Water Loss Management: Conservation Option in Florida's Urban Water Systems

Kenneth R. Friedman and James P. Heaney

The focus of this article is methodologies to estimate water loss in public water supply systems in Florida as part of a water conservation plan. Urban water originates at one or more sources, is transported to one or more treatment plants, is treated and distributed to customers throughout the water system, and then is used by the customer.

The amount of water moving through the urban water system is measured at the source(s), the treatment plant(s), and the delivery points to the customer. The frequency of measurement varies from hourly or daily at the master meters located at the source(s) and treatment plant(s) to typically monthly readings of customer water use.

A portion of the water moving through this system may be lost or gained as measured by differences in meter readings. This paper addresses only losses or gains in the distribution/transmission network. Because water is transported through this network under pressure, it is reasonable to assume that only losses will occur. If a gain occurs, it is caused by meter errors. By contrast, wastewater collection networks typically experience gains in flows because of infiltration and inflow.

This study was initiated as part of activities of the Conserve Florida Water Clearinghouse (**www.conservefloridawater.org**). Water loss is a required input to the Guide software that is used to evaluate water conservation programs in Florida. A detailed description of the *Guide* is available at the Clearinghouse web site.

The current version of the *Guide* allows the user to select from several options for estimating water loss. Questions arose as to the sources of variability in these methods and whether one method is preferable to others.

The American Water Works Association (AWWA) recently published the third edition of M36, a manual of water supply practices titled *Water Audits and Loss Control Programs* (AWWA 2009). Concurrently, the AWWA's Water Loss Control Committee released Version 4.0 of its Free Water Audit Software package that can be used to compile a water audit and evaluate water loss. This software can be downloaded from the AWWA's WaterWiser web site. Earlier versions have been used for water loss analysis in Florida.

Alternative performance metrics are calculated in this analysis, and the question of which ones are useful for Florida utilities is addressed. Also, recommendations are presented for ways to more fully integrate water loss evaluations within the context of overall water conservation evaluations so water loss control can be compared with other options such as toilet retrofits. Finally, recommendations are made on how water loss evaluations can be done in Florida.

Water Loss Evaluation

Water audits and water loss control have been a significant concern of the North American water industry for at least 20 years. The AWWA published the first edition of the M36 Manual of Water Supply Practices titled *Water Audits and Leak Detection* in 1990. The second edition appeared in 1999, and the third edition was released in May 2009. The 2009 edition provides detailed instructions on compiling the water audit and evaluating water losses. It incorporates much of the information found in earlier studies, including Fanner *et al.* (2007) and Thornton *et al.* (2008).

Water audits are done for a variety of reasons. Water balances, including audits, are essential elements of water conservation evaluations. Water loss control can be viewed as a conservation best management practice or measure.

Water budgets for conservation planning rely on an end-use analysis that partitions total water supplied into its end uses such as toilets, showers, irrigation, etc. In this context, water loss components are viewed as an end use, such as pipeline losses. Also, special uses such as water provided for street cleaning can be viewed as end uses.

These components are measured or estimated as part of water audits. Thus, water loss control is viewed as one of many options for managing the water supply-demand equilibrium. Benefit-cost analysis procedures can then be used to find the optimal blend of water conservation practices, including water loss control (Chesnutt *et al.* (2007).

Kenneth R. Friedman is a Graduate Research Assistant and James P. Heaney is a Professor and Chair of the Department of Environmental Engineering Sciences at the University of Florida. This study was done as part of the Conserve Florida Water Clearinghouse program.

Water losses can represent a significant component of the water that is supplied by utilities to their customers. M36 focuses primarily on auditing the part of the water cycle within the treated water transmission/distribution network. Upstream losses from the source(s) to the treatment facilities and within the treatment facility(ies) are mentioned briefly but are not addressed in detail. Similarly, losses on the customer's side of the meter are not given detailed consideration. While these losses can be significant in some systems, the primary scope of M36 is to evaluate losses in the retail transmission/distribution system.

Many regulatory agencies place upper limits on the amount of losses that a utility can incur. A popular way to represent these losses is as "unaccounted-for water" (UAW) expressed as a percent of the water supplied. According to Beecher (2002), regulatory agencies in nearly all states have set upper limits on water losses ranging from 7.5 to 25 percent, with 15 percent being the most common value; however, the same survey also found that actual loss levels are rarely tracked and these limits are rarely enforced. The also survey noted that an improved system of accounting for water was needed to improve accountability in drinking water utilities.

The results of a 2002 AWWA survey indicated that water loss was less than 20 percent for 82 percent of the respondents (Fanner *et al.* 2007). Reported water losses in the Southwest Florida Water Management District for 2007 averaged 6 percent, with a range from 0 to 35 percent (SWFWMD 2009). The district's reported values seem quite low compared to

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national statistics, and many of the district's utilities report no losses, a physical impossibility. Florida regulatory agencies use 10 to 12 percent UAW as the upper limit on acceptable practice for water losses measured, relative to the finished water from the treatment plant.

Historically, a major problem with calculating losses was a lack of agreement on the definition of terms in the accounting process. The AWWA Water Loss Control Committee (Kunkel *et al.* 2003) opposes the use of UAW expressed as a percentage of the water supplied. Instead, the committee advocates the term "non-revenue water" as specifically defined in the IWA/AWWA Water Audit methodology given in the M36 and the AWWA Free Water Audit Software.

The water supplied is measured by master meters and will be referred to as Qs. The amount of water delivered by the supply network, Qd, is the sum of the customer meter readings for all metered uses. Gross gallons per capita per day (gpcd) is a popular metric of the intensity of urban water use for conservation evaluations. The difference between these two terms represents the amount of water lost throughout the distribution system and because of metering/billing error, expressed as Ql. In this macro view, Ql, in units of gpcd, is simply:

$$Q_l = Q_s - Q_d \qquad (1)$$

Alternatively, Ql can be expressed as a normalized percentage using:

$$Q_l\,(\%) = 100*(1 - Q_d/Q_s) \qquad (2)$$

Expressing water loss as a difference or a ratio allows policy makers to prescribe guidelines in either way. In Florida and elsewhere, water loss is expressed as a percent. For example, the goal of the draft 20x2020 Water Conservation Plan for California is to reduce statewide per capita urban water use by 20 percent by the year 2020 (California Water Resources Control Board 2009); however, other conservation programs express water loss goals in usage rates, such as reducing water use by 20 gallons per capita per day (gpcd) during the next 20 years.

<table>
<tr><td colspan="4">AWWA WLCC Free Water Audit Software Version 4.0:
Water Balance Million gallons/year</td><td>Water Audit Report For:
County Water Company, Anytown, USA</td><td>Report Yr:</td></tr>
<tr><td rowspan="8">Own Sources (Adjusted for known errors)
3,617.7</td><td>Water Exported
0.0</td><td colspan="4">Billed Water Exported</td></tr>
<tr><td rowspan="10">Water Supplied
4,401.3</td><td rowspan="4">Authorized Consumption
3,457.2</td><td rowspan="2">Billed Authorized Consumption
3,258.0</td><td>Billed Metered Consumption (inc. water exported)
3,258.0</td><td rowspan="2">Revenue Water
3,258.0</td></tr>
<tr><td>Billed Unmetered Consumption
0.0</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption
199.2</td><td>Unbilled Metered Consumption
15.4</td><td rowspan="8">Non-Revenue Water (NRW)
1,143.3</td></tr>
<tr><td>Unbilled Unmetered Consumption
183.8</td></tr>
<tr><td rowspan="6">Water Losses
944.1</td><td rowspan="3">Apparent Losses
196.6</td><td>Unauthorized Consumption
11.0</td></tr>
<tr><td>Customer Metering Inaccuracies
164.3</td></tr>
<tr><td>Systematic Data Handling Errors
21.3</td></tr>
<tr><td rowspan="3">Water Imported
783.7</td><td rowspan="3">Real Losses
747.5</td><td>Leakage on Transmission and/or Distribution Mains
Not broken down</td></tr>
<tr><td>Leakage and Overflows at Utility's Storage Tanks
Not broken down</td></tr>
<tr><td>Leakage on Service Connections
Not broken down</td></tr>
</table>

Figure 1: Results of the CWC annual audit using the AWWA Free Water Audit Software Version 4.0 expressed in millions of gallons per year (AWWA 2009).

This approach of expressing performance using ratios and differences is used widely in the environmental and water field and in performance evaluations in general. For example, benefit-cost analysis uses both the B/C ratio and B-C to measure the economic desirability of a project.

An important attribute of performance metrics for audits is that they are based on directly measured values. Both Q_s and Q_d are measured directly by flow meters. This simple expression can be expanded to account for real and apparent gains and losses that occur within the supply network.

Real losses are caused by physical factors, such as leaking pipes, while apparent losses can be caused by several non-physical factors, such as errors in the meter readings of the master and/or customer meters or systematic data handling error in customer billing systems. These factors are components of the various water loss methods that are described in the following sections.

The 2009 version of M36 requires several levels of auditing detail to compile the water audit and water loss evaluation. The auditing process is illustrated in Chapter 2 using an example of the fictitious County Water Company. This 57-page chapter provides detailed description of the auditing approaches to quantify components of water consumption and water loss. It includes several tables that provide the quantitative basis for the entries into the water audit. Most importantly, it contains supporting evidence showing how meter-reading inaccuracies were calculated.

The AWWA Free Audit Software is referenced as an appendix in the M36 and contains relatively little documentation. It allows estimates of water use to be included without any backup information regarding how these estimates were made. We suggest acquiring the M36 Manual and the AWWA Free Audit software and using the software as a preliminary tool (the top-down audit approach) before doing the more refined analysis (bottom-up auditing methods) detailed in Chapter 2. Then, the results of the water loss analysis can be used to evaluate its relative importance as a water conservation option.

AWWA Water Audit Method for Water Conservation Analysis

The case study on how water audits can be used as part of conservation analysis is taken from the new M36 Manual (AWWA 2009). The hypothetical utility called County Water Company (CWC) serves a population of 37,000 people. The AWWA's Water Loss Control Committee advocated use of the IWA/AWWA Water Audit Method in its 2003 Committee Report (Kunkel *et al.* 2003).

The general terms of the water balance used in the AWWA Free Water Audit Software are shown in Figure 2 (AWWA 2009). A water balance is used to account for the 19 sources and sinks of water as it moves through the water supply network. The values indicated in this water balance are the entries for CWC and were independently calculated to verify the results shown in M36 (AWWA 2009).

Monthly and annual water use for CWC in gallons per capita per day (gpcd) is shown in Table 1 for residential, industrial, commercial, and agricultural uses, and water losses. The information in Table 1 provides a direct way to evaluate the relative importance of water losses in terms of gpcd. In this example, water losses account for 26 percent of the total water supplied of 326 gpcd. Indeed, water loss is the second largest component of the water supplied.

Peak water demand is also important in urban water management. Peak water demand is 446 gpcd in August, and water losses account for 22 percent of this usage. These major end-use categories can then be further partitioned into their components for conservation evaluations. For example, residential water use can be divided into indoor water use at 71.7 gpcd and outdoor water use of 100 gpcd.

Similarly, the water loss audit partitions this component into its sub-components as seen in Figure 1, which shows a distribution of water uses that is focused on water losses. In a water balance, losses can be calculated as the difference between the metered water supplied and the metered water delivered. Water losses are defined differently in the M36 audit, as discussed next.

The partitioning of total water supplied into its components is shown in Figure 1. It is instructive to examine this water balance in order to understand its development. A more detailed description of the component terms is provided in AWWA (2009), which also includes this same example application to CWC.

The AWWA water audit uses units of million gallons per year. The total gallons per year can be converted to gpcd by dividing by the population served. Then Table 1 and Figure 1 can be compared directly.

To maintain consistency with the AWWA reporting format, the values in Figure 1 are shown in millions of gallons per year (mil. gal./yr.). The total water supplied of 4,401.4 mil. gal./yr. is simply the system input volume (3,617.7 mil. gal./yr.) plus imports (783.7 mil. gal./yr.) and minus exports (0 mil. gal./yr.). Each of these terms is measured and the values are adjusted for meter error as necessary.

Month	Residential gpcd	Industrial gpcd	Commercial gpcd	Agricultural gpcd	Losses gpcd	Total gpcd
1	127.8	31.2	7.1	0.0	38.5	204.6
2	157.2	34.6	7.8	0.0	52.0	251.7
3	142.0	31.2	7.1	0.0	53.4	233.7
4	161.4	35.2	7.3	22.0	160.8	386.7
5	184.7	37.0	7.1	49.7	106.5	384.9
6	205.5	44.1	7.3	67.5	98.7	423.0
7	226.9	42.6	7.1	49.7	89.5	415.8
8	232.3	42.6	7.1	65.3	98.7	446.0
9	205.5	41.1	7.3	58.7	88.2	400.8
10	142.0	31.2	7.1	0.0	80.4	260.7
11	146.8	32.3	7.3	0.0	83.0	269.3
12	127.8	31.2	7.1	0.0	66.2	232.3
Average	171.7	36.2	7.2	26.1	84.7	325.8
% of total	52.7%	11.1%	2.2%	8.0%	26.0%	100.0%

Table 1: Monthly and annual gpcd for four direct-use categories and water losses for CWC.

Item	Description	mil. gal./yr.
1	Fire fighting and training	9.7
2	Flushing water mains, storm inlets, culverts & sewers	2.6
3	Street cleaning	1.8
4	Landscaping/irrigation in large public areas	162.9
5	Decorative water facilities	1.8
6	Swimming pools	0.4
7	Construction sites	0.6
8	Water quality and testing	1.2
9	Water consumption at exempt public buildings	2.2
10	Other	0.9
	Total	183.8

Table 2: Sum of individual estimates of unbilled metered consumption (adapted from AWWA 2009).

The 84.7 gpcd shown in Table 1 corresponds to the 1,143.3 mil. gal./yr. Non-Revenue Water (NRW) in Figure 1. The customer metered billing uses are called Revenue Water (RW) and are measured directly as 3,258.0 mil. gal./yr.

NRW is the calculated difference between two measured quantities. RW is the sum of two terms, the most important of which is billed metered consumption, which is the only non-zero entry in this example. Its value is 3,258.0 mil. gal./yr., the same as RW.

The Billed Authorized Consumption is equal to RW. Unbilled Authorized Consumption is the sum of unbilled metered and unmetered consumption. The largest entry is for unmetered consumption, which is the sum of individual estimates of 10 items, as shown in Table 2. The bulk of this estimate is water use for landscape irrigation that accounts for 162.9 mil. gal./yr. of total use. The other uses are relatively minor.

The quality of these estimates can be expected to vary widely compared to metered values. Returning to Figure 1, Authorized Consumption is actually the sum of metered and

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	Residential usage, mil gal/yr			2,318.8		Meter	Meter
Flow	% of Time	Avg. gpm	gpm%	% volume	mil gal/yr	Registration %	Error, mil gal/yr
Low	15.0%	0.75	0.11	2.0%	46.4	88.8%	5.9
Medium	70.0%	5	3.50	63.8%	1,479.4	95.0%	77.9
High	15.0%	12.5	1.88	34.2%	793.0	94.0%	50.6
Total	100.0%		5.49	100%	2,318.8		134.3

Table 3: Calculated residential meter error for CWC.

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unmetered terms. In this case, the accuracy is still good, since the majority of the authorized consumption is metered.

For water utilities that are just starting the auditing process and are lacking detailed system data, water losses can now be determined as the residual water. Water loss equals water supplied minus authorized consumption.

Water losses are the sum of apparent and real losses. In a purely top-down water audit approach, as used in the AWWA Free Water Audit Software, apparent losses are quantified first, then real losses are estimated as the calculated residual, i.e., total losses minus apparent losses. Thus, real losses are not measured directly but rather are a calculated residual based on a combination of measured and estimated values.

No insight is given to the breakdown of real losses into sub-components in the top-down, or initial, auditing approach. Eventually water utilities should move from a cursory top-down approach and conduct leak detection and flow/pressure measurements that will provide actual quantities of leakage volumes. At this stage, the more valid measured leakage quantities should replace the cursory leakage volumes calculated initially in residual fashion.

Apparent losses are the sum of unauthorized consumption, customer meter inaccuracies, and systematic data handling errors. For the initial top-down approach, the IWA/AWWA Water Audit method suggests estimating unauthorized consumption as 0.25 percent of supplied water. Using this assumption, unauthorized consumption is 11 mil. gal./yr.

Systematic data handling errors are site specific. In this example, they account for only 21.29 mil. gal./yr.; however, such errors in the billing process can be considerable. Also, it is essential to first gauge the extent of data handling error because appreciable error here can compromise the volumes of customer consumption entered into the water audit.

Customer meter inaccuracies can have a major impact on the measure of Non-Revenue Water; however, the auditor must develop reliable local data on the meter population demographics and sample accuracy testing to develop a credible estimate of this term. Procedures for estimating water meter inaccuracies are described next.

Water Meter Inaccuracies

At the utility level, one or more master meters record supplied volumes at critical points in the water network. At the customer level, each residential customer has either a single meter or two meters—one for indoor and one for outdoor usage. Some uses, such as water used for street cleaning, may not be metered. Other users may have submeters to isolate the effects of certain uses, such as cooling water.

Accordingly, a fundamental component of water loss accounting is verification of the accuracy of meter readings. Meter testing procedures and protocols exist to make such measurements, and a requirement for meter testing is often prescribed as a conservation measure (AWWA 1999). The meter error adjustment is an estimate of the systemic error of the meter readings. The meter adjustment, M_e, is:

$$M_e = (1+ e) \qquad (3)$$

Where e = % error.

For example, if the meter error is +2 percent, then e = 0.02 and the corrected reading is 102 percent of the measured reading. This corrected reading is then used as the best estimate of the expected value of the meter reading.

A recent audit performed for the city of Las Vegas, New Mexico, revealed a master meter error of 0.2 to 0.7 percent for meters which were three years old, based on manufacturer specifications (Hydrosphere 2007). Fanner *et al.* (2007) indicate that master meters typically have an under or over registration of 0.2 to 1 percent, depending on meter age and installation procedures.

If meter errors are random and in the range of 1 to 2 percent, then they would not impact a deterministic water balance, which is the topic of this paper. It is easy to include the variability in each parameter estimate and utilize Monte Carlo simulation to evaluate the individual and overall uncertainty of the estimates. Errors in master meters can be either positive or negative.

While the literature suggests that master meters can have a small positive or negative error, customer billing meters are thought to have a stronger tendency to under register (AWWA 2009). If customer meters under register, then the error in equation 3 would be positive. In this case, the utilities have a stronger financial incentive to replace customer meters in order to increase revenue.

The city of Austin, Texas (2006), did an audit of its 2005 water use and reported a loss rate of 15.2 percent. It was estimated that under-recording customer meters were responsible for over 25 percent of this loss, or 3.8 percent. Customer metering inaccuracies represent the collective under registration of all customer meters in a utility. Based on test studies of anonymous water utilities, typical average customer meter under registration is about 5 to 6 percent (Thornton *et al.* 2008).

The overall extent of customer meter inaccuracies should be determined by local meter testing studies where the actual size distribution and ages of meters are known. The M36 Manual includes explicit procedures for estimating meter inaccuracies (AWWA 2009). These local data are essential components of a top-down audit of real and apparent losses.

The residential meter losses for CWC are calculated in Table 3 for 5/8-inch and 3/4-inch meters. These meters register 88.8 percent, 95.0 percent, and 94.0 percent of the correct value for low, medium, and high flows, respectively.

The percent time in each flow regime is multiplied by the flow rates to derive the percent of total residential flow that occurs in each flow range. This number is converted to mil. gal./yr. Finally, the meter error is calculated in mil. gal./yr.

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For this example, the total residential meter error is 134.3 mil. gal./yr. out of a total of 2,318.8 mil. gal./yr. Thus, the residential meters are under recording by 5.5 percent. This answer is very close to Thornton's (2008) estimate of under registration of 5 to 6 percent. Using similar calculations for the non-residential meters, the total customer meter inaccuracy is 164.4 mil. gal./yr., as shown in Figure 1.

Infrastructure Data	Value
Population served	37,000
Miles of mains, Lm	250
Service connections	
Residential	11,490
Commercial, Industrial & Agricultural	706
Total connections	12,196
Average length of service connection, Lp, ft.	18
Number of fire hydrants, Nf	2,750
Average length of hydrant leads, Lh, ft.	12
Average operating pressure, psi	65

Table 4: General physical attributes of the CWC test case.

Table 5: Selected water loss performance indicators from the water audit.

Description	Value	%
Water supplied, gpcd	325.9	100.0%
Non-revenue water, gpcd	84.7	26.0%
Current annual real losses, CARL, gpcd	69.9	21.4%
Apparent losses, gpcd	14.6	4.5%
Real losses, gpcd	55.3	17.0%
UARL, gpcd	6.2	1.9%
ILI = CARL/UARL	8.9	

Real Leakage Losses

The apparent losses for CWC total 196.6 mil. gal./yr. This value is deducted from the total losses of 944.1 mil. gal./yr to derive the final estimate of 747.5 mil. gal./yr. These real losses are called current annual real losses (CARL).

The IWA/AWWA Water Audit Method features several performance indicators to assess leakage standing. The best target-setting indicator expresses the CARL divided by the number of service connections in the system, further divided by 365 to give units of gallons/service connection/day. In the CWC example, a value of 46.8 gallons/service connection/day of leakage was calculated.

The IWA/AWWA Water Audit Method also features a benchmarking performance indicator for real losses known as the Infrastructure Leakage Index (ILI), calculated as:

ILI = CARL/UARL, dimensionless

The UARL is defined as unavoidable annual real losses, which are an estimate of the lower bound on real losses in the network based upon network characteristics such as the size of the system and the average water pressure level (Lambert *et al.* 1999, AWWA 2007). The equation used to estimate UARL is:

$$\text{UARL (gal./day)} = (5.41 {*} L_m + 0.15 {*} N_c + 7.5 {*} L_p) {*} P \quad (4)$$

where

L_m = length of mains and hydrant connections, miles

N_c = number of connections

L_p = length of private service piping from edge of street to customer meter, miles

P = pressure, psi

Equation 4 is considered to be valid for utilities with at least 3,000 connections, a minimum pressure of 35 psi, and at least 32 connections per mile of water main.

This equation was developed by a team of international experts working under the IWA Water Loss Task Force. The database for the equation is 27 water utilities in 19 countries (Fanner *et al.* 2007). UARL depends on four variables and their coefficients, i.e., the length of water mains and hydrant connections, the number of connections, the length of private service piping, and the pipe pressure. The values of the variables needed to calculate UARL for CWC are shown in Table 4. The calculated value of UARL is 83.69 mil. gal./yr.

Knowing CARL and UARL, the Infrastructure Leakage Index (ILI) can be calculated using Equation 5.

$$\text{ILI} = \text{CARL/UARL} = 47.5/83.69 = 8.9 \quad \text{with ILI} \geq 1.0 \quad (5)$$

M36 suggests that utilities with relatively expensive or scarce water should operate with relatively strict leakage controls, reflected by an ILI in the range of 1 to 3. Utilities with somewhat less expensive or scarce water resources could tolerate slightly higher leakage levels, as denoted by an ILI value in the range of 3 to 5.

An ILI value in the range of 5 to 8 can be tolerated if water is relatively inexpensive and abundant. Values greater than 8 are discouraged. Values of ILI less than 1.0 are considered to be impossible because UARL is defined as a best practice lower limit on real losses. The reader is referred to the 2009 M36 for a more complete interpretation of ILI.

Water Audit Performance Indicators

The third edition of M36 presents several water audit performance indicators. The selected subset of these indicators is presented in Table 5. Non-revenue water expressed as a percentage provides a direct estimate of the water loss in the system. A total of 26.6 percent non-revenue water indicates a system with a high level of losses.

The results in Table 5 can be used along with Table 1 to evaluate the relatively important components of water use. For example, non-revenue water of 84.7 gpcd exceeds the estimated residential indoor water use of about 71 gpcd. Apparent losses are of some importance at 14.6 gpcd. Ultimately it is important to compare the relative cost effectiveness of loss control versus available water demand management options and other supply options.

ILI is a useful indicator for evaluating real losses, but it doesn't relate in any obvious way to water losses. For example, Fanner *et al.* (2007) show calculated values of ILI and real losses expressed as a percentage for 17 utilities, as seen in Figure 2. The wide variability in the relationship between ILI and real losses is evident; accordingly, ILI does not appear to be a good substitute for existing measures for water use regulation.

Water loss control regulations in Florida and elsewhere are based on a maximum allowable percent water loss. Thus, it is still necessary to calculate this statistic, along with calculating the relative importance of water loss as a portion of the gross gpcd. A percent system loss of 10 percent or greater and 12 percent or greater in the Southwest Florida Water Management District triggers a requirement for the utility to evaluate its distribution sys-

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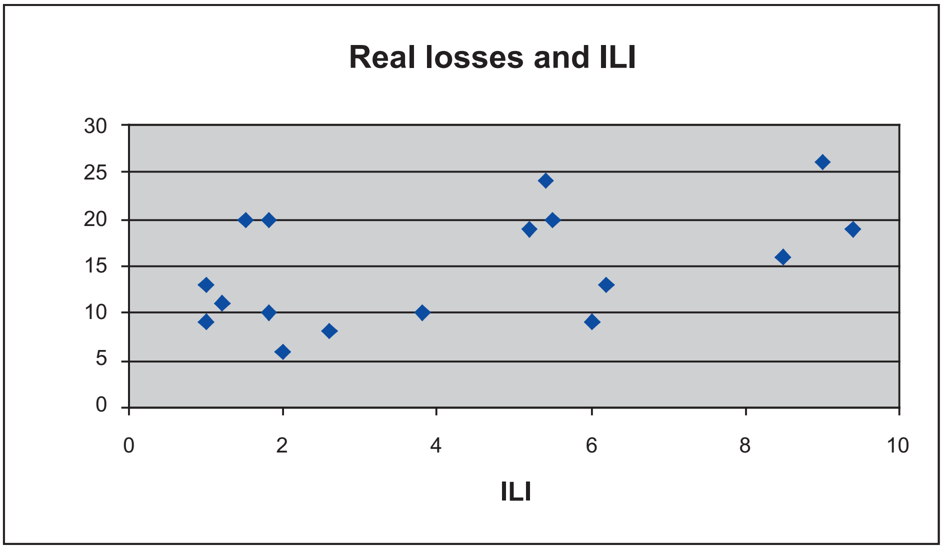

Figure 2: ILI versus real losses for 17 utilities (Fanner et al. 2007).

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tem and fix leaks and meters until the percent loss is below this threshold.

Summary & Conclusions

The focus of this article is methodologies to estimate water loss in public water supply systems in Florida as part of a water conservation plan. Only losses or gains in the distribution/transmission network are addressed. Based on this evaluation, the following recommendations are made:

- Florida water utilities should adopt the water audit and loss control procedures that are described in the third edition of M36, a manual of water supply practices titled *Water Audits and Loss Control Programs* (AWWA 2009), including the water audit procedures outlined in Chapter 2. The process described in the M36 is complimented by use of Version 4.0 of the AWWA Free Water Audit Software, which offers an effective, standardized method to compile water audit data from many water utilities and conduct effective analysis of loss levels and cost impacts. Current procedures for estimating water losses in Florida are not uniform, and the accuracy of the reported estimates of water loss is questionable.
- The water utility industry in North America is at the advent of implementing robust, standardized methods to assess water and revenue losses. Rather than key on loss reduction targets at this time, it is more important for the industry to establish standardized water audit data collection protocols and carry out such data collection over a period of several years. Systematic improvement of data validity should be the primary focus of this phase of activity. Only when a sufficient pool of reliable data exists can reliable assessments of loss levels and realistic target reduction levels be developed.
- Water loss can be viewed as a water use category, as shown in Table 1, so that its relative importance in terms of gpcd can be compared with other uses. The cost-effectiveness of water loss control can then be compared with water conservation options and supply augmentation.
- Quantitative measures of meter accuracy are an essential part of water audits and water conservation evaluations. Regulations regarding meters should require quantitative estimates of meter performance following accepted national procedures, as described in AWWA M6, M22, M33 and M36.
- The M36 water audit method should be added to the *Guide* as the preferred approach to evaluate water loss and conduct water audits.
- Water losses occur from the sources to the treatment facilities, within the treatment facilities, and on the customer's side of the meter. In some cases, these losses might be as significant as distribution/transmission system losses. They also should be considered in systems with extensive raw water transmission piping, and/or where high customer consumption suggests excessive waste is occurring beyond the customer meter.

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