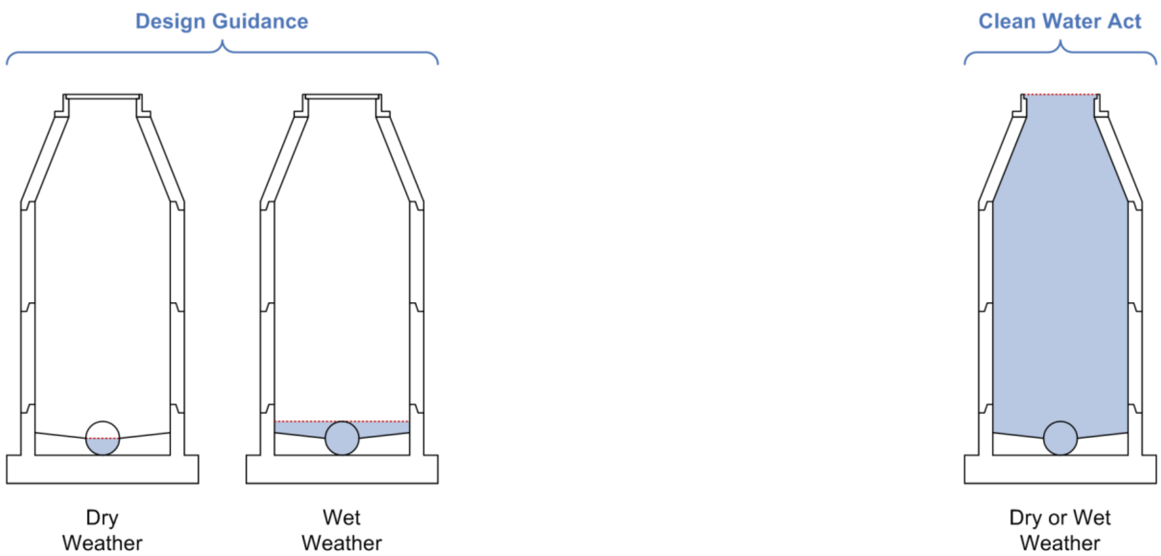


Data from several locations within a sanitary sewer system located in Tennessee are shown as an example. For each sewer evaluated, two data points are plotted on the graph, representing observed maximum hourly average d/D ratios in dry weather (○) and wet weather (○) as a function of sewer diameter. ASCE and WEF sewer design guidance for dry weather (---) and wet weather (---) are also depicted, and when a green data point is above the green dashed line or when a blue data point is above the blue dashed line, the graph indicates that sewer design guidelines have been exceeded at these locations.

When a dry weather d/D ratio is noted above sewer design criteria, this condition does not necessarily imply an immediate problem. However, it does indicate that existing dry weather flows are consuming a greater percentage of available sewer capacity than expected, leaving less capacity than anticipated for wet weather flows. Further investigation may reveal that additional sewer capacity is warranted based on revised land use, or perhaps that sewer rehabilitation is needed to remove groundwater infiltration that is silently consuming sewer capacity. In some cases, operation and maintenance (O&M) problems may also be identified within nearby pump stations, sewers, or related appurtenances.

When a wet weather d/D ratio is noted above sewer design criteria, there is often much debate about how much surcharge is acceptable and under what conditions. The Clean Water Act (CWA) prohibits SSOs and provides an upper limit of what is acceptable – flow depths should not exceed the manhole rim elevation as shown in Figure 3 – but otherwise how much surcharge is too much surcharge? From a capacity management standpoint, where should utilities draw the line and under what conditions?

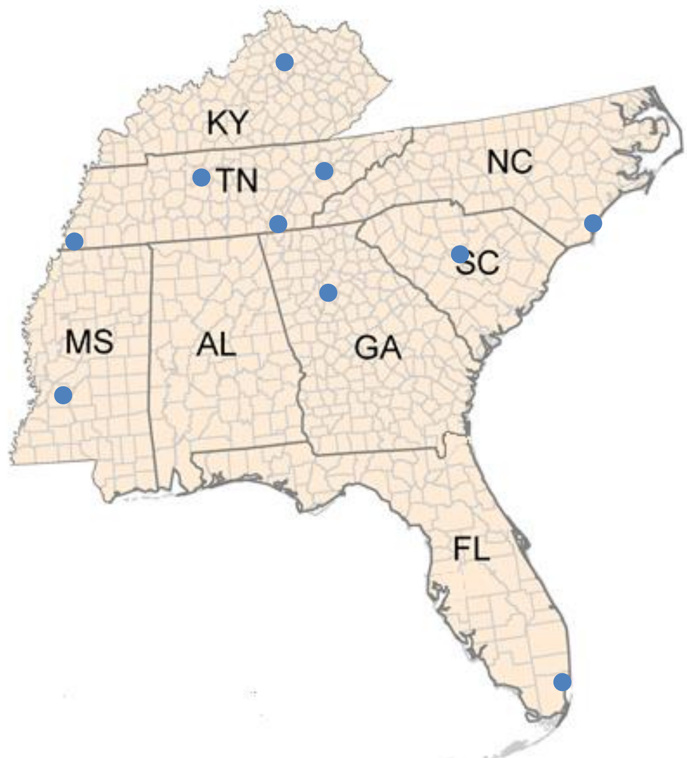
FIGURE 3: Flow Depth KPIs in Design Guidance and Regulatory Requirements



Emerging Regulatory Expectations

Recent Consent Decrees in EPA Region 4 have taken steps to answer the question “How much surcharge is too much surcharge?” From 2004 to 2015, the Environmental Protection Agency (EPA) issued 10 Consent Decrees to sewer utilities located in seven states within Region 4 for violations of the CWA, as shown in Figure 4.

FIGURE 4: Sewer Utilities with Consent Decrees Issued by EPA Region 4 (2004-2015)



While comparing and contrasting these Consent Decree requirements, the authors noted that 50% included an emerging regulatory expectation where the EPA incorporated flow depth thresholds as capacity assurance indicators to highlight sewers that are most susceptible to SSOs. Sewer utilities in EPA Region 4 with Consent Decrees issued within this period are listed in Table 1, and those with this emerging regulatory expectation are noted.

TABLE 1: Sewer Utilities With Consent Decrees Issued by EPA Region 4 (2004-2015)

Issue Date	Sewer Utility
2013-09-10	City of Columbia, South Carolina†
2013-07-11	City of Wilmington, North Carolina & Cape Fear Public Utility Authority
2013-06-06	Miami-Dade County, Florida
2012-11-21	City of Jackson, Mississippi†
2012-07-17	City of Chattanooga, Tennessee†
2012-04-06	City of Memphis, Tennessee
2010-12-14	DeKalb County, Georgia
2008-03-14	Lexington-Fayette Urban County Government, Kentucky†
2007-10-24	Metropolitan Government of Nashville & Davidson County, Tennessee
2004-12-01	Knoxville Utilities Board, Tennessee†

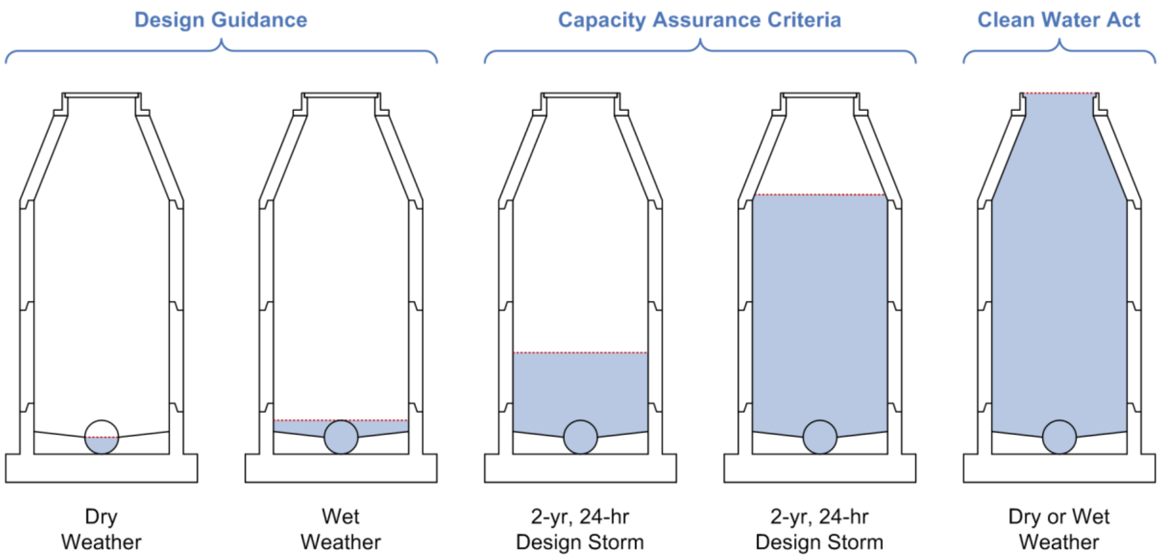
† Consent Decrees with flow depth-based capacity assurance criteria

Within the capacity assurance criteria of these documents, affected sewer utilities are required to "confirm that each gravity sewer line . . . has the capacity to carry the existing one hour peak flow . . . without causing a surcharge condition . . ."[2-9] Reading further, the "one hour peak flow" is defined as the "maximum hourly flow rate associated with a representative 2-year, 24-hour storm event," and a "surcharge condition" is defined as any occasion when the "flow depth is greater than 600 mm above the crown of the sewer or within 900 mm from the manhole rim."[2-9] Discussions with EPA Region 4 representatives indicate that these provisions do not absolve affected sewer utilities of any SSOs that might occur during more extreme return frequencies (a 10-year, 24-hour storm, for example), nor should they be used as design requirements for associated SSO mitigation projects. They do, however, provide an effective means to highlight sewers that are at higher risk for SSOs.[2-9]

Putting the Pieces Together

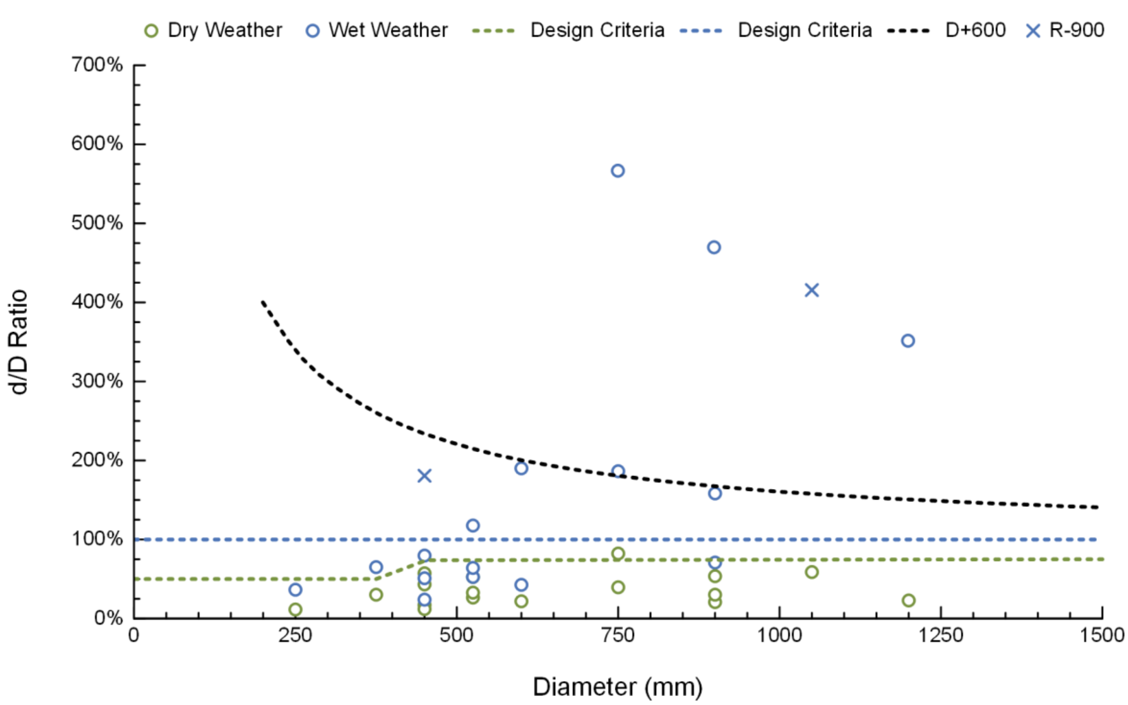
When coupled with sewer design guidance from ASCE and WEF, these emerging regulatory expectations provide an effective framework in which to track, characterize, and manage system performance by highlighting sewer capacity concerns that are more likely to contribute to SSOs. Figure 5 depicts the relationship between existing sewer design criteria, regulatory requirements, and capacity assurance criteria in EPA Region 4 Consent Decrees.

FIGURE 5: Capacity Assurance Criteria vs. Design Guidance and Regulatory Requirements



A graphical method to evaluate maximum hourly average flow depth data in the context of both sewer design guidance and capacity assurance criteria is provided in Figure 6. Once again, data from a sewer utility in Tennessee are shown as an example.

FIGURE 6: Evaluating Sewer Performance in Context of Capacity Assurance Criteria



In addition to the sewer design guidelines, capacity assurance criteria based on emerging regulatory expectations in EPA Region 4 are also provided. Any data point above the black dashed line (**---**) represents a flow depth greater than 600 mm above the crown of the sewer (D+600), while any data point plotted with an × instead of an ○ represents a flow depth within 900 mm of the manhole rim (R-900). Of the 18 locations depicted in Figure 1, one location is considered a dry weather concern, and six locations are deemed wet weather concerns because they exceed capacity assurance criteria. For sewer utilities under a Consent Decree with these provisions, such areas might become subject to a moratorium on new sewer connections – a proposition with serious implications. However, for sewer utilities not under a Consent Decree, this method can be applied in a proactive manner to highlight areas of higher SSO risk that would be of most concern to regulators, allowing utilities to prioritize actions accordingly to help improve sewer performance before more serious SSO conditions ensue.

Conclusion

Flow depth-based sewer design guidance and capacity assurance criteria provide an effective framework to evaluate sewer performance, and implementation can be performed using a variety of methods – including hydraulic modeling or flow depth monitoring – with results evaluated from time-to-time or in real-time. While the capacity assurance criteria that supplement sewer design guidance are currently only emerging regulatory expectations observed in Consent Decrees issued in EPA Region 4, they have broader implications for future enforcement initiatives in other EPA Regions and, therefore, should be of general interest to sewer utilities across the United States. When used proactively, these capacity assurance criteria offer sewer utilities an additional tool in their Capacity Management Operation and Maintenance (CMOM) toolbox to keep tabs on conditions within their sewer systems and focus attention on areas with the highest risk of SSOs.

Symbols and Notation

The following symbols and notation are used in this paper:

VARIABLES

d	= flow depth, mm
D	= diameter, mm
R	= manhole rim, mm

ABBREVIATIONS

d / D	= flow depth-to-diameter ratio
D + 600	= capacity assurance criteria (> 600 mm above crown of pipe)
R - 900	= capacity assurance criteria (≤ 900 mm from manhole rim)

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