Analysis of Calendar Year 2016 Water Audit Data from Public Water Supply Systems in the Delaware River Basin

DELAWARE RIVER BASIN COMMISSION

Delaware River Basin Commission

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Acknowledgements

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Introduction and Background:

For several decades, the Delaware River Basin Commission (DRBC) has employed a comprehensive water efficiency program, which has formed an integral component of its broader strategy to manage water supplies throughout the basin. In 2009, as part of DRBC's effort to ensure its regulations reflect the latest thinking in the field of water efficiency, the commission amended its Comprehensive Plan and Water Code to implement an updated water audit approach to identify and manage water loss in the basin. The purpose of the water audit is to track how effectively water is moved from its source to customers' taps and to ensure that public water supply systems quantify and address water losses.

The public water supply sector is the second largest water withdrawing sector in the Delaware River Basin, behind power generation. Approximately 6.7 million customers (80% of basin residents) obtain their drinking water supply from public water supply systems.

The purpose behind DRBC's water audit program and the objectives of this report are as follows:

- To continue to promote best practices in water efficiency and specifically water loss management
- To gain a better understanding of water losses in the Delaware River Basin
- To identify areas where training, guidance and, ultimately, regulations may be needed to minimize water losses

DRBC anticipates that significant reductions in water losses can be realized through this program and that focus on this issue will allow system operators, utility managers, and regulators to more effectively target their efforts to improve water supply efficiency, saving both water resources and money.

Additional information on DRBC's water audit program can be found on the DRBC's web site at http://www.nj.gov/drbc/programs/supply/water-audit-program.html

Implementation:

The 2009 DRBC rule change required a new reporting format to be used for the calendar year 2012 (CY2012) water audit. The new approach is consistent with the International Water Association (IWA) and American Water Works Association (AWWA) Water Audit Methodology and is considered a best management practice in water loss control.

The water audit requirement applies to all public water suppliers within the Delaware River Basin that have been issued approvals by the DRBC to withdraw and use in excess of an average of 100,000 gallons per day of water during any 30-day period. An important aspect of the new DRBC water audit requirement is an emphasis on electronic reporting and processing of water audit reports. The format for the new report is the AWWA Free Water Audit Software©, available from the AWWA website (www.awwa.org). Water utilities enter their water audit information into the Water Audit Software, which is in the format of a user-friendly MS Excel workbook. The software contains interactive feedback to help users complete the audit correctly and avoid common errors. Water utilities then submit their completed audits electronically to DRBC as an email attachment to a dedicated email address. This process allows DRBC to aggregate the audit data efficiently into a database for further analysis. In preparation for the new reporting, DRBC improved its in-house database to identify which basin water purveyors are subject to the water audit regulation and to ensure that accurate contact information is available. New reports were developed in the database to help track compliance with the reporting requirements. Water Audit FAQs on the DRBC web site have been developed to provide additional information to help users complete water audit reports (http://www.nj.gov/drbc/library/documents/wateraudits/faq.pdf).

Data Validation:

All data presented are self-reported to DRBC by the water purveyor through the use of the AWWA Free Water Audit Software©. Although self-reporting of regulatory data is typical, other water audit programs that utilized the AWWA Water Audit methodology have involved a follow-up process known as "data validation" to determine the likely accuracy of reported data. Data validation has been practiced by the Georgia Environmental Protection Division (GEPD, 2015) and AWWA (AWWA, 2013). Although DRBC's data validation efforts are not as extensive as the above-referenced programs, a validation was performed to ensure that the audit was complete and there were no obvious unit discrepancies or other significant data entry errors.

System Data and Size Classifications:

At the time of this reporting there were 277 water audits submitted for calendar year 2016 (CY2016) and available for analysis for the CY2016 Report. In addition, audits from six utilities submitted in prior calendar years (i.e., 2012 through 2015), but not yet submitted for CY2016, were included in the analysis in order to provide a more complete basinwide water use/loss assessment for 2016. Collectively, audit data from these 283 systems indicate that approximately 760 million gallons per day (MGD) of water was put into distribution systems in the Delaware River Basin. The largest 20 public water supply systems account for approximately 70% of the total volume of "water supplied" by all systems submitting a water audit (see Figure 1). The definition of water supplied is "the volume of treated and pressurized water input to the retail water distribution system of the water utility" (AWWA, 2009).

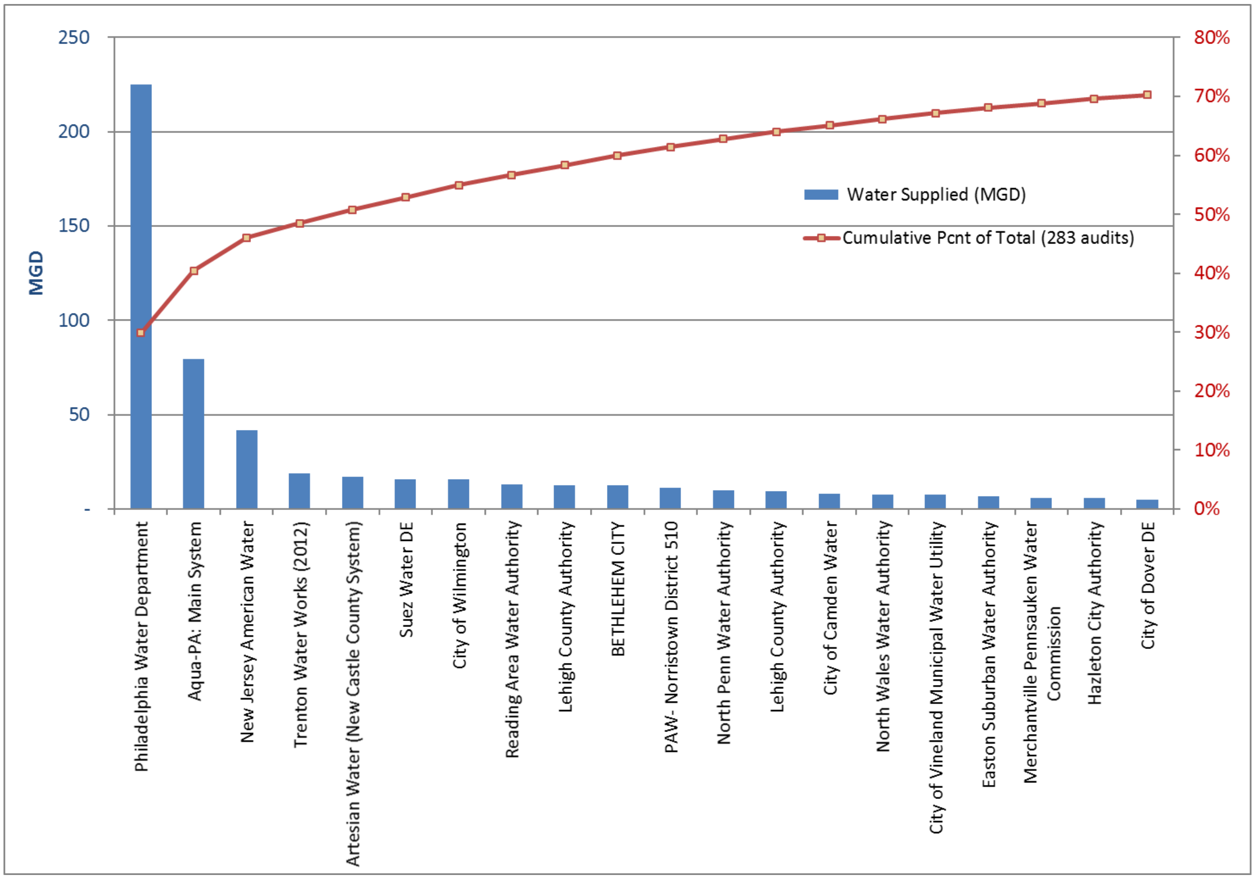


Figure 1. Water Supplied in CY2016: 20 Largest Public Water Supply Systems Subject to DRBC's Water Audit Reporting Requirement.

The largest system in the dataset has a water supplied value of 225 MGD and the smallest has a value of 0.003 MGD. This minimum value is well below DRBC's regulatory threshold (0.1 MGD) but was submitted because the docket holder for this system operates more than one system that collectively meet the DRBC threshold. DRBC encourages docket holders to report water audits at the individual system-level where possible, rather than aggregating and reporting the data at a higher level. The AWWA water audit methodology and the underlying need to accurately measure system data is applicable to water distribution systems of all sizes that have source and customer-level metering in place. In the assessed dataset, 93 systems had a system input of greater than 1 MGD and these systems accounted for 92% of total water supplied (see Figure 2).

To provide additional insight into the data, each water audit was assigned to a size-classification based on the volume of water supplied (see Figure 3a). These size classifications will be used in box and whisker plots in the Results section of this report. Figure 3b is a graphical representation of how a box and whisker plot works.

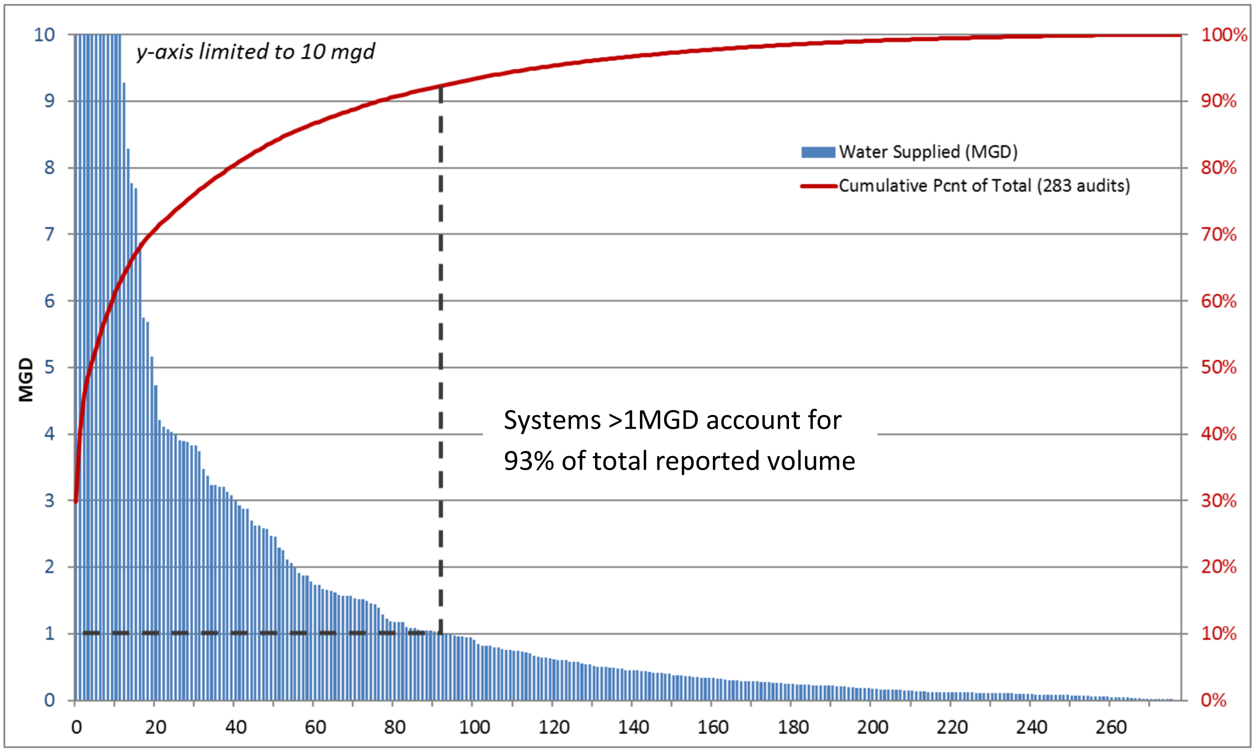


Figure 2. Water Supplied in CY2016 (n = 283 systems).

Classification of Systems by Volume of Water Supplied	Count (n)
≤0.25 MGD	100
>0.25 ≤0.5 MGD	49
>0.5 ≤1 MGD	40
>1 ≤10 MGD	82
>10 MGD	12
Total	**283**

Figure 3a. Grouping of System Data by Size.

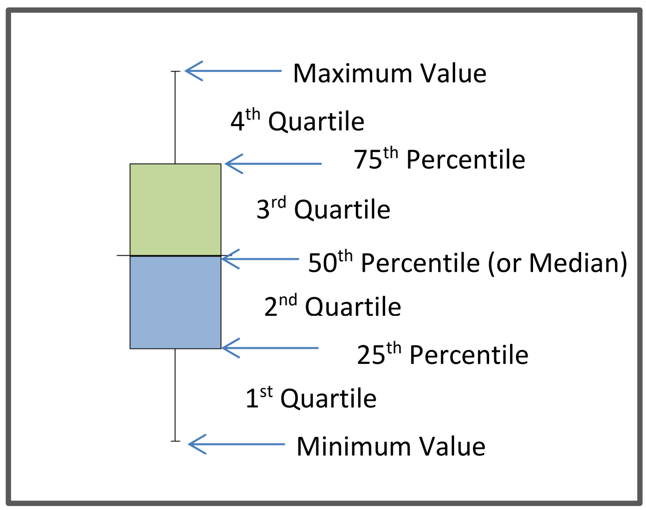


Figure 3b. How to Interpret Box and Whisker Plots.

Results:

The following sections show results from CY2016 reporting under the DRBC's water audit program. The results can be used to draw conclusions on the general state of water loss accounting and reporting in the Delaware River Basin and can also be used to identify areas where education and training in water system auditing may be warranted.

Water Audit Data Validity Score:

An important feature of the AWWA Water Audit Software is the required "grading" of inputs to the audit. Each water audit data input is assigned a grading value of 1-10, by the user, based on how the water purveyors' practices match up to a given set of grading criteria, for the particular audit component. Once all input is complete, an overall water audit data validity score is calculated, out of a maximum achievable score of 100. The water audit data validity score can be considered a measure of confidence in the underlying water audit data. Before evaluating the values of the performance indicators generated by the software, it is important to understand the water audit data validity score, as this will provide insight into the confidence levels of reported results.

Low data validity scores typically indicate many data estimates, whereas high scores indicate good record keeping and accurate metering and meter calibration practices. The box and whisker plots in Figure 4 indicate that systems under 0.25 MGD had lower grading scores and may need assistance in order to improve their data validity score. The median score across the entire data set was 76 with reported scores ranging from 23 to 93. Additional information is provided in Appendix A. Prior to taking action based on the water audit performance indicators, it is necessary to ensure that the input information meets a certain standard of reliability (i.e., minimum data validity score). Additional water audit training and education may be required in order to help systems improve their data validity scores. DRBC is planning to continue, and expand, its outreach and training regarding the value of water audits.

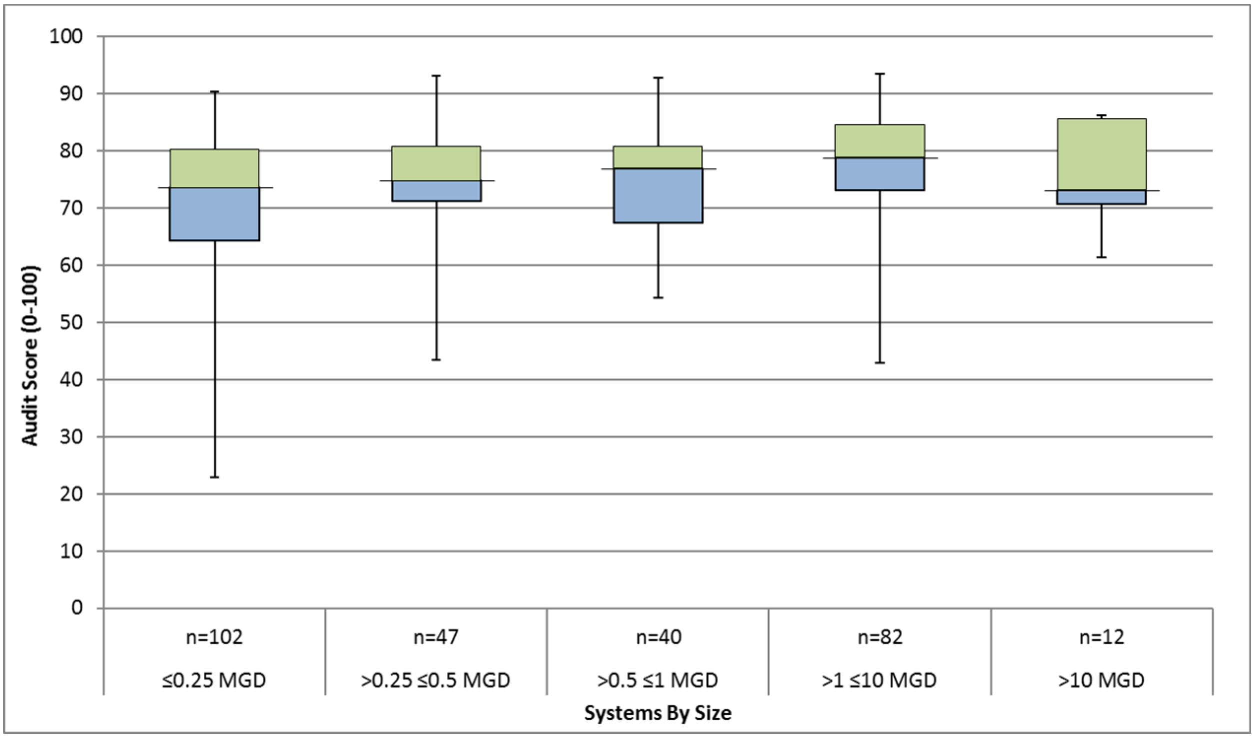


Figure 4. Box and Whisker Plot of Water Audit Data Validity Scores, by System Size (n = 283).

Priority Areas to Improve Water Audit Data Validity Score:

The AWWA Water Audit Software provides feedback to the user on its top three audit inputs, to help users improve their overall data validity score. Figure 5 indicates that nearly 80% of systems could improve their data validity score by focusing attention on the measurement of *Volume from Own Sources,* as one of the three priority areas. Additionally, nearly 60% of the audits indicated *Unauthorized Consumption* and 40% indicated *Customer Metering Inaccuracies* as one of the top three priority items. These findings could be used to focus development of training and guidance materials. Note that the cumulative value of the bars in Figure 5 equals 300%, reflecting the fact that the software returns the top *three* priority areas for improvement.

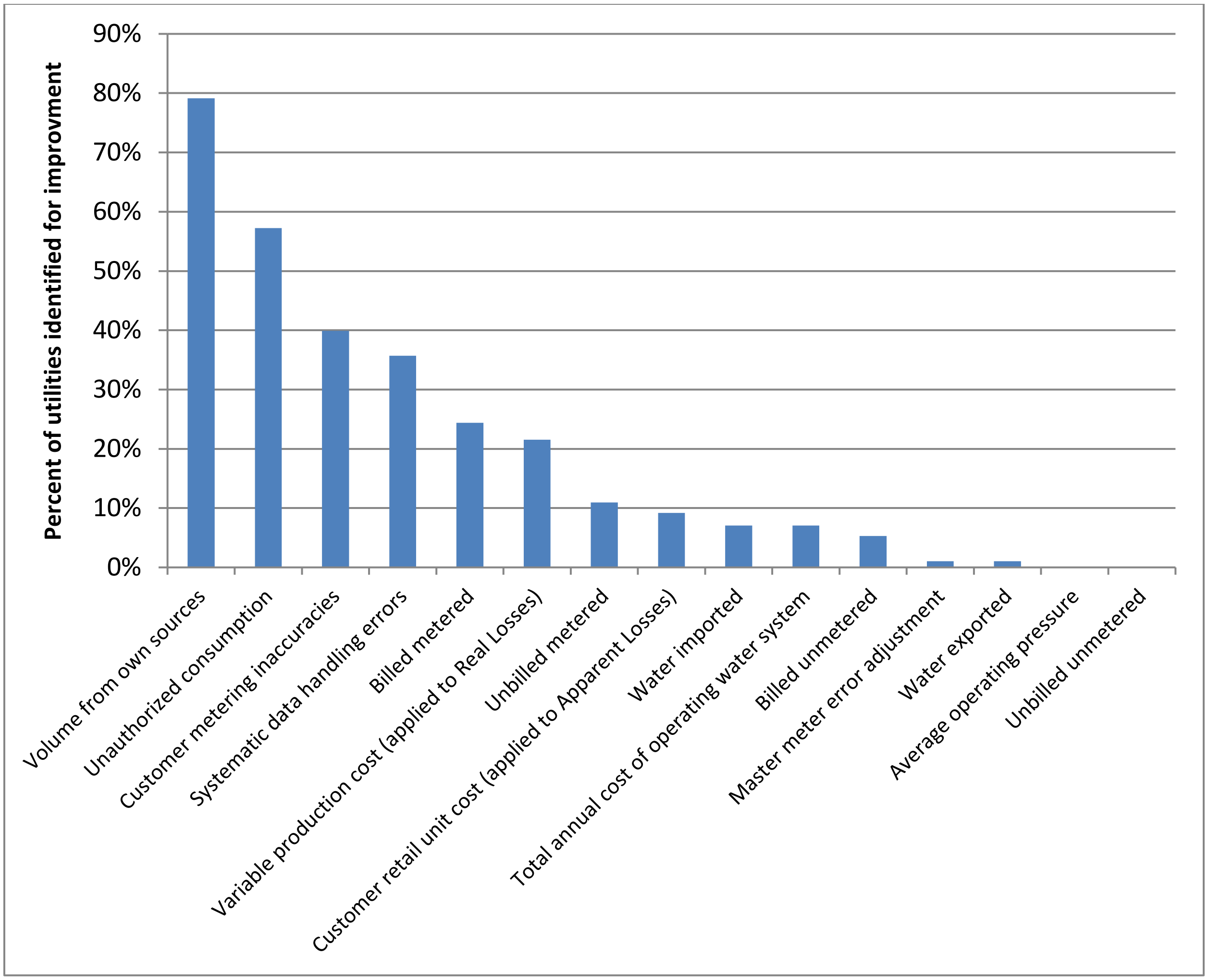


Figure 5. Parameters Identified as One of the Top Three Priority Areas for Attention to Improve the Water Audit Data Validity Score.

Non-Revenue Water:

Non-revenue water is a term used to quantify water losses and unbilled consumption. Non-revenue water is water that has been treated and pressurized and enters the distribution system, but generates no revenue for the water purveyor. Water losses can be ***real*** losses (through leaks, also referred to as physical losses) or ***apparent*** losses (for example, through unauthorized consumption or metering inaccuracies).

Traditionally, performance indicators of water loss in water distribution systems have used percentage-based metrics (e.g., “unaccounted for water” expressed as a percentage of water supplied). However, this simplistic approach has weaknesses (see section on Limitations of Water Loss Expressed as a Percentage) and the recommended best practice (as per AWWA M36 manual) is to use alternative performance indicators. While Figure 6 displays non-revenue water as a percentage of water supplied and is included in this assessment for consistency and familiarity with previous assessments, alternative performance indicators are used in the following pages to indicate water loss rankings that are considered more meaningful indicators and are likely to be preferred in future assessments. Note that data for six of the 283 systems were removed from analysis of this metric pending further investigation because non-revenue water was excessive (e.g., exceeded 80%) or had negative values. See also Appendix B.

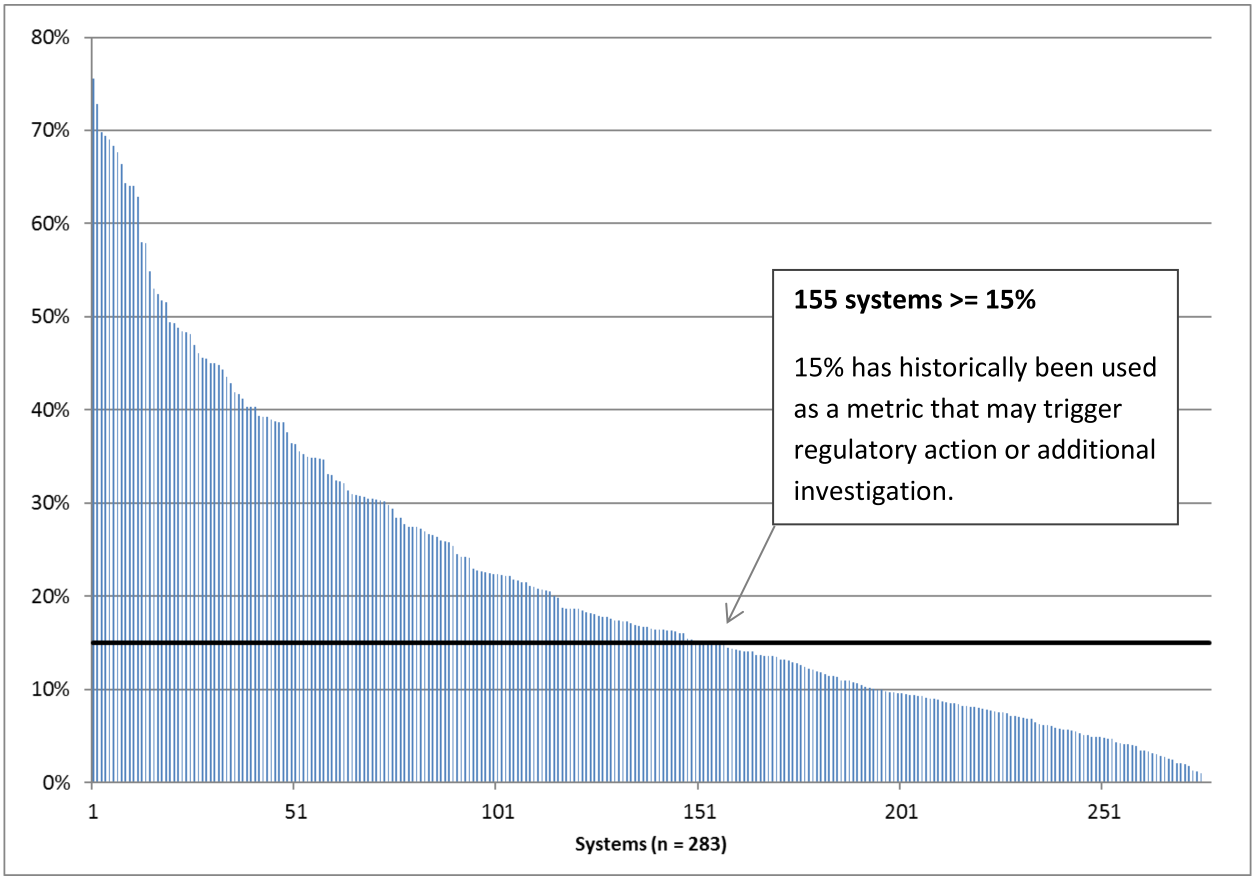


Figure 6. Non-Revenue Water as a Percent by Volume of Water Supplied.

Limitations of Water Loss Expressed as a Percentage:

Percentages are simple to understand and have traditionally been used as a water loss performance indicator (e.g., unaccounted for water expressed as a percentage of distribution input). However, significant flaws exist with the use of a simple percentage approach in the context of water losses in a pressurized water distribution system. Consider a *simplified* example of two identical water systems each with 1,000 houses. The only difference is the water using habits of the communities.

Community A is a water efficient community using 70 gallons per person per day:

1,000 x 2.5 persons/household x 70 gallons = 175,000 gallons / day

Community B is less water efficient, using 100 gallons per person per day:

1,000 x 2.5 persons/household x 100 gallons = 250,000 gallons / day

Because both systems are otherwise identical (including the way in which they have maintained their water distribution infrastructure), they both incur the same level of water losses, 40,000 gallons per day. Therefore, their water losses expressed as a percentage of water supplied are as follows:

Community A: $\frac{40{,}000}{175{,}000 + 40{,}000}$ = 19%

Community B: $\frac{40{,}000}{250{,}000+40{,}000}$ = 14%

As a result of using more water, Community B appears to perform better when using a percentage based approach as a standard measure of water loss; the more water efficient Community A appears to perform worse. Similar problems are encountered in systems that have a few large customers (e.g., a bottling facility). In this case, the large customers would increase the denominator in the equation – producing a lower percentage water loss value. Additionally, if this water use is not constant, comparisons of percentage-based water loss indicators for the system over time could be highly erratic.

In this report, percentage values are still used for the purpose of consistency with traditional measures, but other metrics are also considered such as losses per connection per day and the ILI (Infrastructure Leakage Index). It is anticipated that in the future the DRBC will focus on these alternative and more comparable performance indicators.

Use of Default Values:

The AWWA Free Water Audit Software© allows the use of default values for the input values of Unbilled Unmetered Consumption and Unauthorized Consumption. These two items are typically relatively small volumes compared to other volumetric input values and are often areas of uncertainty for those new to the water audit methodology. The use of default values is an option in the software and is recommended for those who have not conducted detailed work to estimate the actual value of these audit components. Figures 7 and 8 show how default values were used for Unbilled Unmetered Consumption and Unauthorized Consumption, respectively, by system size. On average, across all systems, the default value for Unbilled Unmetered Consumption was used in 77% of the audits and the default value for Unauthorized Consumption was used in 93% of the audits.

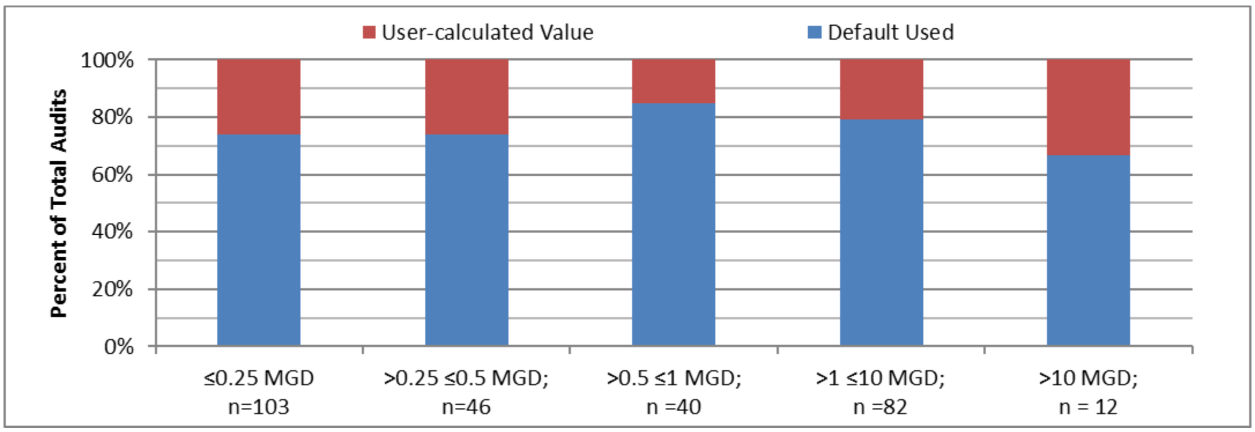


Figure 7. Use of Default vs User-Calculated Values for Unbilled Unmetered Consumption, by System Size (n = 283).

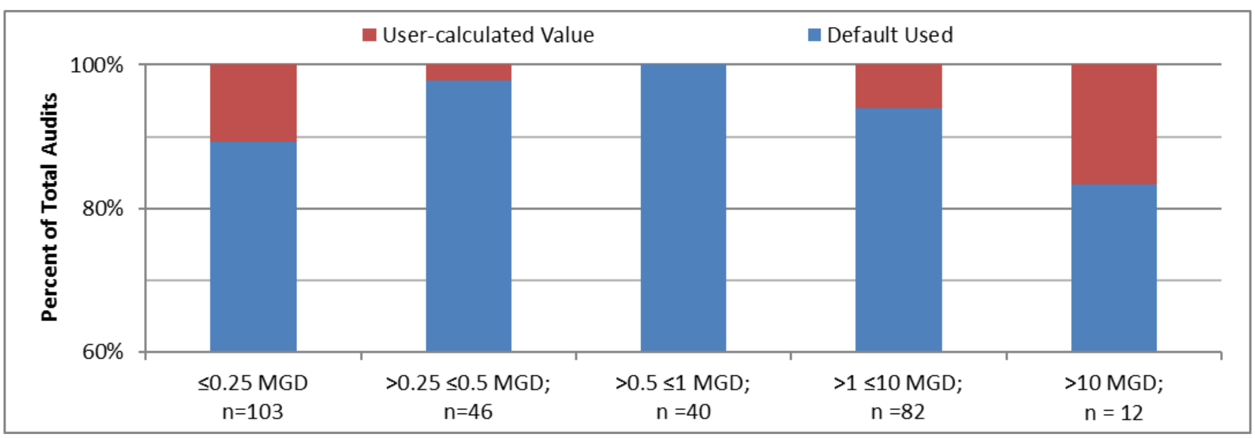


Figure 8. Use of Default vs User-Calculated Values for Unauthorized Consumption, by System Size (n = 283).

Apparent Losses:

Apparent losses include all types of inaccuracies associated with customer metering (worn meters as well as improperly sized meters or wrong type of meter for the water usage profile) and systematic data handling errors (meter reading, billing, archiving, and reporting), plus unauthorized consumption such as theft or illegal use. Figure 9 shows that reported apparent losses are largest among systems operating below 0.25 MGD, which showed the highest 4th quartile range and sample size. However, the largest systems (i.e., those over 10 MGD) also experience large apparent losses, as indicated by their higher median value and a higher 3rd and 4th quartile range.

Apparent losses are reported as *gallons per service connection per day* and this normalized metric can be used to compare systems of different sizes. Apparent losses are valued at the customer retail unit cost as this water makes it to the customer or end user, but is not accurately metered and/or billed. Therefore, systems that reduce apparent losses will likely not realize a decrease in water withdrawals; however, reducing apparent losses will increase the revenue collected by the utility, thus increasing the potential for investment to be made to reduce real losses. See also Appendix C.

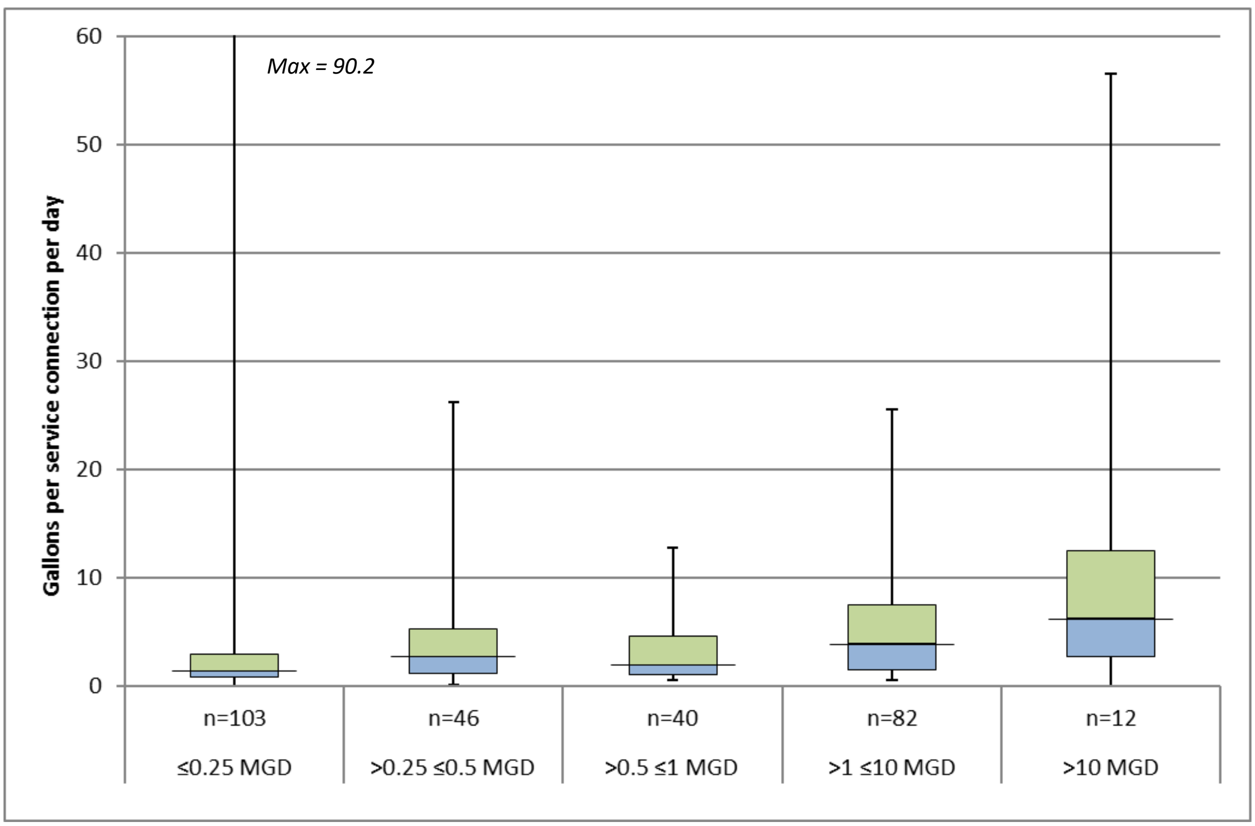


Figure 9. Apparent Losses (Gallons per Service Connection per Day) by System Size (n = 283).

Real Losses:

Real losses are also reported as *gallons per service connection per day* and therefore this metric can be used to compare systems of different sizes. Real losses are physical water losses from the pressurized system (water mains and customer service connections) and the utility's storage tanks, up to the point of customer consumption, that is, the customer's meter in metered systems or the first point of consumption within the property in unmetered situations. The volume of water lost depends on frequencies, flow rates, and average duration of individual leaks, breaks, and overflows.

Figure 10 shows a higher median real loss value for the largest systems (those greater than 10 MGD) in the dataset. This category includes several large, generally older, urban areas where well-recognized problems exist when it comes to investing in maintaining the water infrastructure (e.g., Trenton, NJ, Camden, NJ, Allentown, PA, Philadelphia, PA and Wilmington, DE). Also notable is the fact that the four smaller size categories all show one or more systems with reported real losses of less than 0.3 gallons per service connection per day – a level that is likely unrealistic and indicates that the data reported may be unreliable. See also Appendix D.

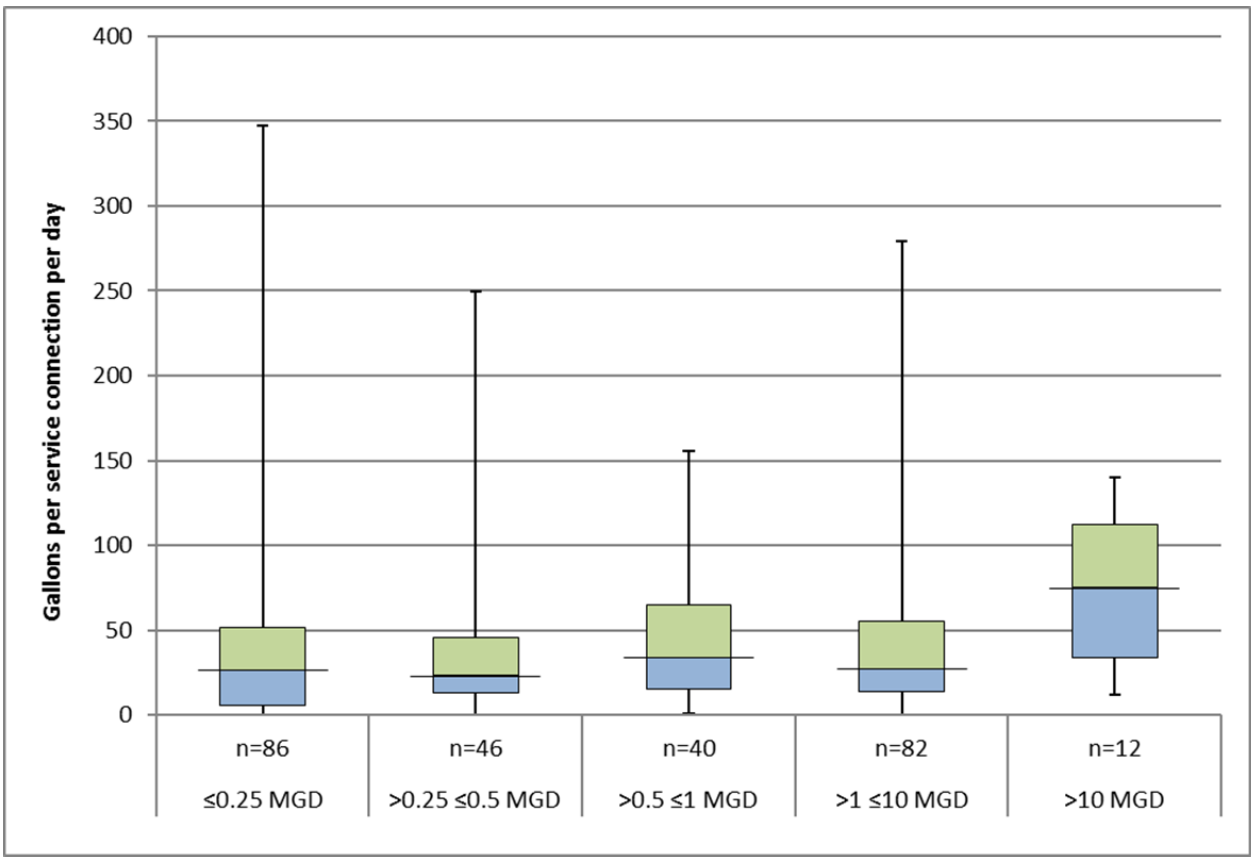


Figure 10. Real Losses (Gallons per Service Connection per day), by System Size (n = 266). ***Note that this performance indicator is not calculated for systems with a low average service connection density (less than 32 connections per mile) as it is not a good measure of performance at low density.***

Infrastructure Leakage Index:

The Infrastructure Leakage Index, or ILI, is the ratio of real losses to the Unavoidable Annual Real Losses (UARL). The UARL is a theoretical reference value representing the technical low limit of leakage that could be achieved if all of today's best technology could be successfully applied; it is a key variable in the calculation of the ILI. It is important to recognize that the UARL value generated within the AWWA software takes into consideration system-specific attributes such as the length of mains, number of service connections and average operating pressure, providing an increased level of sophistication compared to a “one size fits all” metric. The ILI is a highly effective performance indicator for comparing (benchmarking) the performance of utilities in operational management of real losses. According to AWWA, striving to reduce system leakage to a level close to the UARL is usually not needed unless the water supply is unusually expensive, scarce, or both.

Figure 11 shows a higher median ILI value for the largest systems (those greater than 10 MGD) in the dataset. Note that in the CY2016 dataset, only 145 of the 277 water audits (52%) were suitable for calculation of an ILI. This is because the UARL calculation has not yet been proven as fully valid for very small or low-pressure water distribution systems[1].

[1] If Length of Mains in miles x 32 + Number of Active and Inactive Connections is less than 3000, or the Average Operating Pressure is less than 35 psi, then the calculated UARL value may not be valid. The software does not display a value of UARL or ILI if either of these conditions is true.

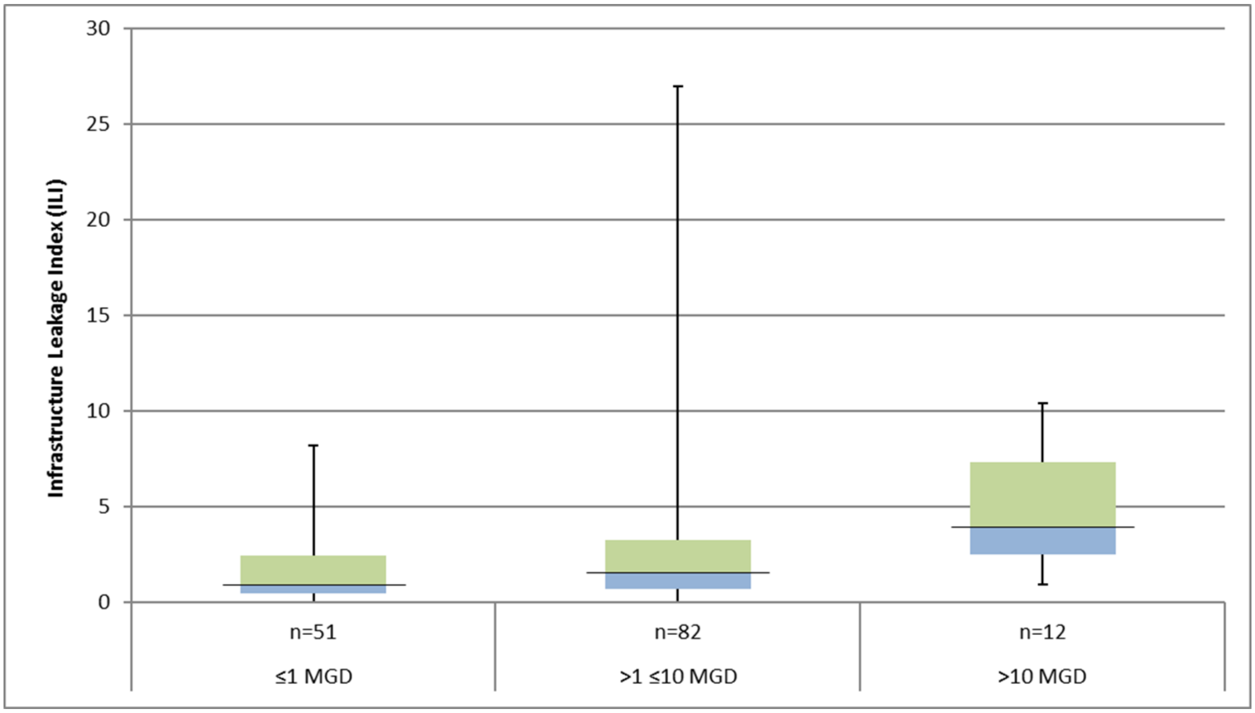


Figure 11. Infrastructure Leakage Index (n = 145). ***Note that this performance indicator is not calculated for small or low-pressure systems.***

Importance of Pressure Management:

As more attention is placed on managing water losses, the role of pressure is often highlighted as an important strategy in reducing real losses. Figure 12 shows reported average operating pressure for the 283 systems in the dataset. The largest variation in average operating pressure exists for the four smaller size classifications of systems. This may reflect that some of these systems operate in geographic areas that require increased pressure, i.e., hilly areas. It may also indicate that there is a need for some of these systems to perform more active leakage management and reduce real losses. See also Appendix E.

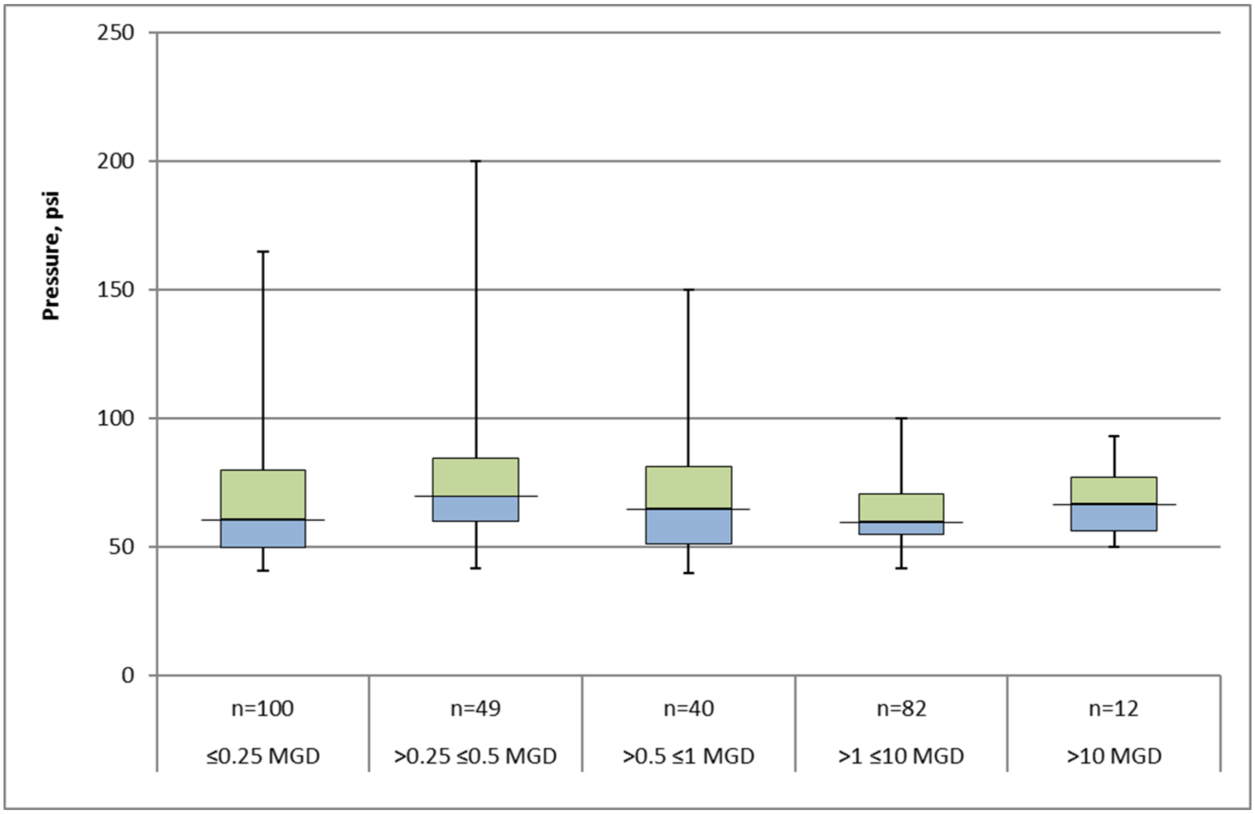
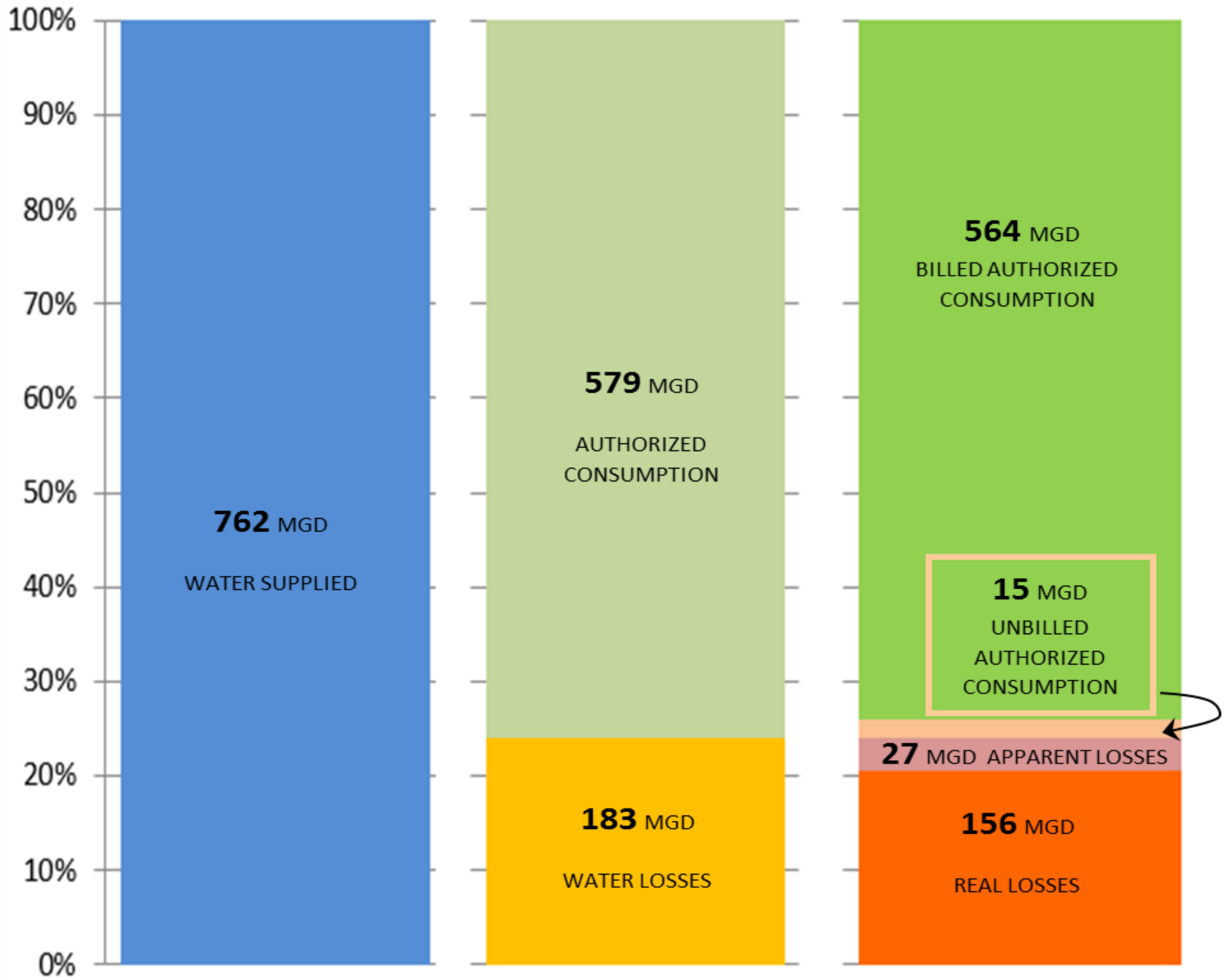


Figure 12. Average Operating Pressure in Pounds per Square Inch (psi), by System Size (n = 283).

Water Loss Summary:

Figure 13 shows a high-level summary of the CY2016 water audit data for the Delaware River Basin (DRB). This graphic represents the aggregate of 283 individual system audits and shows that an average of 762 million gallons of water was put into distribution systems in the Delaware River Basin every day. An estimated 156 MGD was reported as physically lost from distribution systems in the DRB along with an estimated 27 MGD reported as apparent losses. These water losses, in addition to 15 MGD of unbilled authorized consumption, comprise a total of 198 MGD of non-revenue water. This non-revenue water has an estimated value of $132 million to water utilities in the DRB and represents a significant opportunity to improve the efficiency of public water supply in the basin.



Billed authorized: All consumption that is billed to customers of the utility; this includes metered and unmetered connections.

Unbilled Authorized: All consumption that is unbilled but is still authorized by the utility. This is likely to include water used in activities such as firefighting, flushing of mains and sewers, street cleaning and fire flow tests. It may also include water consumed by the utility itself in treatment or distribution operations, or metered water provided to civic or institutions free of charge.

Figure 13. Aggregate Summary Graphic for 283 Systems Reporting Water Audit Data to DRBC for CY2016.

Conclusion and Future Steps:

DRBC's water audit program is a significant step in a long-term effort to improve water efficiency and promote best practices in water loss control for basin water purveyors. During the first years of the program, the emphasis has been on ensuring that water purveyors build confidence in the data submitted in the water audit. Developing and providing accurate data to the water audit process will result in a clearer understanding of the causes of water loss and is a vital first step in the process (akin to "*if you don't measure it, you can't manage it"*). Once a sufficient baseline dataset has been established, DRBC plans to adopt performance indicators and metrics against which water system performance can be assessed.

As part of its efforts to ensure progressive water resources management, the DRBC is one of only a handful of regulators in the U.S. that has made the AWWA Water Audit Methodology a regulatory requirement. The DRBC would like to recognize the efforts of those water utilities that submitted their water audits for CY2016 and their contribution to making DRBC's water audit program a success.

References:

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https://epd.georgia.gov/sites/epd.georgia.gov/files/GAWaterLossManual_V1.2.pdf

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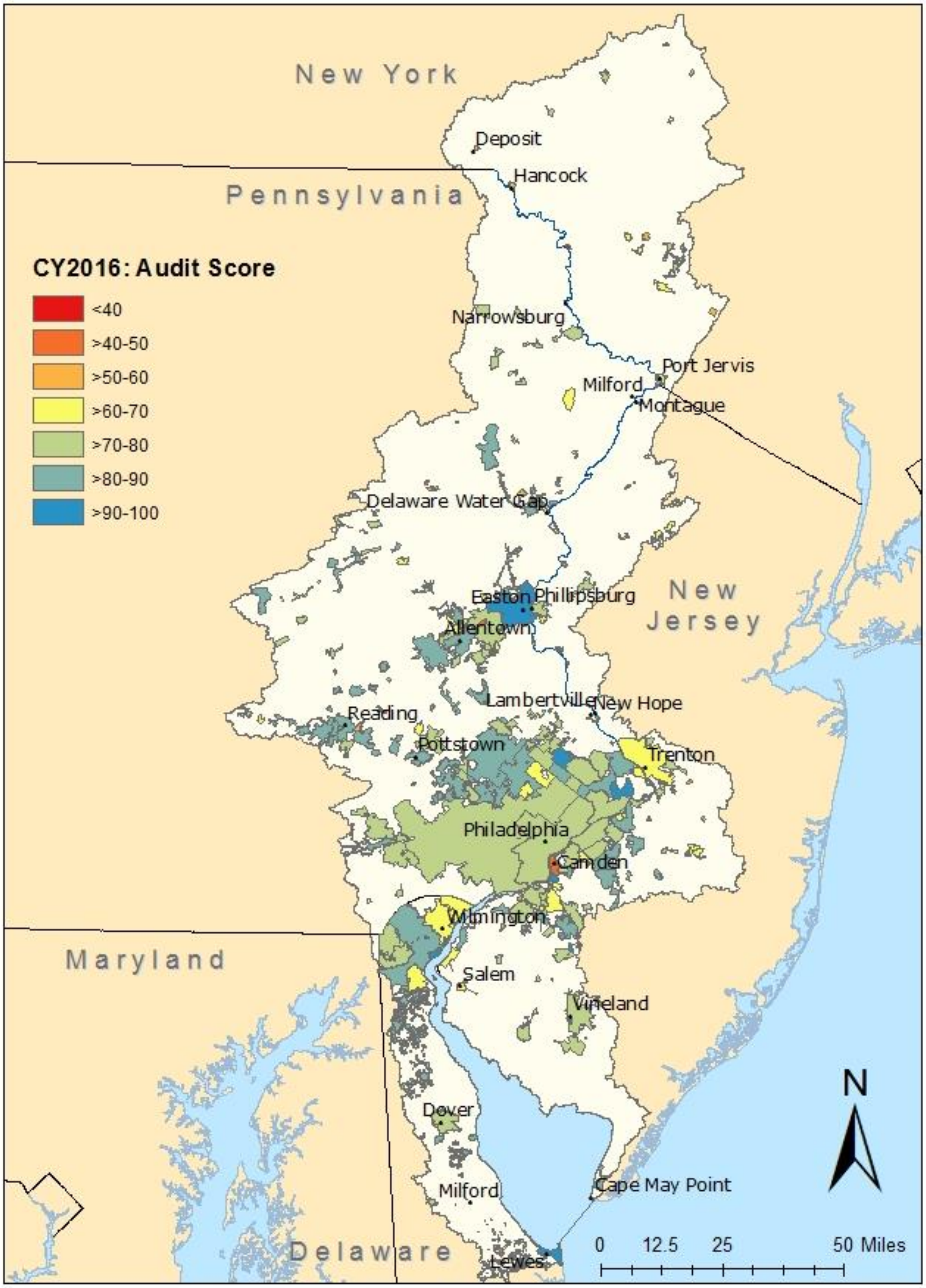
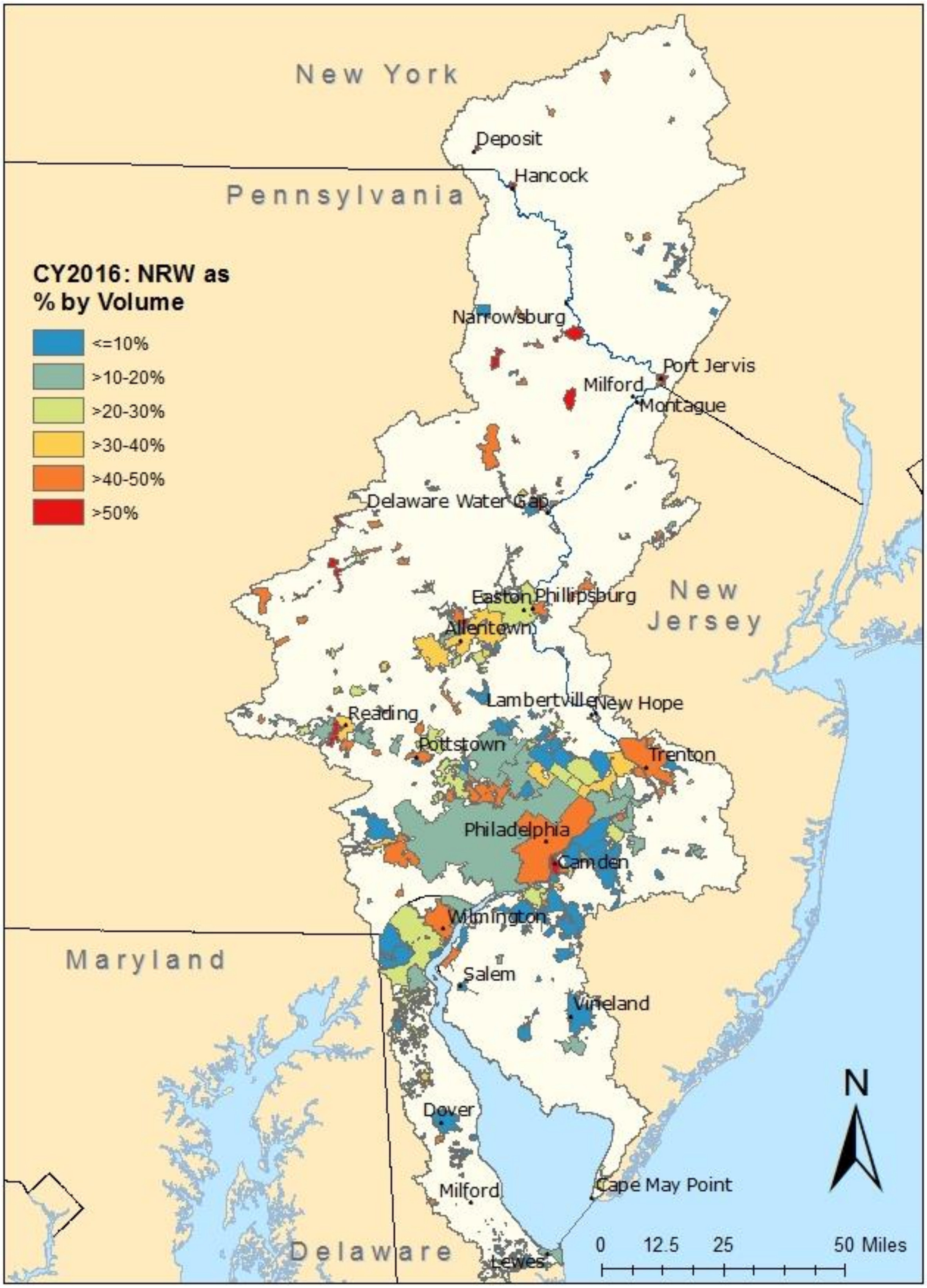
http://www.awwa.org/publications/journal-awwa/abstract/articleid/37425093.aspx AWWA (American Water Works Association), 2009. Water Audits and Loss Control Programs. Manual of Water Supply Practices M36, 3rd ed.

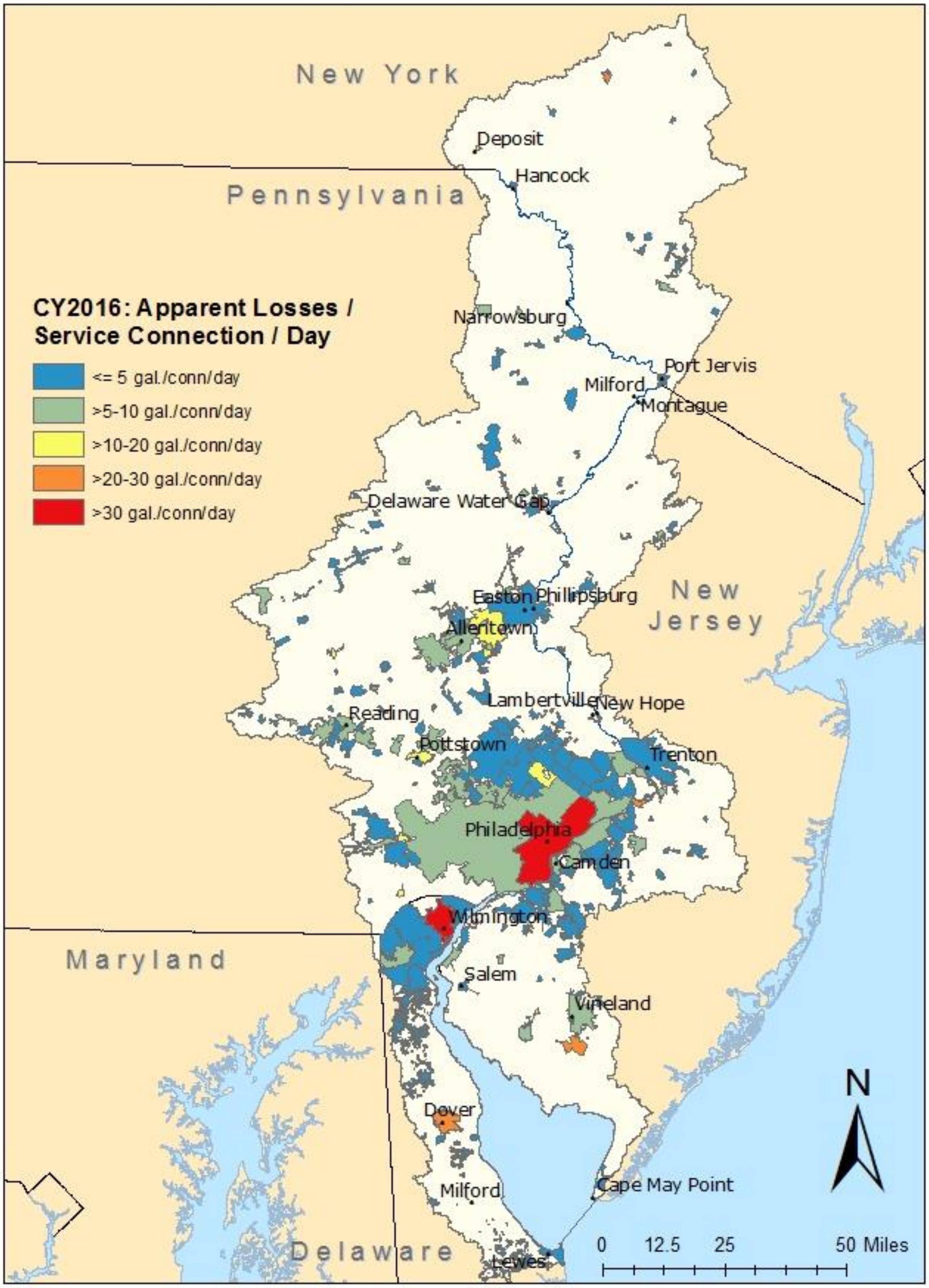
Appendix A: Water System Map of Water Audit Data Validation Scores



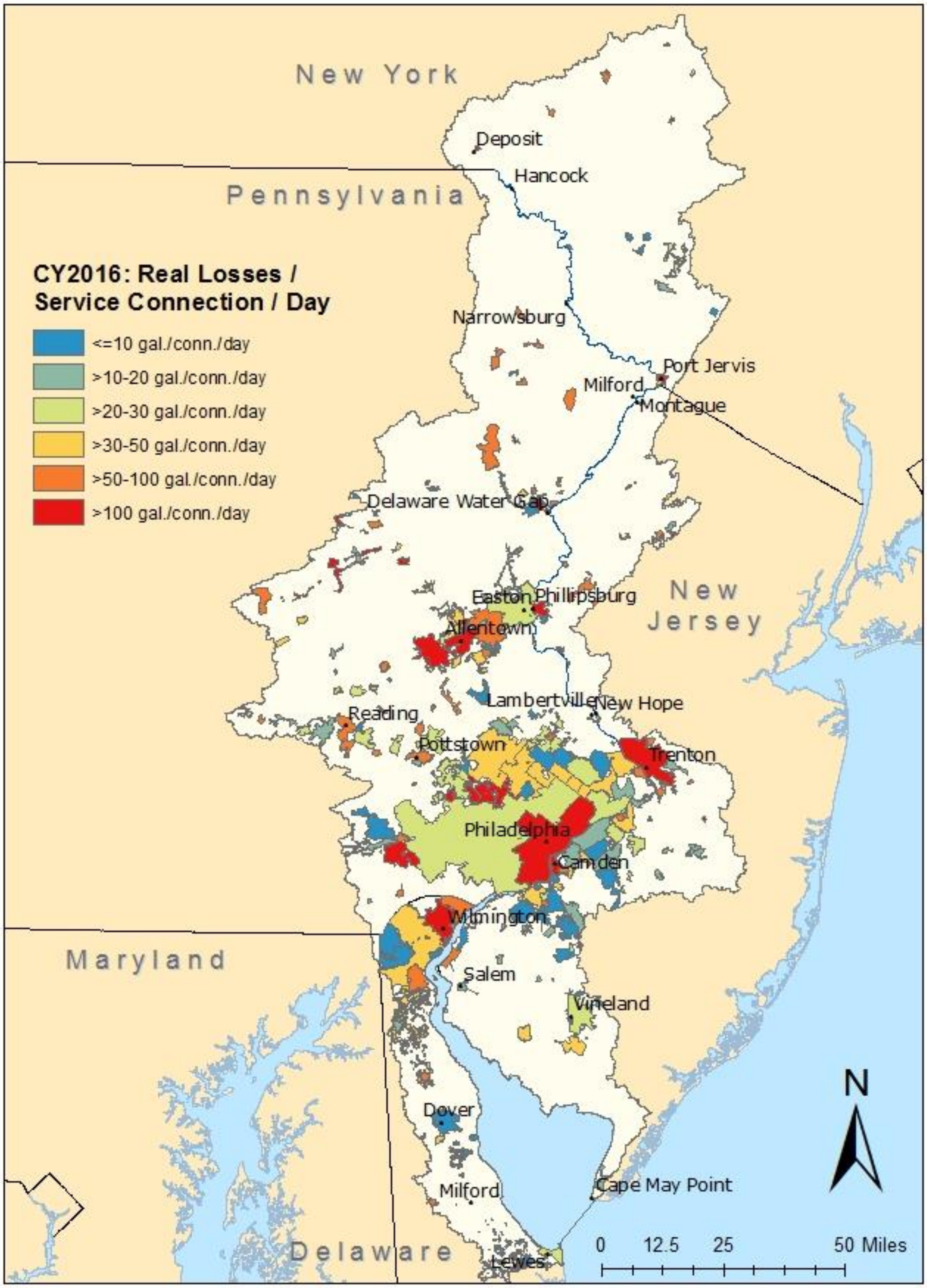
Appendix B: Water System Map of Non-Revenue Water (NRW) Percent by Volume



Appendix C: Water System Map of Apparent Losses reported in Gallons per Service Connection per Day (gal/conn/day)



Appendix D: Water System Map of Real Losses Gallons per Service Connection per Day (gal/conn/day)



Appendix E: Water System Map of Average Operating Pressure in Pounds per Square Inch (psi)