KUNKEL
WATER EFFICIENCY CONSULTING

REPORT ON THE EVALUATION OF WATER AUDIT DATA FOR PENNSYLVANIA WATER UTILITIES

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February 15, 2017

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1. INTRODUCTION

Non-revenue water (NRW) consists of real (leakage) losses and apparent (revenue) losses, and occurs in all drinking water utilities to varying degrees. For many years, water industry efforts to assess and control losses, primarily using “unaccounted-for” water (UAW) terminology, were simplistic and ineffective. Since 2000, work by the American Water Works Association (AWWA) and International Water Association (IWA) produced a rational methodology to assess and characterize losses and their impacts; and innovative technologies have been developed to economically control losses. Progressive work created many useful tools based on the AWWA methodology for auditing water supplies and new methods and technologies to control losses. These best practices are defined in the leading AWWA M36 guidance manual *Water Audits and Loss Control Programs*, 4th ed. (2016) with data collected using the AWWA Free Water Audit Software (FWAS), v5.0 (2014), and AWWA Compiler Software, v5.0 (2014).

In the United States, a number of state and regional water agencies have grasped these methods and tools and have implemented new regulations that require water utilities to audit and report water supply and loss volumes. The Delaware River Basin Commission (DRBC) has a requirement for utility water audit data to be reported by Pennsylvania (PA), New Jersey (NJ), New York (NY), and Delaware (DE) water utilities that exist within the Delaware River Basin. Additionally, PA investor-owned utilities (IOU) must report data in the AWWA FWAS to the Pennsylvania Public Utility Commission (PAPUC). However, the PA Department of Environmental Protection (PADEP) and the Susquehanna River Basin Commission (SRBC), for PA utilities, do not require reporting using the AWWA methodology. Thus, the majority of water utilities in PA are not required to report water audit data in the AWWA format. Hence, inconsistent reporting processes exist across the regulatory agencies that oversee water utilities in PA.

This report discusses the results of work conducted by Kunkel Water Efficiency Consulting (KWEC) to analyze water audit data collected using the AWWA FWAS from PA water utilities, and compare it to AWWA water audit data collected and validated by knowledgeable water auditors in a standardized manner. This account is a companion report to a like assessment conducted by KWEC for water audit data from New Jersey (NJ) water utilities.[1] This report provides a general assessment of the water audit data collected from Pennsylvania water utilities by the DRBC and the PAPUC and compares this data with validated water audit data from the State of Georgia and the AWWA Water Audit Data Initiative

[1] Kunkel Water Efficiency Consulting, *Report on the Evaluation of Water Audit Data for New Jersey Water Utilities*, January 2107.

(WADI). Data is from calendar year 2013; the most recent year of data available from the State of Georgia. This work was conducted under four parts, including:

1. An evaluation of the quality of data used in water audits reported to DRBC and PAPUC and the accuracy of utilities' data validity scores.
2. An evaluation of PAPUC- and DRBC-regulated utilities' reported performance with respect to each component of non-revenue water, in comparison to reported performance of utilities in the validated datasets.
3. An evaluation of PAPUC- and DRBC-regulated utilities' reported performance with respect to system pressure levels and other factors influencing water loss, in comparison to reported performance of utilities in the other validated datasets.
4. Development of estimates of potentially recoverable losses (water, revenue) for PAPUC- and DRBC-regulated utilities and the extrapolation of these estimates to loss levels and recoverable water and revenue statewide.

A summary of the findings of these assessments are listed in Tables 1 and 2:

Table 1 Summary of Findings: Evaluation of 2013 Water Audit Data Reported to the PAPUC and DRBC by 155 Pennsylvania Water Utilities

Parameter	Value
Apparent losses reported	11,220 mg (30.7 mgd)
Estimated economical recoverable apparent losses	8,461 mg (23.2 mgd)
Estimated recoverable annual revenue from economically recoverable apparent losses	$67,033,000
Real losses reported	56,203 mg (154.1 mgd)
Estimated economical recoverable real losses	17,888 mg (49 mgd)
Estimated annual production cost savings from economically recoverable real losses	$10,713,000

Table 2 Estimates of Statewide Losses and Potential Savings

Parameter	Value
Apparent loss estimate – statewide	23,842 mg (65.3 mgd)
Estimated economical recoverable apparent losses – statewide	17,968 mg (49.2 mgd)
Estimated recoverable annual revenue from economically recoverable apparent losses - statewide	$137,637,000
Real losses estimate – statewide	119,313 mg (326.9 mgd)
Estimated economical recoverable real losses -- statewide	37,988 mg (104.1 mgd)
Estimated annual production cost savings from economically recoverable real losses - statewide	$19,754,000

2. THE AWWA WATER AUDIT METHODOLOGY AND DATA VALIDATION

The AWWA water audit is compiled by assembling annual water utility data including the volume of water supplied to the water distribution system and volume of water billed to customers. The difference between these two volumes is Non-revenue water (NRW), which represents an inefficient use of water resources and an inefficiency in the process to charge customers for water service. The water audit also allows the water utility to quantify the sub-components of NRW that are unbilled authorized consumption, apparent (non-physical) losses, and real (physical/leakage) losses. Pertinent costs for system operations and billing are also water audit inputs. Table 3 lists the array of input and output data that are employed in the AWWA water audit, as utilized by the AWWA FWAS.

In 2011 the AWWA Water Loss Control Committee launched an initiative (Water Audit Data Initiative or WADI) that enlisted volunteer utilities willing to compile water audit data, submit it for detailed validation review by the Committee, and allow final posting of the identified data to the AWWA website. The "truthing" of the data in this manner has since become the basis of a formalized data validation process which provides a valuable quality control function on the data reported by water utilities.

Following from this effort, the Georgia (GA) Department of Natural Resources – Environmental Protection Division implemented structured data validation requirements and an established validation process for water audits collected as mandated by the 2010 Georgia Water Stewardship Act. At the present time, data from the AWWA WADI and the State of Georgia are the only two datasets of water audit data that have undergone a formal data validation process, which makes this data more reliable than other data collected in the United States. Starting in 2016, the State of California initiated a data validation requirement for water audit data from over 400 water utilities. This pool of validated data will become available for analysis starting in 2017. Additionally, under Hawaii's recent legislation, all county-run water utilities (about 50 systems) must prepare and submit validated water audit reports beginning with calendar year 2017, to be filed with the state by July 2018, and each year thereafter.

In 2014, the Water Research Foundation (WRF) published the report *Water Audits in the United States: A Review of Water Losses and Data Validity*, Project 4372b, which reviewed water audit data collected by a number of North American water regulatory agencies. The research team for this project established definitions of formal data quality assessments and intervention activities around water loss audits and these are included in Table 4.

Table 3 AWWA Water Audit Method – Water Utility Parameters and Performance Indicators				
Function	Type	Input / Output	Parameter	Description
Volume Inputs	Volume	Input	Volume from Own Sources	Key input parameter
	Volume	Input	Volume from Own Sources / Master Meter and Supply Error Adjustment	Key input parameter
	Volume	Input	Water Imported	Key input parameter
	Volume	Input	Water Imported / Master Meter and Supply Error Adjustment	Key input parameter
	Volume	Input	Water Exported	Key input parameter
	Volume	Input	Water Exported / Master Meter and Supply Error Adjustment	Key input parameter
	Volume	Input	Billed Metered Consumption	Key input parameter
	Volume	Input	Billed Unmetered Consumption	Key input parameter
	Volume	Input	Unbilled Metered Consumption	Key input parameter
	Volume	Input	Unbilled Unmetered Consumption	Key input parameter
	Volume	Input	Unauthorized Consumption	Key input parameter
	Volume	Input	Customer Metering Inaccuracies	Key input parameter
	Volume	Input	Systematic Data Handling Error	Key input parameter
System Information	System Data	Input	Length of water mains	Key input parameter
“	System Data	Input	Number of customer service connections (active & inactive)	Key input parameter
“	System Data	Input	Average length of customer service connection	Key input parameter
“	System Data	Input	Average operating pressure	Key input parameter
“	Cost Data	Input	Total cost to operate the water system	Key input parameter
“	Cost Data	Input	Customer retail cost	Key input parameter
“	Cost Data	Input	Variable production cost	Key input parameter
“	System Attribute	Output	Apparent loss volume	Primary output parameter
“	System Attribute	Output	Apparent loss cost	Primary output parameter
“	System Attribute	Output	Real loss volume	Primary output parameter
“	System Attribute	Output	Real loss cost	Primary output parameter
“	System Attribute	Output	Unavoidable Annual Real Loss (UARL)	A theoretical *reference* level (not a level of leakage)

Audit Data quality	Perf. Indicator	Output	Data Validity Score (DVS)	Strong indicator of data quality of the water audit, particularly if data has been validated
Financial	Perf. Indicator	Output	Non-revenue water percentage by volume	High level *financial* indicator, misleading to use as an operational indicator
"	Perf. Indicator	Output	Non-revenue water percentage by cost	High level *financial* indicator, misleading to use as an operational indicator
Operational	Perf. Indicator	Output	Normalized apparent losses (vol/conn/day)	Sole, but effective, indicator for apparent losses
"	Perf. Indicator	Output	Normalized real losses (vol/conn/day)	Strong indicator for performance tracking by a utility
"	Perf. Indicator	Output	Normalized real losses by pressure (Vol/conn/day/units of pressure)	Same as the indicators immediately above and below, but further normalized by dividing by average system pressure
"	Perf. Indicator	Output	Normalized real losses for low service conn density (vol/length of pipeline/day)	Strong indicator for performance tracking by utilities with a low service connection density
"	Perf. Indicator	Output	Infrastructure Leakage Index (ILI)	Used for benchmarking comparisons, after pressure management has been implemented

The AWWA WADI (25-30 utilities) and State of GA water audit data (~250 utilities) have been validated to Level 1 of the three defined levels of validation rigor. For PA water utility data reported to the DRBC, the data can be considered to exist at the “Filtered” level, since DRBC staff conducts general data screening. However, data collected by PAPUC is considered self-reported since no filtering of the data is conducted. Neither agency has a formal program to require Level 1 validation of the collected water audit data at this time. (Note: a number of PA water utilities report data to both DRBC and PAPUC.)

Table 4 Data Quality Assessments for Utility Water Audit Data (WRF Report 4372b)

Validation Status	Definition
Unvalidated Data	
Self-reported	Water audits have not been subject to an in-depth review. The data is taken as reported by the water utility
Filtered	Water audits have been assessed as a group by the agency for plausibility based upon designated filtering criteria, as well as basic checks to detect implausible data. Flagged audits are referred back to the utility for further review/correction of the inputs.
Validated Data	
Level 1 Validation	Audits have been subjected to a desktop review by a knowledgeable third party, who also evaluates key support documentation.
Level 2 Validation	Audits have been subjected to a desktop review by a knowledgeable third party, with a highly detailed investigation into one or more of the audit input components such as water production data, customer billing data, and customer meter accuracy testing records.
Level 3 Validation	Audits have been subjected to both a desktop review by a knowledgeable third party, complimented with field investigations such as the launching of a customer meter accuracy testing program.

KWEC has undertaken to combine the WADI and GA datasets into a single dataset of 246 water utilities, including 20 utilities of the WADI dataset and 226 systems from GA. (Note: six GA water utilities were included in both the GA and WADI datasets.) This combined dataset includes data for calendar year 2013 since this is the most recent year of data released by GA. Similarly KWEC created a combined PA dataset that includes 2013 data from PA utilities from the DRBC and data from the PAPUC, recognizing that a number of water utilities report data to each agency. The combined PA dataset includes 155 water utilities, including 50 IOUs (31 systems of PA-American Water Company, 18 from Aqua PA, and the York Water Company). PA PUC collects water audit data from more than 50 systems; however, it was found that only PA-American Water Company and Aqua-PA submitted consistent data in the MS Excel format of the AWWA FWAS. York Water Company submitted water audit data in a paper format, but its data was transposed into electronic format for the purposes of this assessment, since this utility is one of the larger water suppliers in PA and has a single service area. A number of IOUs submitted photocopied versions of the water audit to PAPUC, a practice which is not disallowed by PAPUC. Except for York Water Company, these hard-copy audits were not included in this analysis due to the additional workload to transpose all of the data into an electronic format. A valuable improvement in regulatory procedure can be gained by PAPUC by requiring electronic submittal of water audit data by all water utilities. Electronic data can be readily tabulated and analyzed using the AWWA Compiler Tool, and paper records represent a great impediment to efficient data handling and analysis.

By comparing the non-validated data of PA water utilities with the validated data of the combined WADI/GA dataset, KWEC was able to make comparisons of data quality (via the data gradings and Data Validity Score of the AWWA FWAS) and formulated conclusions on the shortcomings of the PA data due to its unvalidated status. (Note: one PA water utility – the Philadelphia Water Department – included validated data since it participates in the AWWA WADI).

3. AWWA WATER AUDIT PERFORMANCE INDICATORS

The AWWA water audit method includes eight key performance indicators (KPI) as shown in Table 3, with additional information presented in Table 5. These KPIs provide financial (two KPIs) and operational (five KPIs) evaluations of the audited water utility. Additionally, the Data Validity Score (DVS) characterizes the quality of the data entered into the water audit worksheet. These KPIs can be used for both performance tracking (monitoring changes within the water utility on a year-to-year basis) and benchmarking (making like comparisons among water utilities).

In addition to the KPIs the AWWA water audit compiles data on system attributes and costs, which provide valuable information about the water utility and are most appropriate for performance tracking within the water utility. Certain parameters can be used to make utility-to-utility comparisons; however, additional insight can be gained by making such comparisons among peer systems, or systems of a similar size and scale of data. North American water utilities exist in a wide range of system sizes and attributes, with widely varying system average pressures, costs, and other characteristics. Thus, it is insightful to create small groups of utilities with similar system size in order to compare system data, costs, and attributes directly. It is also possible to chart this data in summary manner for large groups of data in order to display the range of values that exist for North American water utilities.

Table 5 Performance Indicators of the AWWA Water Audit Method

Presentation	Units (for USA utilities)	Purpose
Normalized Apparent Losses	Gal/serv conn/day	used for utility performance tracking of apparent loss standing over time
Normalized Real Losses	Gal/serv conn/day	used for utility performance tracking of real (leakage) loss standing over time (this form is for water utilities that do not have a low customer service connection density)
Normalized Real Losses	Gal/mile of main/day	the same KPI as the above, but in an appropriate form for utilities with a low customer service connection density
Normalized Real Losses per pressure level	Gal/serv conn/day/psi of pressure Gal/mile of pipeline/day	a KPI to track leakage management for water utilities that is additionally normalized by dividing the value by the average distribution system pressure. Two forms exist: a standard form and the second form for utilities with a low service connection density.
Infrastructure Leakage Index (ILI)	Dimensionless ratio of Current Annual Real Losses (from water audit) over the Unavoidable Annual Real Loss (UARL) which has a standard calculation.	a benchmarking indicator used to compare leakage standing across water utilities. This KPI is most appropriate for use after any pressure management improvements have been conducted in the distribution system. Note: this KPI is not workable for very small water systems; thus a value of ILI is not calculated for these systems in the AWWA Free Water Audit Software.
Date Validity Score (DVS)	Score ranging 1-100	A number representative of the overall quality – or trustworthiness – of the data input into the water audit. The DVS should be scrutinized through the lens of the validation conducted on the water audit. The DVS for self-reported, or unvalidated data, may not be as credible as the DVS for water audit data that has been validated to at least Level 1.
Variable Production Cost	$/million gallons	a system attribute that represents the costs to produce the water; typically including costs for water treatment and electricity for pumping operations, and related supply costs. This unit cost is typically applied to the volume of real losses to determine the cost of the annual leakage volume. The Variable Production Cost may also be the cost of bulk Imported Supply.
Customer Retail Unit Cost	$/1,000 gallons	a system attribute that is a composite of the various water rates and charges, at different tiers, that a utility charges its customers (for those utilities that charge for water service based upon the volume consumed.) This unit cost is applied to the volume of apparent losses to determine the total cost attributed to apparent losses in the system. This total cost represents the amount of uncaptured revenue in utility billing operations due to apparent losses.

DRBC has conducted analyses of collected water audit data and stratified utility data by system water production. DRBC established five levels of stratification. Due to time limitations, KWEC did not undertake direct comparisons of system data, cost data, and system attribute data using peer-system comparisons. Further analysis of the data of the PA Dataset using comparisons among peer systems is an initiative that can be considered in the future.

KWEC instead keyed upon making comparisons using the normalized performance indicators and the unit costs of the utilities. Most of the AWWA performance indicators are normalized values which monitor a parameter that is divided by a size-related parameter (such as number of customer service connections or length of pipeline). The normalized KPIs can be compared across the range of system sizes. Note that the normalized real loss indicator has two forms, one that applies generally, and one that applies to systems with a low customer service connection density.

4. FOCUS OF THE ANALYSIS – COMPARING WATER AUDIT DATA OF PA WATER UTILITIES WITH THE COMBINED AWWA WADI/STATE OF GEORGIA DATASET

The primary work of this study was to provide a general assessment and comparison of the water audit data collected by PA water utilities (**PA Dataset**) vs. data from water utilities across North American (**NA Dataset**). The water audit data of the PA Dataset was gathered by the Delaware River Basin Commission (DRBC) and the Pennsylvania Public Utility Commission (PAPUC). The NA Dataset was collected by the State of Georgia Department of Natural Resources – Environmental Protection Division and the AWWA Water Audit Data Initiative (WADI). All data was submitted in the AWWA Free Water Audit Software (FWAS) and is from calendar year 2013 (most recent year of published data from GA). The charts presented herein are in US customary units and in US dollars. Units for customer retail rate are in $/1,000 gallons rather than $/1,000 cubic feet, for consistency in the water utilities in the datasets.

Data presentations (charts) show values of all of the utilities in the datasets; utilities are anonymized. Median values of the utility data are shown, along with 90th percentile values (the level at which 10% of the values are higher). Average values are not shown since averages can differ notably from the median if extreme values exist in the data. The median is a better indicator of central tendency in this data.

The analysis work included four sub-components (Parts 1-4) and findings for each are presented below.

Part 1: Data Validity

Figure 1 plots the Data Validity Score (DVS) from the AWWA FWAS for the utilities of the NA Dataset.

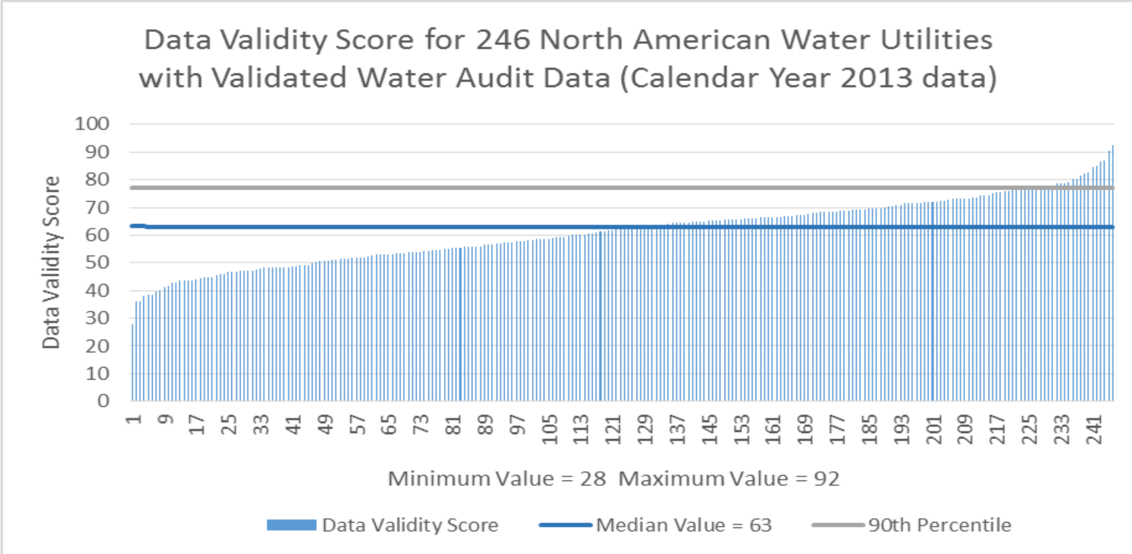

Figure 1 Data Validity Score (DVS) for NA Dataset

Figure 2 plots the (DVS) the utilities for the PA Dataset. The NA Dataset's median value of 63 is notably less than the PA Dataset median value of 80. Water auditing practitioners have consistently observed that self-reported (unvalidated) water audits contain higher water audit data gradings and higher Data Validity Scores than validated data. This was also confirmed in research report *Water Audits in the United States: A Review of Water Losses and Data Validity*, published by the Water Research Foundation. Data validation, a quality control process, usually results in reduced gradings since it finds that a notable amount of self-reported water audit components are graded at overly-generous levels by utility auditors. **This notable difference in median DVS values serves as a strong illustration of the need for data validation in Pennsylvania**.

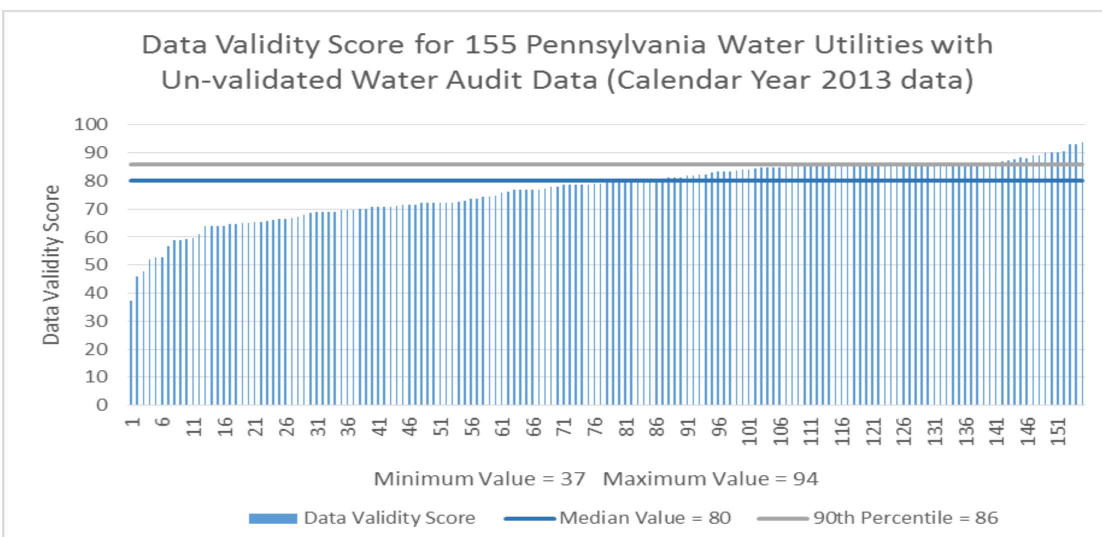

Figure 2 Data Validity Score (DVS) for PA Dataset

An additional observation regarding data grading found that one IOU (PA-American) graded 31 PA water systems within its company exactly the same in all components, thereby calculating a DVS of 86 for all systems. While PA-American likely does manage a number of utility functions in a consistent manner across all of its separate service areas, it is highly unlikely that all of these separate systems can substantiate the same grading for all of its water audit inputs. The relatively high DVS of 86 is likely over-stated and a data validation process would result in lower DVS values for most of these systems. Note also, that Aqua-PA, which also operates many separate water systems across PA in the same manner as PA-American, did not have identical gradings for all of its systems.

Two additional checks on data quality were conducted by noting either the absence of key values from the annual water audit, and the input of extreme values. The primary area reviewed in this manner included the cost components. For the Variable Production Costs (VPC), 12 water utilities failed to include any value in the water audit software and another 12 reported unrealistically low values of less than $10.00 per million gallons. For the latter, it is conceivable that these low values were reported in error with regard to the units requested, with the utilities providing a number in $/1,000 gallons instead of the required $/million gallon. The values are then under-reported by three decimal places. Seventeen utilities (mostly small systems) of the Aqua-PA network of systems reported the *same* production cost of $520/mg. While Aqua-PA likely performs cost tracking on a global basis for all of its systems, each distinct water system is unique and an individual VPC should be calculated for each system.

Regarding the Customer Retail Unit Cost (CRUC), four small systems failed to report this number in the water audit software. All four may be water systems that supply “developments” or grouped communities of homes or resort properties that perhaps do not bill customers based upon the volume of water consumed. Instead property owners in these communities may pay for water through a periodic fixed fee included in a community owners fee, or similar fee.

It is fortunate to note that all utilities in the PA Dataset reported a value in the water audit software for the Total Cost of Operating the Water System. All water utilities in the dataset also reported a value for the Volume from Own Sources and/or Water Imported and Authorized Consumption. However, one system reported such an unrealistically low volume of Authorized Consumption such that virtually all of its supply is calculated to be Non-revenue water. Again, it appears that this system may be a resort community that bills customers on a fixed basis and does not tally customer consumption based upon billed, metered volumes.

As a final observation, it is noted that over half of the PA utilities report a very low or zero value of Systematic Data Handling Error, which illustrates that water utilities do not have a strong understanding of the meaning of this component, and, perhaps, are not very engaged with their customer billing operations. The current version 5.0 of the AWWA FWAS includes the option to enter a default quantity for this component, so utilities should now be better populating this field. A default value was not available for the utilities in 2013, when Version 4.2 of the AWWA Software was in use, and the subject data was compiled.

Part 2: Non-revenue Water Comparisons

Apparent Losses**:** Figure 3 plots the value of apparent losses as measured by the Apparent Loss performance indicator in units of gallons/service connection/day for the NA Dataset while Figure 4 gives the same presentation for the PA Dataset.[1] The median volume of apparent losses for the NA Dataset is 5.77 gal/connection/day, while the median volume for the PA Dataset is 4.58 gal/connection/day. It has been the author's observation that the concept of apparent losses is not well understood by most water utilities. Systems who have not obtained training in the water audit process or have had their water audit validated tend to report relatively low apparent losses, often applying the default values of the AWWA FWAS. This results in a likely understatement of the actual amount of apparent loss occurring in the water utility.

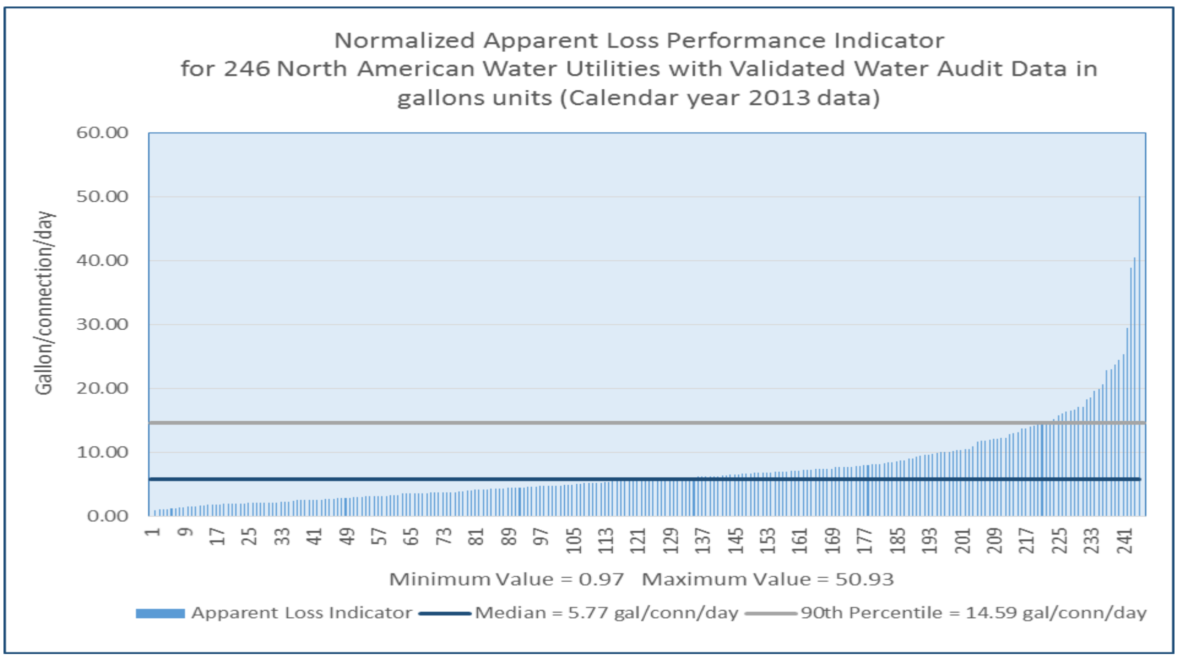

Figure 3 Normalized Apparent Losses for NA Dataset

[1] Dividing a utility's losses by the number of service connections in its system allows for more useful evaluation of water loss volume data from both large and small utilities.

Unfortunately, due to the calculation of real losses as a "catch-all" in the AWWA FWAS, when apparent losses are under-stated, then the real loss volume calculated by the Software is over-stated. The findings that the apparent loss volumes of the PA Dataset are less than the NA Dataset confirm that many PA utilities have likely under-stated their apparent losses. This stems from a lack of formal training of utilities in the water audit process, and lack of validation of water audits. One PA utility was excluded from this presentation due to an inordinately high normalized apparent loss value. However, this high value is considered an outlier since the water utility reported only 4 customer service connections.

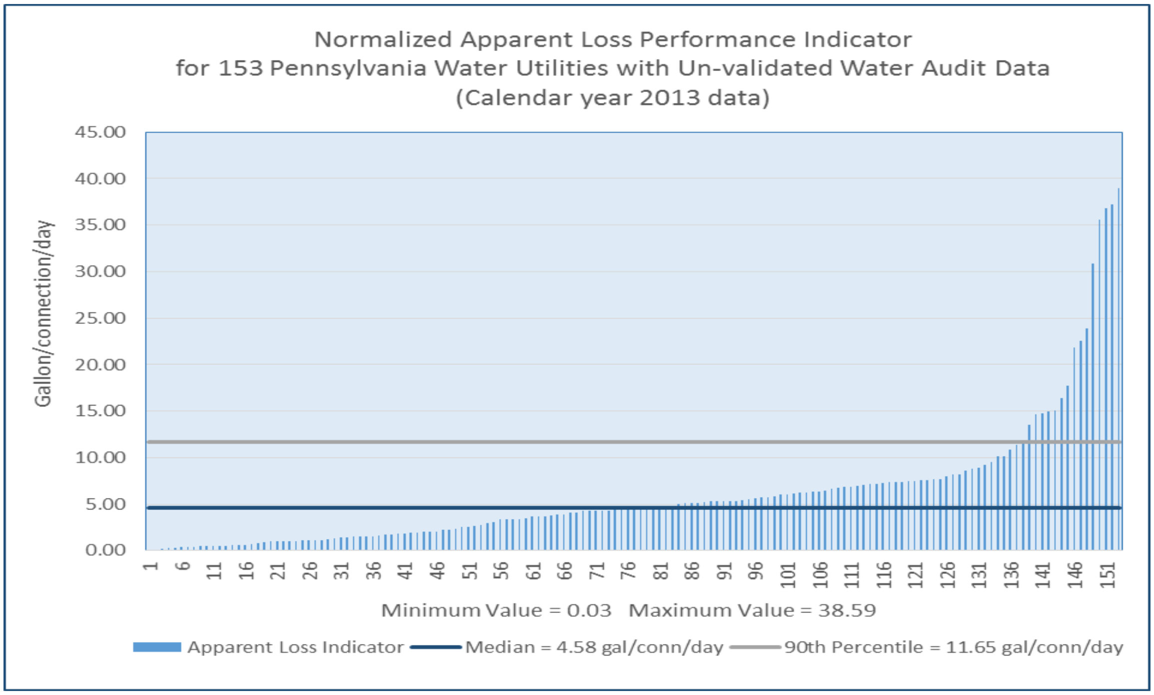

Figure 4 Normalized Apparent Losses for PA Dataset

Real Losses**:** Figure 5 plots the value of real losses as measured by the normalized real loss performance indicator in units of gallons/service connection/day for the NA Dataset while Figure 6 gives the same presentation for the PA Dataset. The median value for the NA Dataset is 43.30 gal/connection/day, while the median value for the PA Dataset is notably lower at 35.71 gal/connection/day. As noted above, apparent losses for PA utilities are likely to be under-stated, thus leakage losses are likely to be over-stated. Thus, PA utilities may have a median normalized leakage rate that is below 35.71 gal/conn/day. This is a notable difference in median leakage rates and suggests that PA water utilities are not suffering leakage rates as high as utilities in the NA Dataset.

However, there are many unknowns about the occurrence and management of leakage in the water utilities of the two datasets, thus it is difficult to make a distinct conclusion on the leakage rate of PA utilities. Still, the lower rate in PA relative to the NA Dataset is notable. One PA utility was excluded from Figure 5 because it did not enter a number of customer service connections.

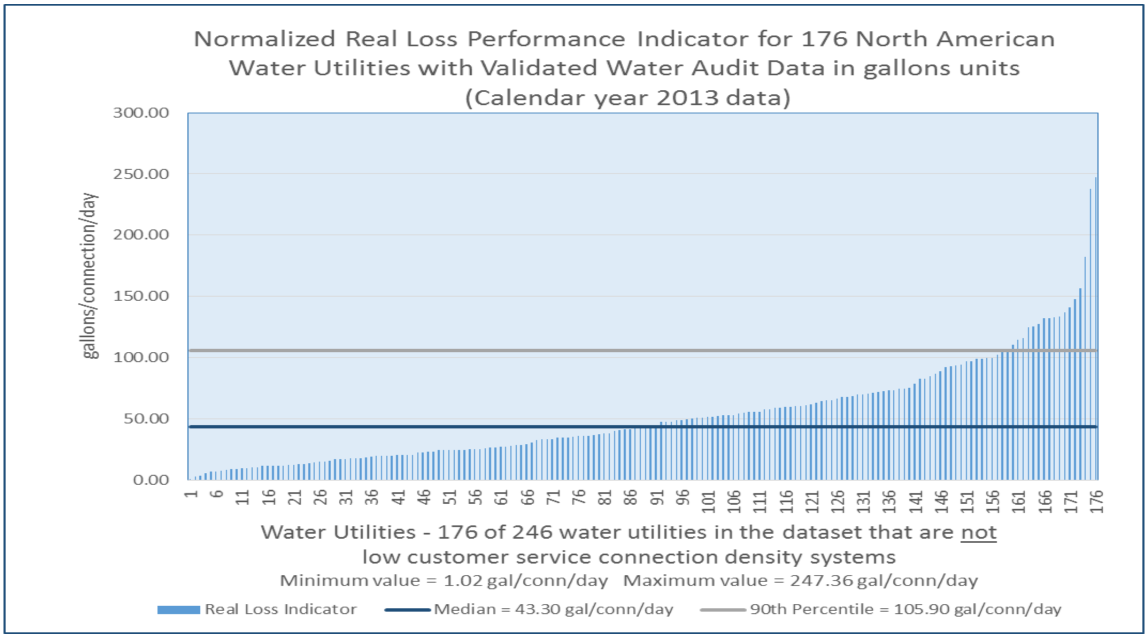

Figure 5 Normalized Real Losses for NA Dataset

(High Customer Service Connection Density Systems)

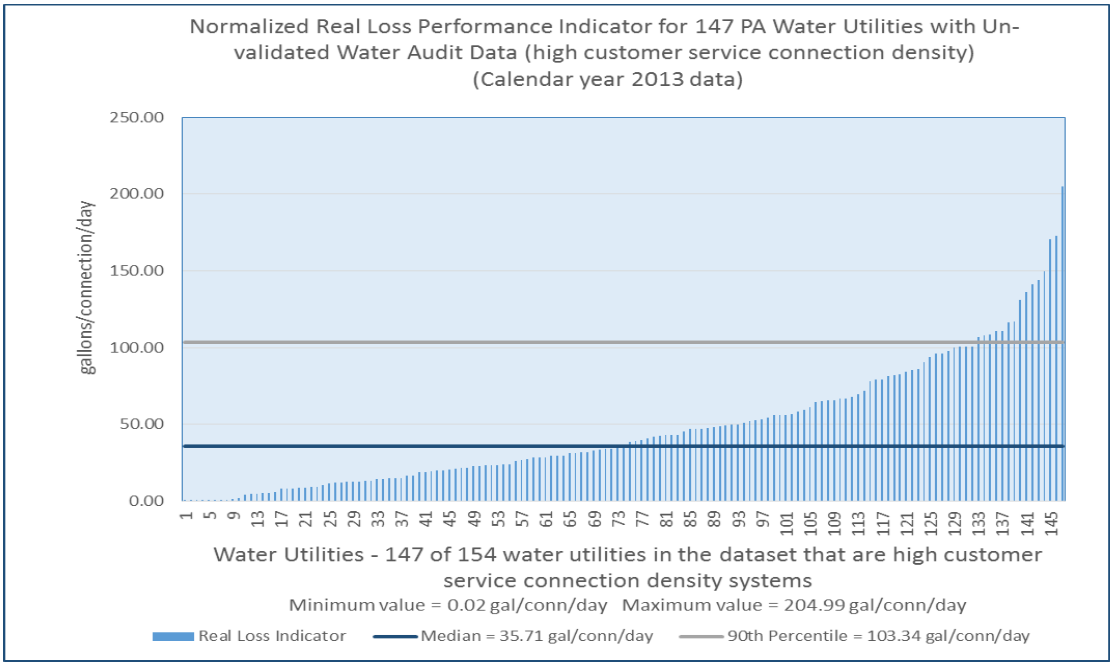

Figure 6 Normalized Real Losses for PA Dataset

(High Customer Service Connection Density Systems)

Figure 7 plots the value of real losses for low service connection density utilities as measured by the Normalized Real loss performance indicator in units of gallons/mile of pipeline/day for the NA Dataset while Figure 8 gives the same presentation for the PA Dataset. The median value for the NA Dataset is 1,091.5 gal/mile of pipeline/day, while the median value for the PA Dataset is 2,292.2 gal/mile of pipeline/day.

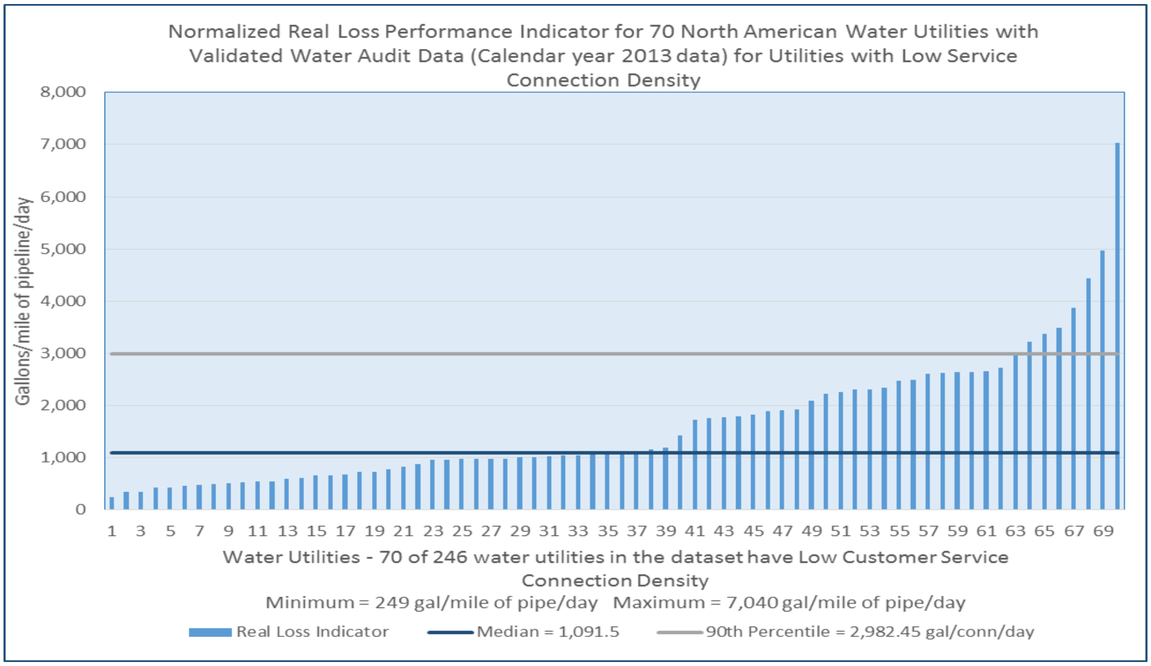

Figure 7 Normalized Real Losses for NA Dataset

(Low Customer Service Connection Density Systems)

The median value of normalized real loss for low density utilities in PA is more than double that of the low density systems in the NA Dataset. However, the fact that only seven systems are included in the PA Dataset means that sample size of the PA data is too small to draw a meaningful conclusion. PA has many very small systems that would be categorized as low density systems as per the AWWA FWAS. Unfortunately most of these systems do not currently compile an annual water audit using the AWWA FWAS. More data from PA low density systems is needed to make a reliable comparison between the NA Dataset and the PA Dataset for these systems.

Variable Production Costs (VPC)**:** In addition to assessing normalized loss levels, KWEC also undertook a comparison of costs. These included the two unit costs compiled in the water audit process: the Variable Production Cost (VPC) and the Customer Retail Unit Cost (CRUC). The VPC of the NA Dataset is shown in Figure 9 and the PA Dataset shown in Figure 10.

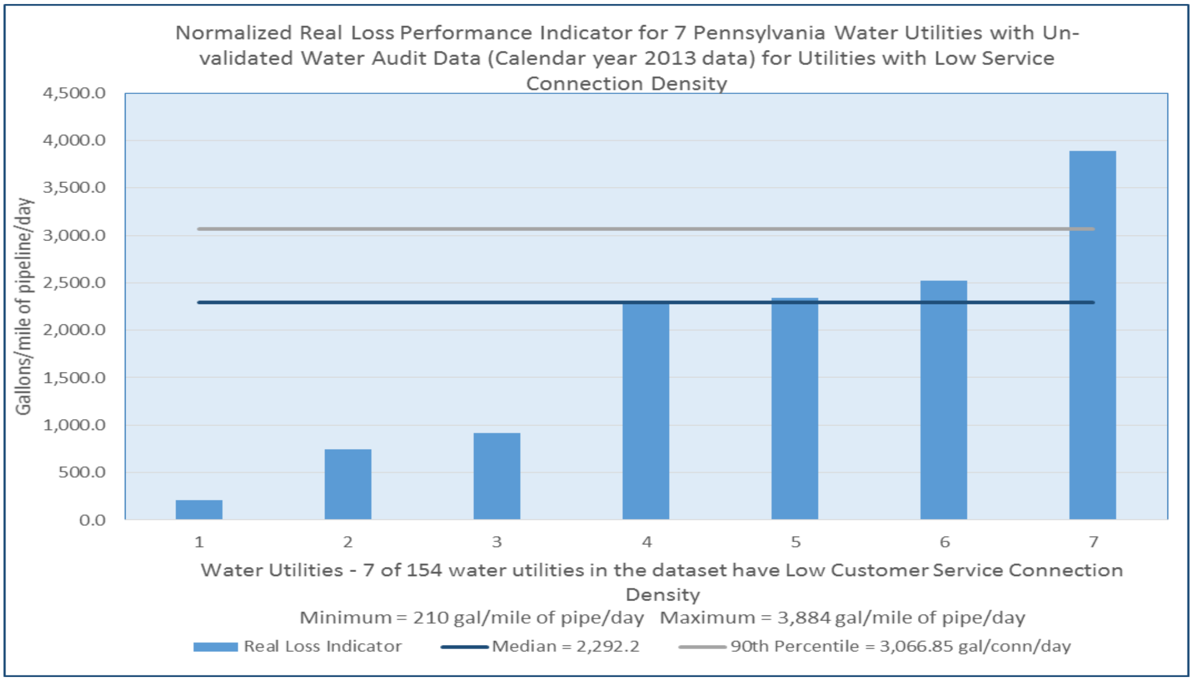

Figure 8 Normalized Real Losses for PA Dataset

(Low Customer Service Connection Density Systems)

The median value VPC for the NA Dataset is shown as $425.60 for the NA Dataset in Figure 9 and the median value VPC for the PA Dataset is shown as $520.00 for the PA Dataset in Figure 10. Thus it appears that the costs to treat and distribute water in PA water utilities are notably higher than the cost of the NA Dataset.

Several caveats in the PA data are worth noting, however. The median value for the PA data is $520.00/mg, which is the same cost that Aqua-PA assigned as VPC for 14 of its systems included in the PA Dataset. Using the same cost for each separate system over-simplifies the water audit process since the cost to produce water is unique for each water system. The other large IOU in the PA Dataset - PA-American Water Company – included a wide range of VPC values for its systems, which is representative of the different costs to produce water at each unique system. Despite the use of the same value by Aqua-PA for many of its systems, this value resides at the median of the dataset and is not a high value.

A strong factor in elevating the median VPC of a dataset is the presence of utilities that provide all of their water supplied volume as purchased imported water. The PA Dataset features five such water utilities and the median VPC value of these systems is $3,154.73/mg. Imported water is always costly, relative to utilities that are self-supplied. The greater the number of systems that fully rely on imported supplies, the higher the median VPC will be in the dataset.

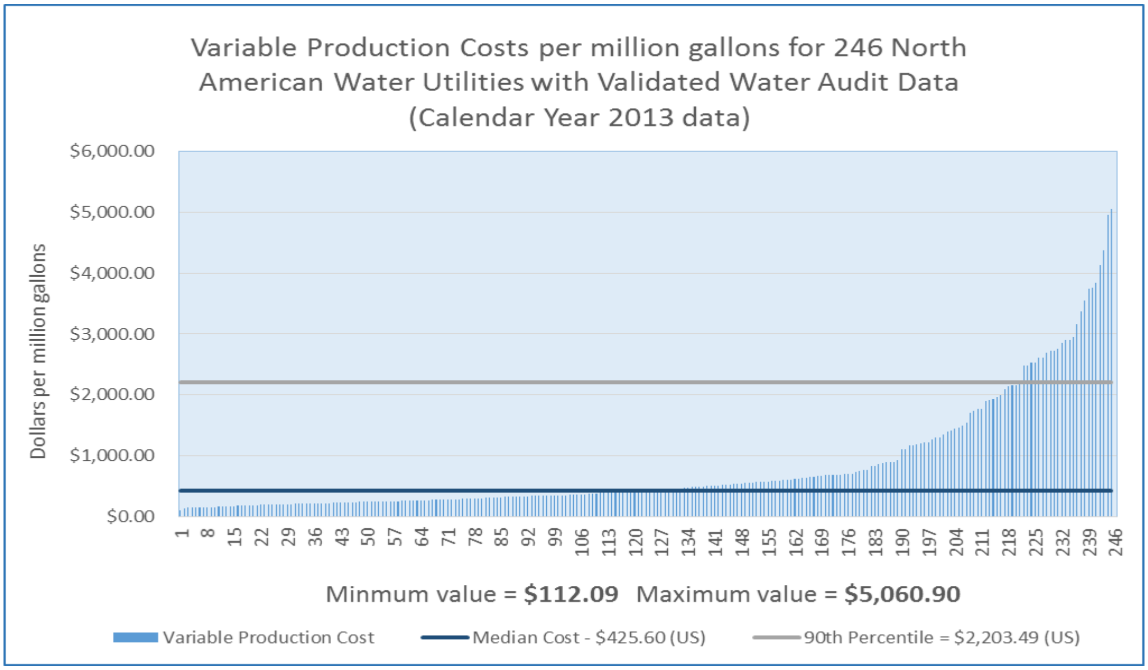

Figure 9 Variable Production Costs (VPC) for utilities in the NA Dataset

While the NA Dataset includes water utilities from across North America, close to 90% are from the State of Georgia. If Georgia production costs are notably lower than most of the US, then the VPC of the NA Dataset may be low, and perhaps the PA Dataset is more of an average value. Still, the higher the VPC the stronger the economic incentive for water utilities to address leakage losses. Thus PA water utilities appear to have strong economic incentive to cut their leakage.

Customer Retail Unit Cost (CRUC): The median value CRUC for the NA Dataset is shown as $4.16/1,000 gallons for the NA Dataset in Figure 11, with the PA Dataset median value shown as $7.66/1,000 gallons in Figure 12. Thus it appears that the costs that water utilities charge their customers in PA well exceed the median costs of the utilities in the NA Dataset.

Several caveats in the PA data are worth noting, however. The maximum CRUC in the PA Dataset is a very high value of $39.00/1,000 gallons, with two other utilities above $20.00/1,000 gallons. The trustworthiness of these values is questionable, particularly since the PA data is un-validated. Also, the 90th percentile value for the PA data is $13.98/1,000 gallons, which is the same value that Aqua-PA assigned as CRUC for 17 of its systems included in the PA Dataset. Similarly, PA-American Water Company listed a CRUC of $9.10/1,000 gallons for all 31 of its systems within the PA Dataset.

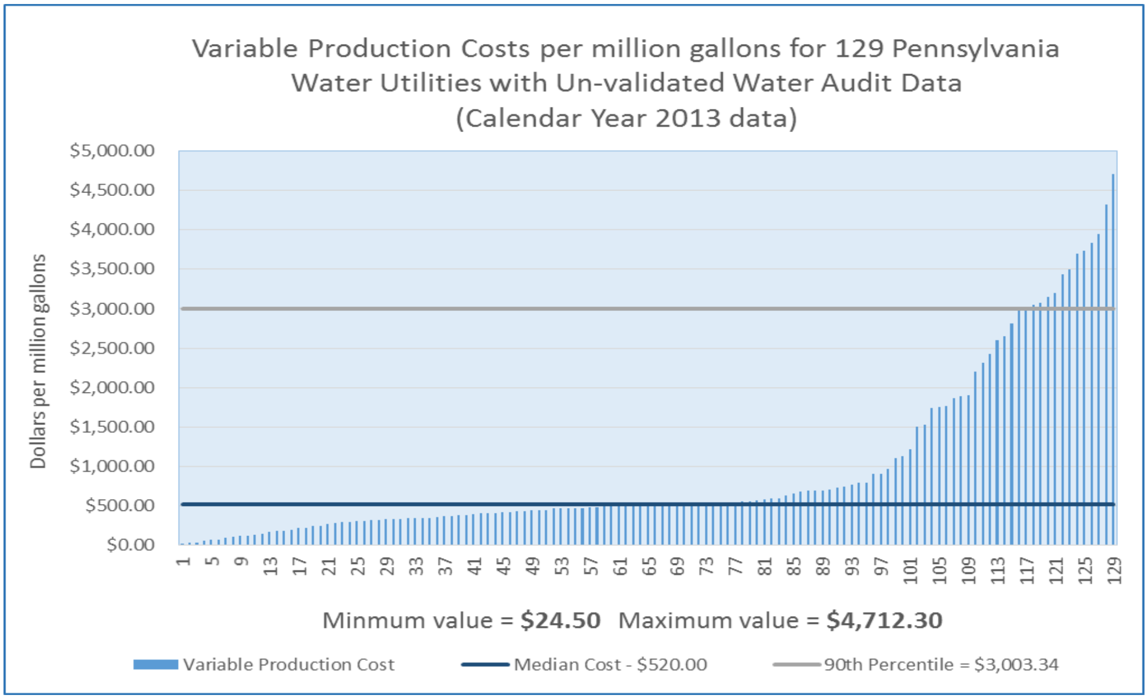

Figure 10 Variable Production Costs (VPC) for utilities in the PA Dataset

These CRUC for the two large IOUs in PA (Aqua-PA and PA-American) are notable because of the higher range of these costs but also, with 48 of their systems existing in the PA Dataset, they have a strong effect in increasing the median value of the dataset upwards. This heavy influence of IOUs in the PA Dataset would be expected to be greatly diluted if the PA Dataset were greatly expanded to include many more of the Commonwealth's water utilities. It may be likely that many of PA's small water utilities who are not included in the PA Dataset have CRUC that are notably less than the median value of the PA Dataset; thus a larger dataset will likely result in a lower median CRUC for PA utilities.

The CRUC represents the rates charged to customers for water service and for any other services that are billed by the volume recorded on the water meter, such as sanitary sewer service. The CRUC is also used to assign the cost value to the volume of apparent losses occurring in the utility. Missed billings due to customer metering inaccuracies, unauthorized consumption, and systematic data handling errors result in under-recovery of retail charges by the water system. Thus, the higher the CRUC, the stronger the financial incentive for water utilities to address apparent losses.

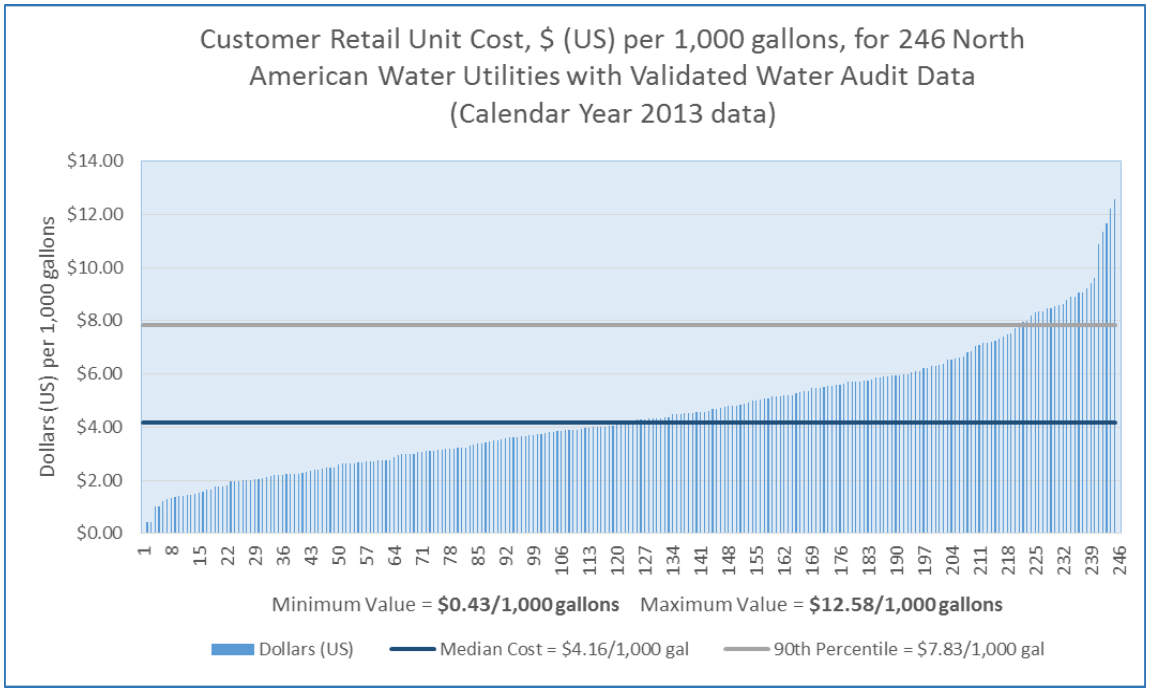

Figure 11 Customer Retail Unit Costs (CRUC) for utilities in the NA Dataset

PA water utilities appear to have strong financial incentive to reduce apparent losses and recover additional revenue. Finally, with every rate increase enacted by a water utility, the cost rate of the apparent losses also increases. For those customers who are under-paying (or not paying at all) due to apparent losses, the paying portion of the customer population must shoulder a growing proportion of the revenues ultimately collected by the water utility.

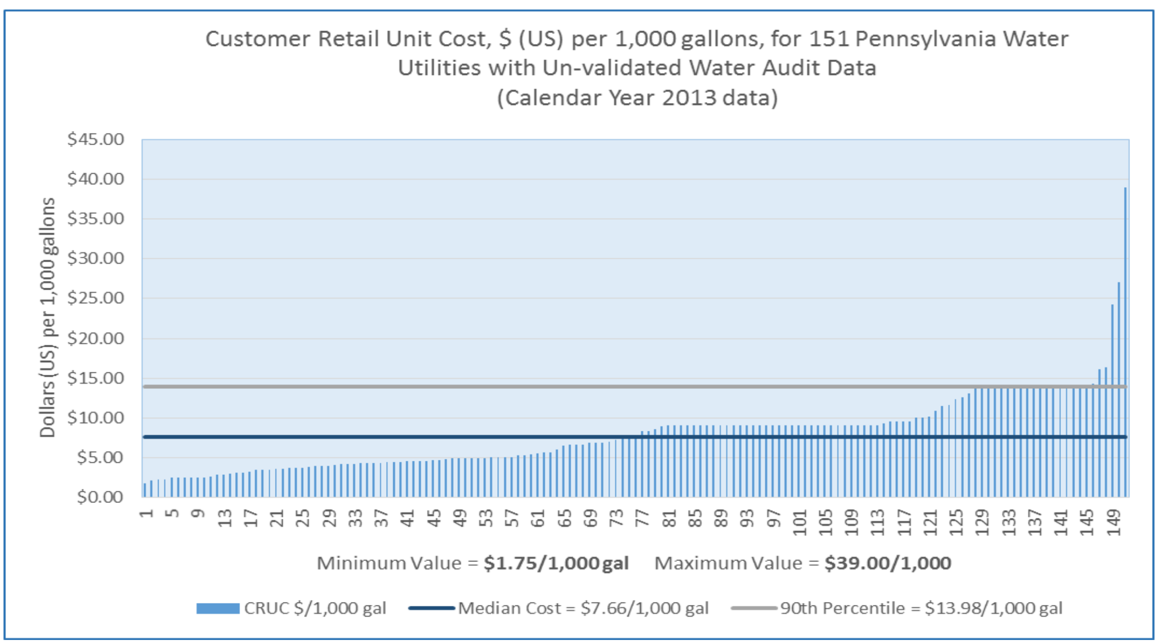

Figure 12 Customer Retail Unit Costs (CRUC) for utilities in the PA dataset

In summary a comparison of apparent and real losses of utilities in the PA Dataset and NA Dataset found lower loss rates for PA utilities for apparent losses and real losses for high customer service density systems than the utilities of the NA Dataset. It was not possible to draw a reliable comparison of real loss rates for low customer density utilities since the number of PA utilities (seven) is too low to serve as a representative sample. Since the NA dataset is a validated dataset and the PA dataset is not, the lack of validation is a distinct factor that may influence the comparisons. The possibility exists that lower apparent and real losses reported for PA utilities may be due to the fact that the data has not been "truthed" through the data validation process. Just as gradings are often over-stated in self-reported data, losses may be under-stated in self-reported data. A notable finding is that costs in PA utilities – both VPC and CRUC – are higher than the NA Dataset. While the cost data is also un-validated and may include some questionable values, the fact that reported costs are high in PA provides a strong economic incentive for PA water utilities to control both real and apparent losses to economic levels.

Part 3: Pressure Levels as a Factor Influencing Water Loss

System Pressure: Many factors have an influence on the occurrence of NRW in water utilities. Of the 18 inputs required by the AWWA FWAS, perhaps the most influential factor in leakage levels is the average pressure level. KWEC examined pressure levels in the NA and PA Datasets and these are discussed below.

Average water pressure data presentations are given in Figure 13 and Figure 14 for the NA Dataset and PA Dataset, respectively. Figure 13 shows the NA Dataset with a median average system pressure of 70 psi and a 90^{th} percentile value of 105.75 psi. Figure 14 shows the PA Dataset with very similar statistics with a median average system pressure of 75 psi and a 90^{th} percentile value of 100.00 psi.

The "Ten State Standards" (Water Supply Committee of the Great Lakes–Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers *Recommended Standards for Water Works*), stipulates that water systems "shall be designed to maintain a minimum pressure of 20 psi at ground level at all points in the distribution system under all conditions of flow." Additionally, the program specifies that the normal working pressure in the distribution system should be "approximately 60 to 80 psi and not less than 35 psi."

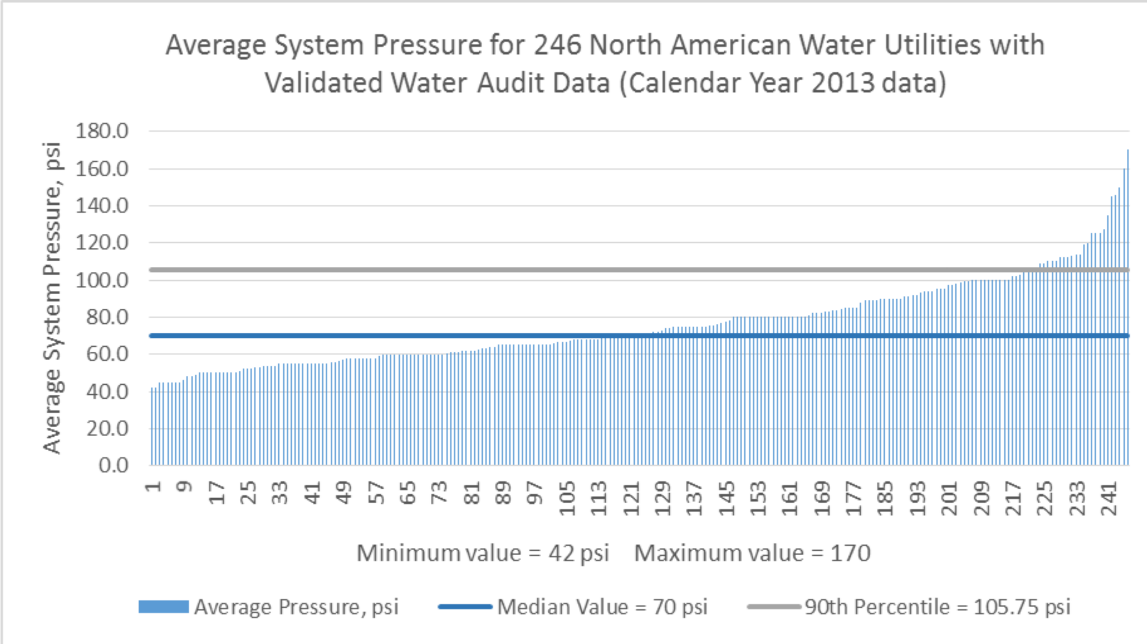

Figure 13 Average Pressure for the NA Dataset

Systems with areas of pressure routinely falling below 35 psi may have difficulty providing reliable supply to buildings at higher elevations under all conditions and may struggle to fully meet local fire flow requirements. No utilities in either dataset have an average pressure under 40 psi, a finding which affirms the widely held perception within the water industry that most US water utilities are successful in exceeding minimal pressure guidelines.

For systems with pressures above 80 psi, pressure reducing valves may be needed on customer service lines to prevent damage to customer plumbing, hot water heaters, and other customer devices. In the same vein, water distribution systems operating with pressure levels notably higher than 80 psi may encounter a greater opportunity for high leakage and rates of ruptures on water distribution piping. The AWWA Partnership for Safe Water *Self-Assessment Guide for Distribution System Optimization* flags water pressure levels above 100 psi as noteworthy.

In assessing the AWWA Partnership for Safe Water action level of 100 psi, it is interesting to note that 39 of 246 utilities in the NA Dataset (~16%) have an average pressure of over 100 psi. With an average system pressure over 100 psi, utilities will also have a portion of their distribution piping operating at a pressure of well over 100 psi, and these areas of distribution piping are very susceptible to increased leakage and accelerated water main breaks. Very similar to the NA dataset, 26 of 154 utilities in the PA Dataset (~17%) have an average pressure of over 100 psi. In focusing advocacy efforts on improved pressure management, efforts could initially key on the "one-in-six" water utilities that have considerably high average pressure levels at or over 100 psi.

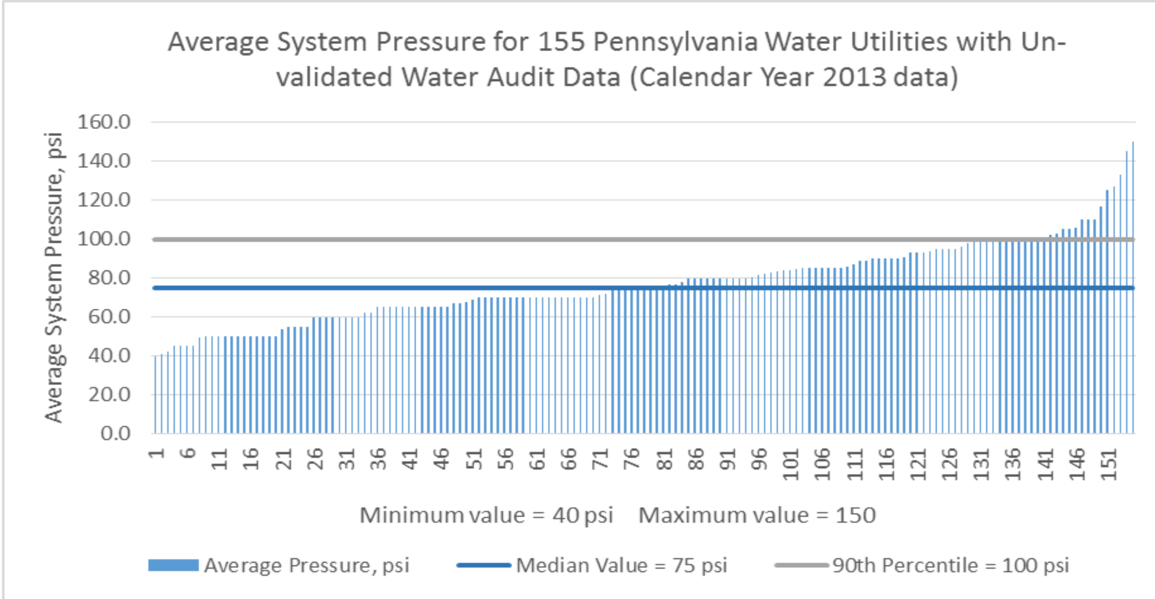

Figure 14 Average Pressure for the PA Dataset

The drinking water industry has well-established guidelines for minimal pressure levels and water utilities have been largely successful in designing and building water infrastructure that meets or exceeds these guideline minimal levels. Unfortunately, the water industry does not have in place sufficiently definitive maximal pressure level guidelines, and water infrastructure designs seemingly rarely take into account the long-term operational risks of having system pressures at high pressures of over 100 psi. Pressure management has been found to be a highly effective means of economically controlling leakage and slowing the rate of water main ruptures, thereby extending infrastructure life and deferring renewal and rehabilitation of assets prematurely. Unfortunately in North America, the negative impacts of water pressure are not widely known and pressure management is greatly under-utilized. A stronger focus that identifies systems with high pressure and projects to implement pressure management could have great potential for improved water utility management in NA systems.

The assessment of factors contributing to NRW was limited to average water pressure in this study. However, in addition to conducting a water audit annually, utility loss control practices management are the most important factors in the level of losses occurring in a given system. For the water audit, information on practices can only be garnered indirectly from data gradings, and no information is available regarding leakage management practices, since real (leakage) losses are not an input to the AWWA FWAS, but instead a calculated value. Data on utility loss control practices must be gathered in an effort separate from the water audit in order to assess other contributing factors.

Part 4: Potentially Recoverable Losses in Pennsylvania Water Utilities

The PA Dataset of 155 water utilities produced the following totals:

1. Water supplied volume of 244,060 mg (668.6 mgd)
2. Authorized consumption volume of 176,638 mg (483.9 mgd)
3. Non-revenue water of 73,459 mg (201.3 mgd)
    a. Unbilled Authorized Consumption of 6,036 mg (16.5 mgd)
    b. Apparent losses of 11,220 mg (30.7 mgd), a cost impact of $92.5 million of uncaptured revenue
    c. Real (leakage) losses of 56,203 mg (154.1 mgd), and a cost impact of $23.4 million of excessive production costs to treat and deliver water.

These statistics reflect high water and revenue losses with only 155 of PA's +2,000 community water supply systems reporting; although some of the largest PA utilities (and Philadelphia Water Department largest by far) are included in the PA Dataset. It is likely that a large portion of these losses can be considered economic to recover. However, the most reliable means to identify economically recover losses entails assessing each water utility's losses and costs individually, and determining the economic level of apparent losses and economic level of leakage for each system based upon its unique costs, loss levels and appropriate loss control interventions. Such an assessment is very detailed and beyond the scope of this study. However, several broad assessments were conducted in order to obtain a very general estimation of potentially recoverable losses.

Potentially Recoverable Apparent Losses: Apparent losses under-state the volume of water consumed by the customer population, causing under-billings and a loss of revenue. KWEC undertook an estimation of potentially recoverable apparent losses within PA water utilities. Figure 4 shows that median value of the Normalized Apparent Loss indicator of the PA Dataset is 4.60 gal/connection/day. Figure 12 shows the median value of the CRUC to be $7.66/ 1,000 gallons.

Figure 15 plots the CRUC vs. the normalized apparent losses for systems in the PA Dataset. Three water utilities with high CRUC were excluded, as was one utility with a very high normalized apparent loss value of 114.85 gal/conn/day (due to the fact that it is listed as having only 4 customer service connections). This relationship was examined in order to gauge the extent to which PA utilities with high rates of apparent loss also have high CRUC. Systems with CRUC higher than the PA median values of $7.66/ 1,000 gallons and normalized real losses of over 4.60 gal/conn/day likely have both high apparent losses that offer revenue recovery potential and a strong economic incentive to do so.

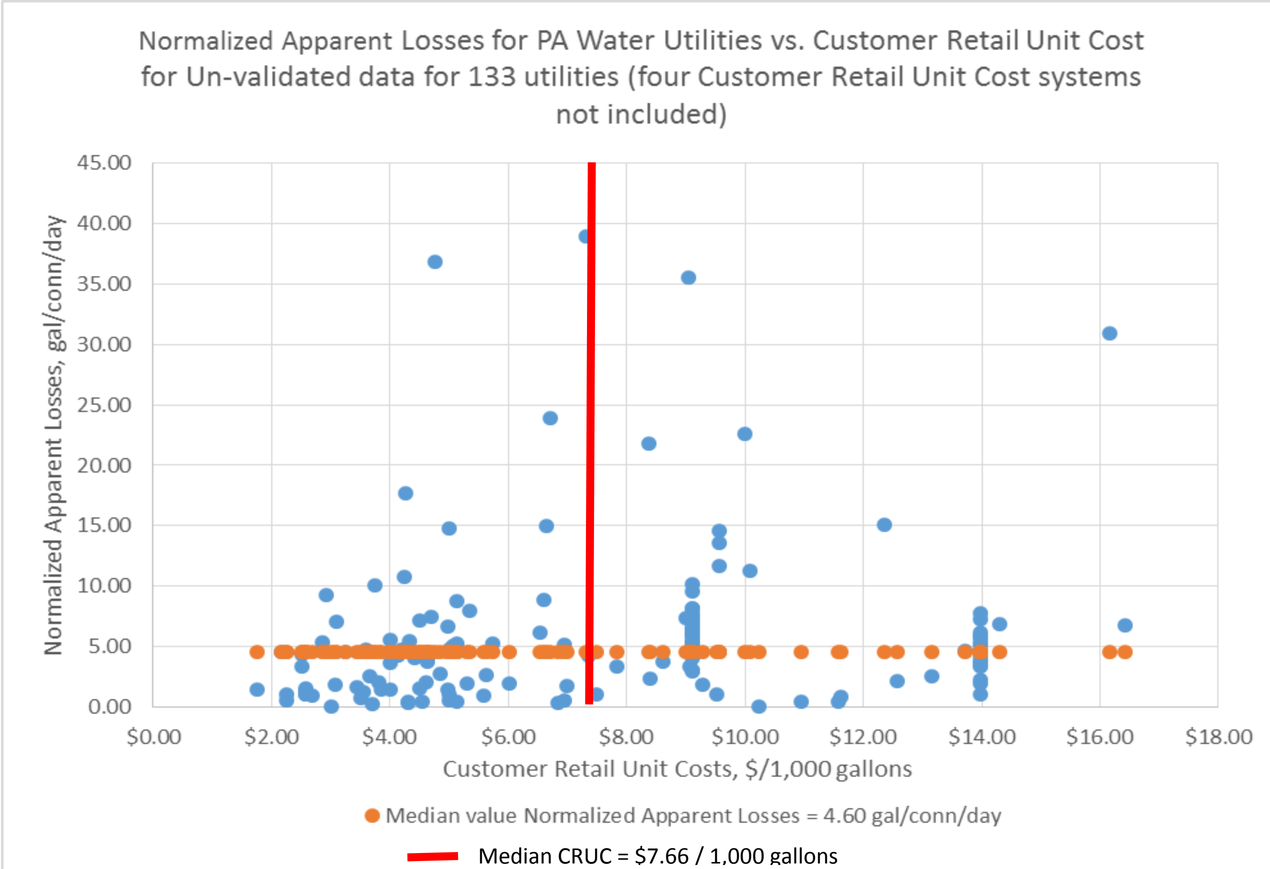

Figure 15 Plot of Normalized Apparent Losses vs. Customer Retail Unit Costs for PA Utilities

Furthermore, the product of median values for CRUC and the volume of apparent losses/connection/day yield a median value for the cost of apparent losses of $11.57/connection/year. Systems with a cost of apparent losses higher than this median value should also have significant revenue recovery potential.

An initial evaluation shows 46 PA utilities had both normalized apparent losses and CRUC at or above the median levels. Further evaluation found 73 PA utilities with an apparent loss cost above the median for the PA dataset.[2] Table 6 shows the analysis of these PA utilities for potentially recoverable apparent losses, which were quantified by identifying the apparent loss reduction volume for each utility to realize a normalized apparent loss cost of $11.57/conn/year (PA median). This resulted in an estimate of 8,461 mg/year (23.2 mgd); a significant portion of the total apparent losses of the PA Dataset of 11,202.5 mg (30.7 mgd). The projected revenue recovery benefit is shown in Table 6 as $67,033,385, which is more than two-thirds of the uncaptured revenue of $92.5 million for all apparent losses in the PA Dataset.

[2] Nine utilities were excluded due to missing or erroneous data. This resulted in 146 of the 155 PA utilities being analyzed for their apparent loss cost rate. One half of these numbers (73 utilities) fall above the median value of apparent losses of $11.57/connection/year for the PA dataset.

Table 6 PA Water Utilities Assessed for Potentially Recoverable Apparent Losses

Name of City/Utility	Apparent Losses mg	Number of Active and Inactive Service Connections	Customer Retail Unit Cost, $/1,000 gallons	Apparent Loss Cost	Apparent Losses gal. per service connection per day	Normalized Apparent Loss Cost Rate ($/conn/year) for 73 (out of 146) utilities above the Median value	Normalized Apparent Loss Rate (g/conn/d) if Normalized Apparent Loss Cost Rate = Median of $11.57/conn/yr	Annual Apparent Losses (mg) if Normalized Apparent Loss Cost Rate = Median of $11.57/conn/yr	Potentially Recoverable Annual Apparent Losses, mg	Potential Additional Revenue Capture
Philadelphia Water Department	7,495.000	527,205	$7.31	$54,788,450	38.95	$103.92	4.34	834.44	6660.56	$48,688,688
Aqua-PA: Main/Great Valley/WestWhiteland/Media Systems PWSID # 14600	675.489	298,743	$13.98	$9,443,336	6.19	$31.61	2.27	247.24	428.25	$5,986,880
Pennslyvania American Water / Pittsburgh Division	547.187	232,692	$9.10	$4,979,398	6.44	$21.40	3.48	295.85	251.34	$2,287,152
Pennslyvania American Water / Wilkes-Barre Scranton District # 910	408.395	149,104	$9.10	$3,716,394	7.50	$24.92	3.48	189.58	218.82	$1,991,260
HAZLETON CITY AUTHORITY	121.058	15,200	$8.38	$1,014,463	21.82	$66.74	3.78	20.99	100.07	$838,599
Pennslyvania American Water / Mechanicsburg Dist # 610	108.079	39,019	$9.10	$983,518	7.59	$25.21	3.48	49.61	58.47	$532,068
Pennslyvania American Water / Norristown Dist # 510	100.027	33,605	$9.10	$910,241	8.15	$27.09	3.48	42.73	57.30	$521,432
Reading Area Water Authority	207.050	32,000	$4.26	$882,031	17.73	$27.56	7.44	86.91	120.14	$511,791
EAST STROUDSBURG WATER DEPARTMENT	33.550	2,978	$16.16	$542,175	30.87	$182.06	1.96	2.13	31.42	$507,720
Pennslyvania American Water / Butler Dist #330	74.301	20,010	$9.10	$676,141	10.17	$33.79	3.48	25.44	48.86	$444,626
Horsham Water & Sewer Authority	41.741	7,576	$12.35	$515,496	15.09	$68.04	2.57	7.10	34.64	$427,842
Downingtown Municipal Water Authority	48.748	3,758	$9.05	$441,174	35.54	$117.40	3.50	4.80	43.94	$397,693
Pennslyvania American Water / Hershey Palmyra Dist # 620	67.679	19,364	$9.10	$615,875	9.58	$31.81	3.48	24.62	43.06	$391,834
Pennslyvania American Water / New Castle /Ellwood # 310	70.533	30,365	$9.10	$641,851	6.36	$21.14	3.48	38.61	31.93	$290,528
Aqua-PA: Bristol System PWSID # 1090001	28.479	10,745	$13.98	$398,133	7.26	$37.05	2.27	8.89	19.59	$273,814
Aqua-PA: West Chester System PWSID # 1150098	27.704	9,814	$13.98	$387,302	7.73	$39.46	2.27	8.12	19.58	$273,754
Pennslyvania American Water / Royersford District # 640	44.319	15,758	$9.10	$403,302	7.71	$25.59	3.48	20.04	24.28	$220,982
Aqua-PA: Uwchlan System PWSID # 1150035	26.846	13,674	$13.98	$375,308	5.38	$27.45	2.27	11.32	15.53	$217,100
Phoenixville Borough	26.573	6,427	$10.09	$268,126	11.33	$41.72	3.14	7.37	19.20	$193,765
Pennslyvania American Water / Yardley Dist # 520	33.559	12,428	$9.10	$305,390	7.40	$24.57	3.48	15.80	17.76	$161,598
Pennslyvania American Water / Coatesville District # 650	33.406	12,737	$9.10	$303,994	7.19	$23.87	3.48	16.19	17.21	$156,627
Pennslyvania American Water / Uniontown&Connelsville District #230U&230C	37.374	16,880	$9.10	$340,101	6.07	$20.15	3.48	21.46	15.91	$144,800
Pennslyvania American Water / Indiana District # 410	24.766	8,315	$9.10	$225,368	8.16	$27.10	3.48	10.57	14.19	$129,163
Pennslyvania American Water / Glen Alsace Dist # 633	23.689	9,361	$9.10	$215,569	6.93	$23.03	3.48	11.90	11.79	$107,262
Pennslyvania American Water / Blue Mnt /Nazereth Dist # 560	23.033	9,947	$9.10	$209,598	6.34	$21.07	3.48	12.65	10.39	$94,511
SOUTH WHITEHALL TOWNSHIP AUTHORITY	32.186	5,954	$5.00	$160,931	14.81	$27.03	6.34	13.78	18.41	$92,043
Lehighton Water Authority	9.276	3,700	$14.31	$132,733	6.87	$35.87	2.22	2.99	6.28	$89,924
Pennslyvania American Water /Warren Dist # 450	17.069	6,310	$9.10	$155,323	7.41	$24.62	3.48	8.02	9.05	$82,317
Nesquehoning Borough Authority	17.831	1,328	$4.76	$84,873	36.79	$63.91	6.66	3.23	14.60	$69,508
Aqua-PA: Hatboro System PWSID # 1460028	9.481	5,598	$13.71	$129,980	4.64	$23.22	2.31	4.72	4.76	$65,211
Weatherly Borough	10.262	1,176	$6.70	$68,754	23.91	$58.46	4.73	2.03	8.23	$55,147
Pennslyvania American Water / Clarion Dist # 430	12.038	4,769	$9.10	$109,549	6.92	$22.97	3.48	6.06	5.97	$54,372
Borough of Kutztown	4.533	1,826	$16.43	$74,485	6.80	$40.79	1.93	1.29	3.25	$53,358
Pennslyvania American Water / Abington Dist # 530	13.231	5,846	$9.10	$120,404	6.20	$20.60	3.48	7.43	5.80	$52,766
Pennslyvania American Water / Philipsburg District # 720	17.757	9,642	$9.10	$161,591	5.05	$16.76	3.48	12.26	5.50	$50,033
Pennslyvania American Water / Berwick District # 730	13.936	7,106	$9.10	$126,818	5.37	$17.85	3.48	9.03	4.90	$44,602
Kennett Square Municipal Water Works	9.506	1,737	$6.65	$63,218	14.99	$36.39	4.77	3.02	6.48	$43,121

Table 6 (continued)

Name of City/Utility	Apparent Losses mg	Number of Active and Inactive Service Connections	Customer Retail Unit Cost, $/1,000 gallons	Apparent Loss Cost	Apparent Losses gal. per service connection per day	Normalized Apparent Loss Cost Rate ($/conn/year) for 73 (out of 146) utilities above the Median value	Normalized Apparent Loss Rate (g/conn/d) if Normalized Apparent Loss Cost Rate = Median of $11.57/conn/yr	Annual Apparent Losses (mg) if Normalized Apparent Loss Cost Rate = Median of $11.57/conn/yr	Potentially Recoverable Annual Apparent Losses, mg	Potential Additional Revenue Capture
Pennslyvania American Water / Punxsutawney Dist #420	8.916	4,222	$9.10	$81,134	5.79	$19.22	3.48	5.37	3.55	$32,285
Mun. Auth.of the Township of Blythe-Crystal Run	4.660	1,088	$9.57	$44,598	11.73	$40.99	3.31	1.32	3.34	$32,010
Mun. Auth. Of the Twp. Of Blythe-Silver Creek	4.010	751	$9.57	$38,379	14.63	$51.10	3.31	0.91	3.10	$29,690
Myerstown Water Authority	9.124	2,800	$6.61	$60,310	8.93	$21.54	4.80	4.90	4.22	$27,914
Portland Borough Authority	3.240	393	$10.00	$32,400	22.59	$82.44	3.17	0.45	2.79	$27,853
Aqua-PA: UGS South System (Spring Run) PWSID # 1150089	3.798	2,270	$13.98	$53,098	4.58	$23.39	2.27	1.88	1.92	$26,834
Aqua-PA:Honesdale System PWSID #2640018	3.356	1,796	$13.98	$46,919	5.12	$26.12	2.27	1.49	1.87	$26,139
Pennslyvania American Water / Pocono Dist # 570	14.557	9,356	$9.10	$132,470	4.26	$14.16	3.48	11.90	2.66	$24,221
Aqua-PA: Perkiomen Twp PWSID# 1460069	2.823	1,320	$13.98	$39,466	5.86	$29.90	2.27	1.09	1.73	$24,194
Municipal Auth. Of the Twp. Of Blythe-Moss Glen	3.326	672	$9.57	$31,834	13.56	$47.37	3.31	0.81	2.51	$24,059
Aqua-PA: Chalfont System PWSID# 1090005	3.652	2,346	$13.98	$51,053	4.26	$21.76	2.27	1.94	1.71	$23,910
Pennslyvania American Water / Bangor Dist # 550	7.475	3,875	$9.10	$68,019	5.28	$17.55	3.48	4.93	2.55	$23,185
Brodhead Creek Regional Authority	16.416	5,616	$5.35	$87,826	8.01	$15.64	5.92	12.15	4.27	$22,849
Aqua-PA: UGS North PWSID # 1150137	3.792	2,659	$13.98	$53,014	3.91	$19.94	2.27	2.20	1.59	$22,249
Pennslyvania American Water / Susquehanna Dist # 540	6.115	3,116	$9.10	$55,647	5.38	$17.86	3.48	3.96	2.15	$19,595
Borough of Catasauqua	8.945	2,265	$4.25	$38,016	10.82	$16.78	7.46	6.17	2.78	$11,810
Pennslyvania American Water / Kittanning Dist #440	4.328	2,492	$9.10	$39,382	4.76	$15.80	3.48	3.17	1.16	$10,550
Audubon Water Company	6.325	2,785	$6.53	$41,305	6.22	$14.83	4.85	4.93	1.39	$9,082
Pennslyvania American Water / Kane Dist # 460	4.521	2,773	$9.10	$41,141	4.47	$14.84	3.48	3.53	1.00	$9,058
Aqua-PA: Flying Hills System PWSID# 3060018	1.821	1,457	$13.98	$25,457	3.42	$17.47	2.27	1.21	0.62	$8,599
Borough of Richland	1.739	645	$9.00	$15,652	7.39	$24.27	3.52	0.83	0.91	$8,190
Aqua-PA: Waymart PWSID# 2640032	0.797	381	$13.98	$11,146	5.73	$29.25	2.27	0.32	0.48	$6,738
Pennslyvania American Water / Frackville District # 740	4.104	2,733	$9.10	$37,347	4.11	$13.67	3.48	3.47	0.63	$5,726
Minersville Municipal Water Authority	6.795	3,624	$6.95	$47,228	5.14	$13.03	4.56	6.03	0.76	$5,299
Morrisville Municipal Authority	11.523	4,237	$4.69	$54,044	7.45	$12.76	6.76	10.45	1.07	$5,022
Pennslyvania American Water Center Co. District # 770-780	1.227	560	$9.10	$11,164	6.00	$19.93	3.48	0.71	0.51	$4,684
Aqua-PA: Honeybrook System PWSID # 1150195	0.733	578	$13.98	$10,245	3.47	$17.72	2.27	0.48	0.25	$3,558
Aqua-PA: Perkiomen Woods PWSID# 1460068	0.593	436	$13.98	$8,296	3.73	$19.03	2.27	0.36	0.23	$3,252
Pennslyvania American Water / Lake Heritage District # 660	1.381	836	$9.10	$12,565	4.52	$15.03	3.48	1.06	0.32	$2,892
Pennsylvania Utility Company	1.625	508	$5.13	$8,336	8.76	$16.41	6.18	1.15	0.48	$2,458
Boyertown, PA	7.543	3,080	$4.98	$37,563	6.71	$12.20	6.37	7.16	0.39	$1,928
Plum Creek Municipal Authority	2.453	2,643	$13.15	$32,259	2.54	$12.21	2.41	2.33	0.13	$1,679
Delaware Water Gap Borough	1.814	491	$3.75	$6,803	10.12	$13.86	8.45	1.51	0.30	$1,123
WOMELSDORF-ROBESONIA JOINT AUTHORITY	5.744	2,190	$4.50	$25,850	7.19	$11.80	7.04	5.63	0.11	$512
Bedminster Municipal Authority	1.561	1,138	$8.62	$13,453	3.76	$11.82	3.68	1.53	0.03	$286
Aqua-PA: Fawn Lake (Lackawaxan) System PWSID # 2520037	2.036	2,455	$13.98	$28,466	2.27	$11.60	2.27	2.03	0.00	$61
									8,461	**$67,033,385**

This approach makes a broad assumption that it would be financially rewarding for all of these 73 utilities to enact revenue protection interventions to drive the cost of their apparent losses down to the median level. This may not be the case for all utilities. However, since these utilities have either relatively high CRUC or relatively high apparent loss volumes, they generally have greater financial incentive to control apparent losses compared to other PA water utilities that do not appear in Table 6. Many PA water utilities do not compile an annual water audit, including some of PA's largest water utilities.

The above approach projects potentially recoverable apparent losses for 73 of 133 water utilities that have compiled an annual water audit and have data acceptable for analysis. It is valuable to attempt to project the potential recoverable apparent losses for <u>all</u> water utilities in PA. However, the vast majority of water utilities are not included in the PA Dataset and do not regularly compile an annual, standardized water audit. Thus, lacking statewide water audit data, the author devised a projection of statewide apparent losses and potentially recoverable apparent losses by referencing data on public water supply withdrawals from standardized reporting from the United States Geologic Survey (USGS)[1]. The USGS report on water use in 2010 found that total water withdrawals from PA water utilities were 518,300 mg (1,420 mgd). The total volume of Water Supplied for 155 utilities in the PA Dataset is 244,060 mg (668.6 mgd). These volumes are shown in Table 7. By calculating the proportion of apparent losses and potentially recoverable apparent losses to the Water Supplied volume of the PA Dataset, and applying these percentages to the USGS water withdrawal volume shown in Table 7, an extrapolated estimate of total and recoverable apparent losses is projected.

Table 7 Calculation of Potentially Recoverable Apparent Losses in Pennsylvania Utilities State-wide

Utility Population	Water Supplied/Withdrawn, mg	Apparent Losses, mg	Potentially Recoverable Apparent Losses, mg
PA Dataset (155 Utilities)	244,060	11,220 = 4.60% of Water Supplied	8,461 = 3.46% of Water Supplied
Statewide in PA (number of utilities is unknown)	518,300	(518,300)(0.0460) = **23,841.8**	(518,300)(0.0346) = **17,968.3**

Table 7 illustrates that, by extrapolating the data from 155 utilities in the PA Dataset to the total public water supply withdrawals in PA (USGS Report), it is projected that all water utilities in Pennsylvania experience **23,841.8 mg (65.3 mgd) of apparent losses, and that at least 17,968.3 mg (49.2 mgd) are potentially recoverable**. At the median CRUC of $7.66/kgal, the **value of the potentially recoverable apparent losses is $137,637,178 of uncaptured annual revenue.** Note that these are likely very

[1] Estimated Use of Water in the United States for 2010, USGS, Circular 1045 (2014)

minimal estimates of apparent losses and potentially recoverable apparent losses occurring in PA water utilities.

By better controlling apparent losses, utilities recover missing revenue that is vital to financing the long-term renewal of deteriorating water distribution infrastructure. Infrastructure renewal – and the ability to pay for it – is one of the greatest concerns for water utilities throughout the USA, yet few utilities focus consistently on their billing efficiency and revenue capture. PA water utilities have notable potential to save water, fund infrastructure renewal, and improve their finances by better controlling apparent losses.

Potentially Recoverable Real Losses (Leakage): A broad assessment of real (leakage) losses was conducted since these losses cause utilities to withdraw and treat more water than the customer population needs. This assessment keyed on plotting VPC vs. the normalized real loss performance indicator for systems with high customer service density. This relationship was examined in order to gauge the extent to which PA utilities with high rates of real loss also encounter high VPC. Systems with VPC of more than the PA median values of $520/mg and normalized real losses of over 38.54 gal/conn/day likely have both excessive leakage losses that offer good leakage recovery potential and a strong economic incentive to do so. Figure 16 plots the real loss indicator values and variable production costs along with the median values, but excludes one utility with an unusually high VPC value. Closer evaluation found that 32 PA utilities had both normalized real losses and VPC at or above the median levels, and these utilities were analyzed in more detail. Additionally, the Philadelphia Water Department was included in the analysis as the 33rd utility since it is the largest water supplier in PA and has the highest leakage volume. Its normalized real loss indicator is 110.52 gal/conn/day, well over the median value for PA utilities, but with a VPC of $346.46/mg, less than the PA median value.

Additionally, the product of median values for VPC and the volume of real losses/connection/day yields a median value for the cost of real losses of $4.92/connection/year. Systems with a cost of real losses higher than this median value should also have significant leakage reduction potential. Table 8 shows the analysis of 68 PA utilities for potentially recoverable real losses, which were quantified by identifying the leakage reduction volume for each utility to realize a normalized real loss value of $4.92 /conn/year (the PA median).[2] This resulted in an estimated leakage reduction of 17,888 million gallons per year (49 mgd) representing a significant portion of the total real losses of the PA dataset of 56,203 mg (154.1 mgd). The projected cost savings from reduced VPC are shown in Table 8 as $10.7 million, which is a notable portion of the production cost impact of $23.4 million for the entire PA Dataset.

[2] Thirteen utilities were excluded due to missing data and 6 low service connection density systems were also excluded. This resulted in 136 of the 155 PA utilities being analyzed for their real loss cost rate. One half of this number (68 utilities) fall above the median value of real loss cost rate for the PA dataset.

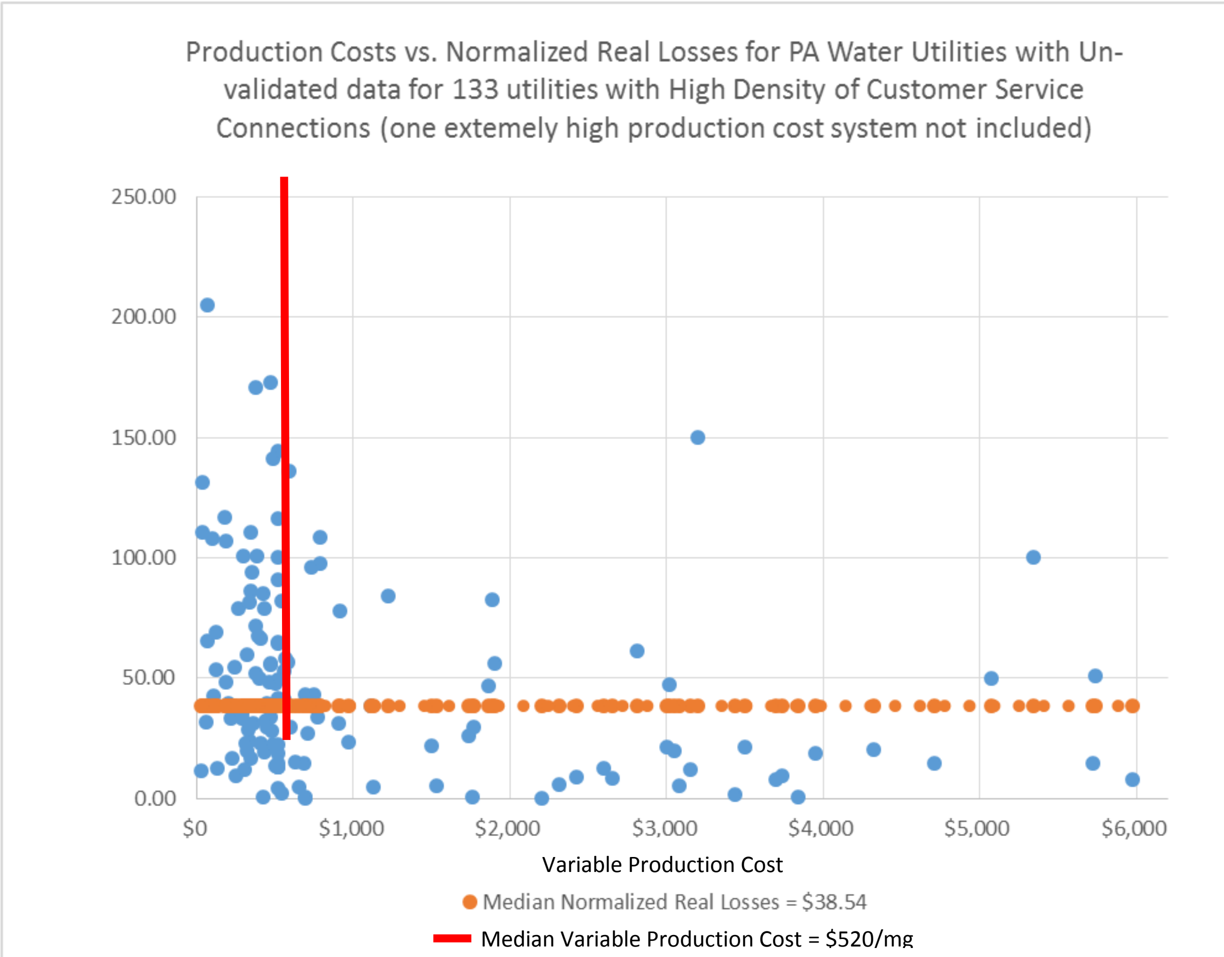

Figure 16 Plot of Production Costs vs. Normalized Real Losses (High Customer Service Connection Density PA Utilities)

This approach suggests that it would be economic for all of the 68 utilities to enact leakage interventions to drive their cost of leakage down to the median level. This will not likely be the case for all utilities. However, since these utilities have either relatively high VPC or relatively high real loss volumes, they generally have greater economic incentive to control leakage losses compared to PA water utilities not included in Table 8.

While a very general approximation of the "low hanging fruit" of leakage losses in PA, these figures are attractive in terms of saving significant water volumes lost to leakage, and reduced production costs to water utilities, with indirect benefits such as reduced pumping energy costs. Generally, such leakage reductions should be considered economic for the utilities shown in Table 8.

Table 8 PA Water Utilities Assessed for Potentially Recoverable Real Losses

Name of City/Utility	Real Losses, mg	Number of Active and Inactive Service Connections	Variable Production Cost $/mg	Variable Production Cost, Adjusted Unrealistically Low Values, $/mg	Real Losses, gal per service connection per day	Normalized Real Loss Cost Rate ($/conn/year) 68 utilities above median of PA Dataset	Normalized Real Loss Rate (g/conn/d) if Normalized Real Loss Cost Rate = Median of $7.81/conn/yr	Annual Real Losses (mg) if Normalized Real Loss Cost Rate = Median of $7.81/conn/yr	Potentially Recoverable Annual Real Losses, mg	Potential Variable Production Cost Savings
Philadelphia Water Department	21,267.500	527,205	$346.46	$346.46	110.52	$13.98	61.76	11884.41	9,383.095	$3,250,867
Allentown, PA	1,003.139	33,318	$1,887.02	$1,887.02	82.49	$56.81	11.34	137.90	865.243	$1,632,730
Pennslyvania American Water / Pittsburgh Division	7,966.200	232,692	$350.00	$350.00	93.79	$11.98	61.14	5192.36	2,773.844	$970,845
Reading Area Water Authority	912.913	32,000	$0.91	$910.00	78.16	$25.96	23.51	274.64	638.276	$580,831
Easton Suburban Water Authority	335.384	31,141	$1,764.32	$1,764.32	29.51	$19.00	12.13	137.85	197.534	$348,514
Borough of Kutztown	66.907	1,826	$5,347.83	$5,347.83	100.39	$195.95	4.00	2.67	64.240	$343,544
Horsham Water & Sewer Authority	130.469	7,576	$3,016.70	$3,016.70	47.18	$51.95	7.09	19.61	110.855	$334,417
HAZLETON CITY AUTHORITY	542.650	15,200	$789.00	$789.00	97.81	$28.17	27.12	150.46	392.191	$309,439
Plum Creek Municipal Authority	48.970	2,643	$5,738.64	$5,738.64	50.76	$106.33	3.73	3.60	45.373	$260,378
Pennslyvania American Water / Uniontown&Connelsville District	122.148	16,880	$3,052.00	$3,052.00	19.83	$22.09	7.01	43.20	78.953	$240,963
North Wales Water Authority	224.243	23,516	$1.74	$1,740.00	26.13	$16.59	12.30	105.55	118.691	$206,522
SOUTH WHITEHALL TOWNSHIP AUTHORITY	122.101	5,954	$1.90	$1,900.00	56.18	$38.96	11.26	24.47	97.627	$185,492
Aqua-PA: Main/Great Valley/WestWhiteland/Media Systems PV	4,463.141	298,743	$560.00	$560.00	40.93	$8.37	38.21	4166.40	296.743	$166,176
Kennett Square Municipal Water Works	31.765	1,737	$5,078.43	$5,078.43	50.10	$92.87	4.21	2.67	29.094	$147,753
Aqua-PA: West Chester System PWSID # 1150098	417.277	9,814	$520.00	$520.00	116.49	$22.11	41.15	147.40	269.878	$140,337
HAMBURG MUNICIPAL AUTHORITY	49.910	2,235	$2.81	$2,810.00	61.18	$62.75	7.61	6.21	43.698	$122,791
Aqua-PA: Bristol System PWSID # 1090001	392.454	10,745	$520.00	$520.00	100.07	$18.99	41.15	161.38	231.073	$120,158
Doylestown Borough	98.162	3,200	$1,219.00	$1,219.00	84.04	$37.39	17.55	20.50	77.660	$94,668
Pennslyvania American Water / New Castle /Ellwood # 310	953.403	30,365	$346.00	$346.00	86.02	$10.86	61.84	685.41	267.997	$92,727
Delaware Water Gap Borough	26.840	491	$3,200.00	$3,200.00	149.77	$174.93	6.69	1.20	25.642	$82,055
Pennslyvania American Water / Mechanicsburg Dist # 610	1,019.954	39,019	$374.00	$374.00	71.62	$9.78	57.21	814.81	205.146	$76,724
Pennslyvania American Water / Norristown Dist # 510	815.552	33,605	$408.00	$408.00	66.49	$9.90	52.44	643.27	172.280	$70,290
Borough of Schuylkill Haven	200.429	3,181	$468.00	$468.00	172.62	$29.49	45.72	53.08	147.344	$68,957
Pennslyvania American Water / Susquehanna Dist # 540	154.641	3,116	$591.00	$591.00	135.97	$29.33	36.21	41.18	113.463	$67,057
Pennslyvania American Water / Coatesville District # 650	264.249	12,737	$581.00	$581.00	56.84	$12.05	36.83	171.22	93.033	$54,052
EAST STROUDSBURG WATER DEPARTMENT	185.554	2,978	$378.41	$378.41	170.71	$23.58	56.55	61.46	124.091	$46,957
Borough of Ambler	81.218	5,774	$1,108.71	$1,108.71	38.54	$15.60	19.30	40.67	40.544	$44,952
Aqua-PA: UGS South System (Spring Run) PWSID # 1150089	119.562	2,270	$520.00	$520.00	144.30	$27.39	41.15	34.09	85.469	$44,444
Pennslyvania American Water / Pocono Dist # 570	269.979	9,356	$430.00	$430.00	79.06	$12.41	49.76	169.93	100.048	$43,021
Phoenixville Borough	235.993	6,427	$386.40	$386.40	100.60	$14.19	55.38	129.90	106.089	$40,993
Northampton Borough Municipal Authority	173.451	15,282	$908.00	$908.00	31.10	$10.31	23.57	131.45	42.005	$38,141
Pennslyvania American Water / Butler Dist #330	409.617	20,010	$473.00	$473.00	56.08	$9.68	45.24	330.40	79.219	$37,471
Morrisville Municipal Authority	126.863	4,237	$0.54	$540.00	82.03	$16.17	39.62	61.28	65.584	$35,415
Pennslyvania American Water / Hershey Palmyra Dist # 620	394.519	19,364	$468.00	$468.00	55.82	$9.53	45.72	323.15	71.372	$33,402

Table 8 (continued)

Name of City/Utility	Real Losses, mg	Number of Active and Inactive Service Connections	Variable Production Cost $/mg	Variable Production Cost, Adjusted Unrealistically Low Values, $/mg	Real Losses, gal per service connection per day	Normalized Real Loss Cost Rate ($/conn/year) 68 utilities above median of PA Dataset	Normalized Real Loss Rate (g/conn/d) if Normalized Real Loss Cost Rate = Median of $7.81/conn/yr	Annual Real Losses (mg) if Normalized Real Loss Cost Rate = Median of $7.81/conn/yr	Potentially Recoverable Annual Real Losses, mg	Potential Variable Production Cost Savings
Borough of Jim Thorpe	61.569	1,753	$728.44	$728.44	96.23	$25.58	29.37	18.79	42.775	$31,159
Weatherly Borough	46.530	1,176	$0.79	$790.00	108.40	$31.26	27.09	11.63	34.903	$27,574
LEHIGH COUNTY AUTHORITY-NORTH WHITEHALL DIVISIOI	19.521	1,139	$1,862.79	$1,862.79	46.96	$31.93	11.49	4.78	14.746	$27,468
Myerstown Water Authority	8.214	2,800	$5,978.00	$5,978.00	8.04	$17.54	3.58	3.66	4.556	$27,236
The Borough of Orwigsburg, PA	5.882	1,108	$5.72	$5,720.00	14.54	$30.37	3.74	1.51	4.369	$24,992
Upper Southampton Municipal Authority	22.768	5,021	$2,600.00	$2,600.00	12.42	$11.79	8.23	15.08	7.686	$19,984
Pennslyvania American Water / Clarion Dist # 430	101.277	4,769	$565.00	$565.00	58.18	$12.00	37.87	65.92	35.355	$19,976
Pennslyvania American Water / Lehman Pike District # 680	243.627	9,854	$394.00	$394.00	67.74	$9.74	54.31	195.33	48.298	$19,029
Aqua-PA:Honesdale System PWSID #2640018	59.470	1,796	$520.00	$520.00	90.72	$17.22	41.15	26.97	32.495	$16,898
Aqua-PA: Hatboro System PWSID # 1460028	108.083	5,598	$560.00	$560.00	52.90	$10.81	38.21	78.07	30.011	$16,806
BOROUGH OF LEESPORT	7.497	950	$3,000.00	$3,000.00	21.62	$23.67	7.13	2.47	5.024	$15,072
Downingtown Municipal Water Authority	59.248	3,758	$749.21	$749.21	43.19	$11.81	28.56	39.17	20.074	$15,039
Borough of Richland	4.457	645	$3,950.00	$3,950.00	18.93	$27.29	5.42	1.28	3.182	$12,567
Aqua-PA: Fawn Lake (Lackawaxan) System PWSID # 2520037	57.572	2,455	$520.00	$520.00	64.25	$12.19	41.15	36.87	20.699	$10,764
LOWER SAUCON AUTHORITY	7.468	2,200	$3,738.00	$3,738.00	9.30	$12.69	5.72	4.60	2.871	$10,733
Borough of Fleetwood	53.453	1,715	$425.00	$425.00	85.39	$13.25	50.35	31.52	21.938	$9,323
Schwenksville Borough Authority	17.768	2,245	$1,502.33	$1,502.33	21.68	$11.89	14.24	11.67	6.097	$9,160
Lehighton Water Authority	110.143	3,700	$334.02	$334.02	81.56	$9.94	64.06	86.51	23.630	$7,893
Borough of Catasauqua	83.404	2,265	$295.00	$295.00	100.88	$10.86	72.53	59.96	23.439	$6,914
Portland Borough Authority	20.242	393	$490.00	$490.00	141.11	$25.24	43.67	6.26	13.978	$6,849
Midlakes Water System Northeast Land Co. D-89-10 CP3	1.925	260	$4,320.00	$4,320.00	20.29	$31.99	4.95	0.47	1.455	$6,286
Birdsboro Municipal Authority	31.630	2,009	$693.44	$693.44	43.13	$10.92	30.86	22.63	9.003	$6,243
Telford Borough Authority	33.759	2,717	$774.31	$774.31	34.04	$9.62	27.63	27.40	6.355	$4,921
Pennslyvania American Water / Glen Alsace Dist # 633	80.068	9,361	$973.00	$973.00	23.43	$8.32	21.99	75.14	4.930	$4,797
Utilities Inc - Westgate	3.335	771	$3,154.73	$3,154.73	11.85	$13.65	6.78	1.91	1.427	$4,501
Lyons Borough Authority	1.735	224	$3,500.00	$3,500.00	21.22	$27.11	6.11	0.50	1.235	$4,323
Wallenpaupack Lake Estates	4.068	1,379	$3.70	$3,700.00	8.08	$10.91	5.78	2.91	1.157	$4,282
Aqua-PA: Honeybrook System PWSID # 1150195	13.702	578	$520.00	$520.00	64.95	$12.33	41.15	8.68	5.021	$2,611
Upper Saucon Township	40.909	2,347	$504.38	$504.38	47.75	$8.79	42.42	36.34	4.567	$2,304
Pennland Water System (Bedminster Municipal Auth)	0.635	120	$4,712.30	$4,712.30	14.49	$24.93	4.54	0.20	0.436	$2,054
Aqua-PA: Tanglwood Lakes Golf PWSID# 2520065	11.926	664	$520.00	$520.00	49.21	$9.34	41.15	9.97	1.953	$1,016
Bedminster Municipal Authority	3.538	1,138	$2,652.00	$2,652.00	8.52	$8.24	8.07	3.35	0.187	$495
Aqua-PA: Chalfont System PWSID# 1090005	35.765	2,346	$520.00	$520.00	41.77	$7.93	41.15	35.24	0.530	$276
Pemberton Heights	2.390	135	$465.00	$465.00	48.51	$8.23	46.02	2.27	0.123	$57
								Totals	**17,888**	**$10,712,682**

The above approach projects potentially recoverable real losses for 68 of 133 water utilities that have compiled an annual water audit and have data acceptable for analysis. It is valuable to attempt to project the potential recoverable real losses for all water utilities in PA. However, the vast majority of water utilities are not included in the PA Dataset and do not regularly compile an annual, standardized water audit. Thus, lacking statewide water audit data, the author devised a projection of statewide real losses in the same manner as was executed for apparent losses previously. The USGS report on water use in 2010 was again used to calculate total real losses for all PA water utilities, and potentially recoverable real losses in the State, with calculations shown in Table 9 executed in the same manner at Table 7.

Table 9 Calculation of Potentially Recoverable Real Losses in Pennsylvania Utilities State-wide

Utility Population	Water Supplied/Withdrawn, mg	Real Losses, mg	Potentially Recoverable Real Losses, mg
PA Dataset (155 Utilities)	244,060	56,203 = 23.03% of Water Supplied	17,888 = 7.33% of Water Supplied
Statewide in PA (number of utilities is unknown)	518,300	(518,300)(0.2302) = **119,312.6**	(518,300)(0.0733) = **37,988**

Table 9 illustrates that, by extrapolating the data from 155 utilities in the PA Dataset to the total public water supply withdrawals in PA (USGS Report), it is projected that all water utilities in PA experience **119,312.6 mg (326.9 mgd) of real losses, and that at least 37,988 mg (104.1 mgd) are potentially recoverable**. At the median VPC of $520/mg, the **value of the potentially recoverable real losses is $19,753,760 in reduced production costs.** Note that these are likely very minimal estimates of real losses and potentially recoverable real losses occurring in PA water utilities.

The assessment of potentially recoverable losses (real and apparent) discussed herein reveals that significant loss recovery potential exists for both types of losses. The recovery is attractive from the perspective of saving water (through better leakage control) and increasing utility revenues and promoting equity among the rate-paying customer population. This analysis keyed on utilities that have both high loss rates and high costs, thereby identifying the utilities with the greatest likelihood of developing a positive business case for focused loss control. However, all of the utilities in the PA Dataset should ultimately review the losses and costs of their operations to determine the level of loss reduction that could be economically attained.

The impacts of the significant real and apparent losses on PA communities are varied. Pennsylvania is a relatively water-rich region which receives over 40 inches of rain each year. Water resources are generally in good supply, although periodic droughts impact utilities relying on water supply from shallow wells. Thus, concern for the quantity of available water resources may not be a strong driver for increased leakage management across all utilities in the Commonwealth. Utilities of the PA Dataset were found to have lower median real loss volumes than the utilities of the NA Dataset (35.71 gal/conn/day for PA vs. 43.30 gal/conn/day for the NA), although improved data validation may produce a somewhat different real loss value.

These findings might suggest that the volume of leakage losses is not as concerning in PA as for other parts of North America. However, improved leakage and pressure management can play a strong role in better sustaining and renewing water distribution infrastructure. PA has some of the oldest water piping in the country and disruptive leaks and water main breaks are a frequent unfortunate occurrence. PA water utilities could prevent many such occurrences by employing improved leakage and pressure management.

By better controlling apparent losses, utilities would recover missing revenue that is vital to financing the long-term renewal of deteriorating water distribution infrastructure. Infrastructure renewal – and the ability to pay for it – is one of the greatest concerns for water utilities throughout the USA, yet few utilities focus consistently on their billing efficiency and revenue capture. PA water utilities have great potential to save water, maintain and renew infrastructure, and improve their finances by launching comprehensive water loss control in their operations.

5. Summary

Kunkel Water Efficiency Consulting (KWEC) conducted an assessment of water audit data from Pennsylvania water utilities which included a comparison with validated water audit data of a larger dataset of North American water utilities. A number of findings and conclusions are drawn from this work, including:

1. **Data Quality**: PA water audit data is un-validated and – not surprisingly – has a notably higher median Data Validity Score (DVS) of 80 compared to the NA Dataset's median value of 63. Investor owned utilities provided the same data in several different manners, with one company using the same data gradings for all systems, and another using the same variable production cost for all of its systems. Every system is unique, thus applying the same data to a group of systems is less accurate. A number of data gaps also occur in the PA Dataset. **These findings suggest that additional training is needed for water utility staff in compiling the water audit, and that Level 1 validation is needed to "truth" the data and make the data more representative of the actual operations of PA utilities**.

2. **Apparent Losses**: are notably less in the PA Dataset compared to the NA Dataset. However, these losses are likely to be under-stated in the PA Dataset; and cause real losses to be somewhat over-stated. Analysis found apparent losses of 11,220 mg (30.7 mgd) occurring in the PA Dataset. **It is projected that apparent losses for <u>all</u> PA water utilities are likely to be approximately 23,842 mg (65.3 mgd), and approximately 17,968 mg (49.2 mgd) of these losses are likely to be economically recoverable, with a potential revenue recovery of $137,637,178.**

3. **Real Losses**: are notably less in the PA Dataset compared to the NA Dataset. Analysis found real (leakage) losses of 56,203 mg (154.1 mgd) occurring in the PA Dataset. **It is projected that real losses for <u>all</u> PA water utilities are likely to be approximately 119,312 mg (326.9 mgd), with 37,988 mg (104.1 mgd) of these losses estimated to be economically recoverable, with a total production cost savings of $19,753,760.**

4. **Costs**: the median Variable Production Costs and Customer Retail Unit Costs of PA utilities are both notably higher than the median value of utilities of the NA Dataset. **This gives PA water utilities a strong financial incentive to pursue loss reduction activities**.

The results of the analysis undertaken by KWEC to assess annual water audit data of Pennsylvania water utilities is likely the first study of its kind to develop estimates of potentially recoverable losses (real and apparent) for water utilities across the Commonwealth. The findings show significant potential for water to be saved, infrastructure to be better maintained, cost savings to be garnered by water utilities, and improved equity of payments for water customers to be achieved. It is time for all Pennsylvania water utilities to lay the foundation for cost-effective water loss reduction programs by completing standardized water loss audit reports on an annual basis and reporting validated results to their customers and state agencies.