Reducing Non-Revenue Water: A Myriad of Challenges

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The functional population of the Tampa Water Department service area has steadily increased to approximately 640,000 persons. As a consequence, demand for potable water in the area has increased significantly over the past several decades.

Raw water from the Hillsborough River Reservoir is treated at the David L. Tippin Water Treatment Facility, which has a treatment capacity of 100 million gallons per day (MGD). By permit, the city can not withdraw more than an annual average of 82 MGD from the Hillsborough River Reservoir, so demand greater than 82 MGD is supplied by Tampa Bay Water, a wholesale supplier.

There is a significant cost differential between wholesale water and water produced at the David L. Tippin Facility (see Table 1). As a result of continued population growth, the average daily flow has exceeded 82 MGD, requiring increasing amounts of water to be purchased from Tampa Bay Water at the increased unit cost.

Historically the Tampa Water Department has had very low rates when compared to other Florida water utilities. The existing rate structure will be gradually increased during the next five years to fund buried infrastructure replacement, minimum flows and levels (MFL), and supplemental wholesale water purchases, so there is a strong incentive for the water department to continue its tradition of optimizing the use of its water resources.

Beginning in 1989, the water department implemented a number of water conservation strategies to better manage the city's potable water supply and preserve water resources. Some of these strategies included an increasing block tiered rate structure, public education campaigns, irrigation demand reduction programs, and requirements to install low consumption plumbing fixtures for all new construction and renovated buildings.

After acute regional shortages occurred during the 2001 drought, the department also launched the South Tampa Area Reclaimed (STAR) Project in an effort to decrease demands on regional potable water supplies using reclaimed water. A water use restriction ordinance became effective November 2003, placing restrictions on lawn and landscape watering and other non-potable uses, such as car washing. This ordinance was further amended in May 2006, imposing even stricter guidelines.

As part of its overall water-loss management efforts, the water department also established a program to measure and track non-revenue water (NRW). The NRW percentage — a simplified comparison of the quantity of water produced and the quantity of water-generating revenue — historically has been used as an efficiency metric for water utilities.

The department has been tracking NRW closely since the early 1990s. This continual tracking provides a mechanism to detect changes or anomalies on an ongoing basis. The department launched investigations to determine the cause(s) of an apparent eight-month increase in its NRW water percentage occurring during fiscal year 2003 (Figure 1).

Internal Investigations

Much effort was expended by water department staff to discover a "smoking gun" cause for the apparent NRW increase. The nature of the initial spike in Figure 1 suggests a smoking gun, but the near-linear increase beginning in mid fiscal year 2003 does not

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Cost per Unit Volume for Potable Water from Tippin Water Treatment Plant	Cost per Unit Volume for Potable Water Demands >82 MGD Annual Average
$600 / MG	$3,150 / MG

Table 1. 2006 Potable Water Costs

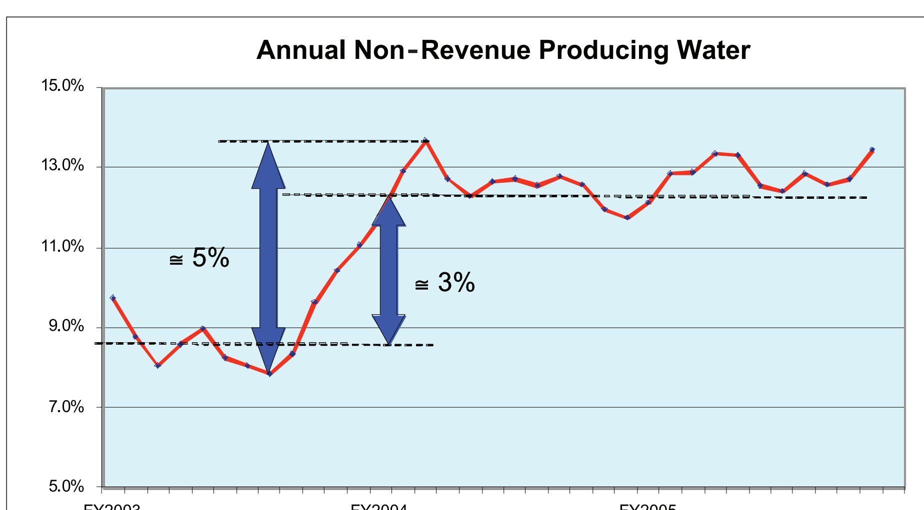

Figure 1. TWD Non-Revenue Water 12-month rolling average.

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continue for a full 12 months, as would be expected when calculating a 12-month rolling average after a step input. This situation added to the frustration and complexity of determining the cause(s).

An internal investigation of particular interest is the effort in testing and calibrating the five finished water venturi meters at the David L. Tippin Water Treatment Facility. The instrumentation for these meters is checked and calibrated quarterly by production personnel, but it is necessary to rely on manufacturer-supplied information to utilize the instrumentation data correctly to determine flow from the primary device.

Because of a period of time when the water department increased the calcium carbonate precipitation potential in reaction to a red water episode, the flow equations for the primary devices (venturi meters) came into question. Figure 2 illustrates how a uniform coating of scale on the inside of a venturi causes the meter to read fast. This was a theory potentially explaining the increase in non-revenue water.

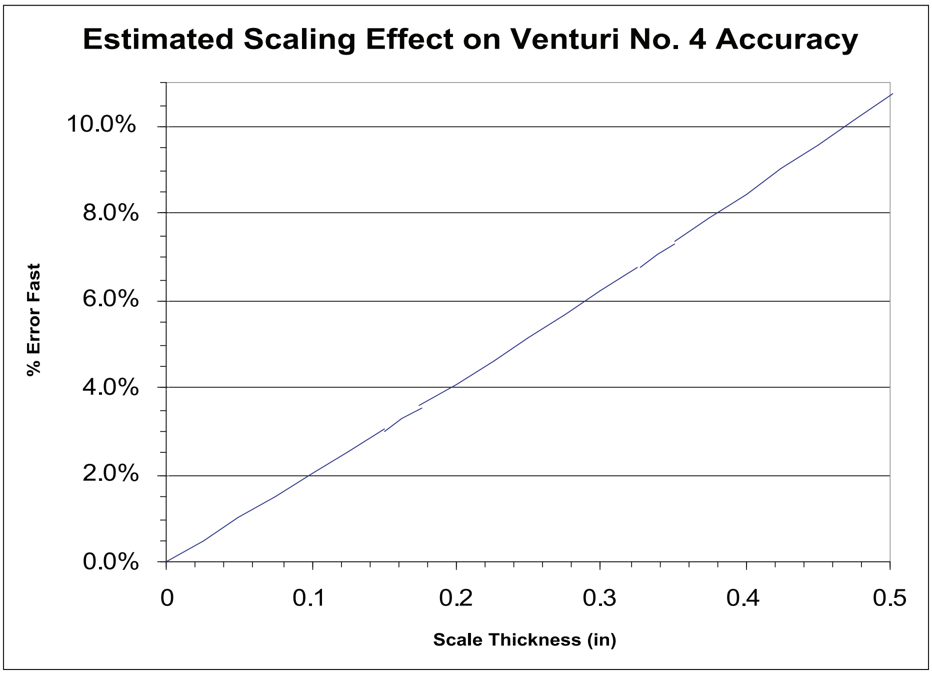

Figure 2. A decrease in pipe and venturi inside diameters causes a venturi meter to read fast.

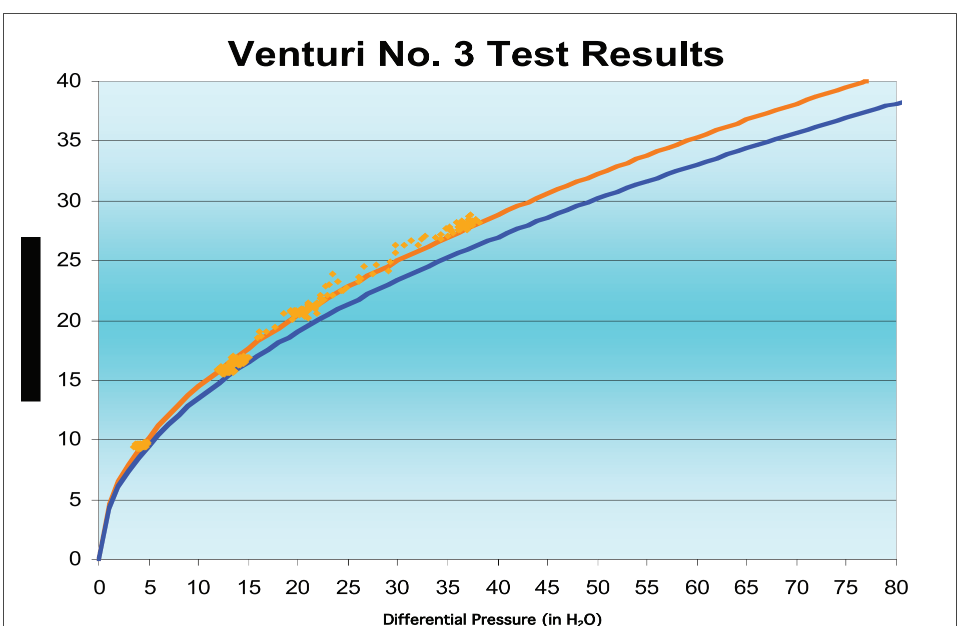

Figure 3. Test results (orange line) compared against actual meter readings (blue line.) The test for this particular meter indicates that it was reading slightly slow.

Operational and physical constraints did not allow for a direct inspection of these specific meters to determine scale thickness, so their accuracy was checked by utilizing traditional pitot tubes. This testing was performed on site under a variety of flow ranges, and results indicated that the meters were reading slightly slow, as opposed to fast. Applying a correction factor further increased the accuracy of the plant-wide water balance, providing evidence that the finished water venturi meters were not the cause of the increase in non-revenue water.

Other water department investigations included analyzing available meter accuracy data, accounting procedures, meter studies and a review of the city's billing system.

Water Audit Using AWWA-IWA Methodology

The American Water Works Association (AWWA)-approved methods and tools for such projects were developed through the AWWA Water Loss Control Committee and published in a peer-reviewed committee report in the August 2003 *AWWA Journal*. This article adopts the International Water Association's (IWA's) Water Loss Committee methodology.

The initial step was to complete a comprehensive water audit applying the AWWA's new Microsoft Excel-based water audit tool. The water audit, which was conducted through a highly interactive consultant/water department team, included a complete analysis of all physical flow streams between the source water and end users.

The audit resulted in quality data on authorized consumption, apparent water losses, and real water losses. Step 1 also included an analysis of the financial impacts of non-revenue water, including the computation of unavoidable annual real loss (UARL), the infrastructure leakage index (ILI), and an analysis of lost revenues from apparent water losses.

Real losses are caused by system leakage in the distribution system and storage overflows. Normally they are valued at the marginal cost of additional water production to offset losses, but in the Tampa Water Department's case, the marginal cost of leakage is a blended rate that includes the cost of purchasing and pumping water from a wholesale supplier, currently approximately $3,150. Figure 5 shows the increasing marginal cost of water based on projected future demand increases and an increased percent-

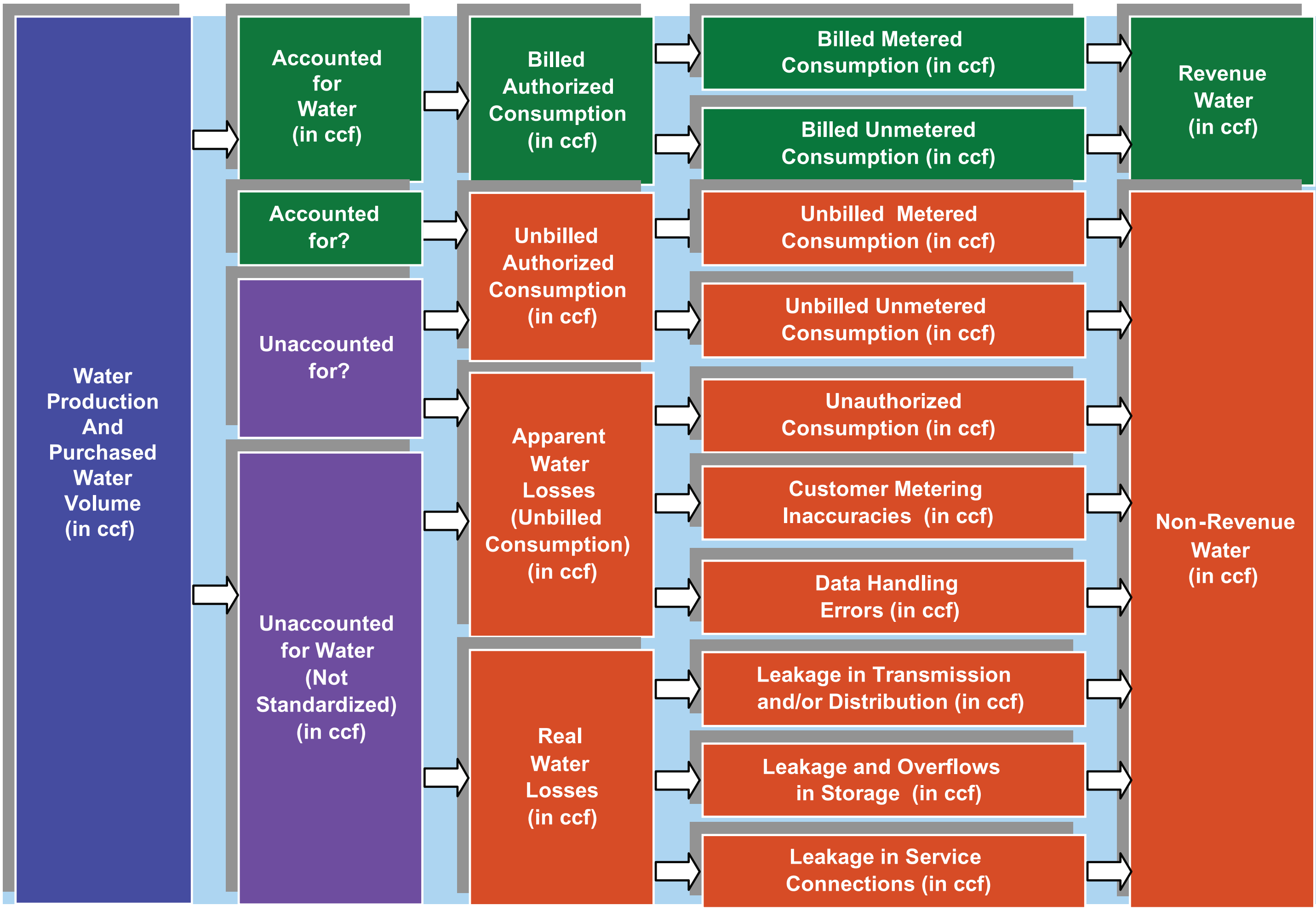

Figure 4. Water Balance Summary Chart (Not to Scale)

age of purchased water at the higher rate.

Apparent losses result from customer meter errors, administrative/billing errors, unauthorized consumption (theft) and authorized unbilled uses. These losses may be more significant financially than real losses and equate to lost revenues valued at the full tariff rate. Based on the inclining block tariff structure for different classes of customers, an average blended rate of $1.86 per 100 cubic feet or $2,487 per million gallons (MG), was used in the water balance.

Water Audit Results & Analysis

Some key results of the initial water audit analysis are summarized in the following series of figures: Non-revenue water for fiscal year 2005 was 12.7 percent, or approximately 3,700 MG (Figure 6). Real water losses are the dominant component by volume (Figure 7). Apparent losses, specifically meter error and theft, are far more dominant on a cost basis (Figure 8).

Real water losses are valued at the marginal cost of water production. Figure 9 shows the more likely cost of real losses when inflation and the blended rate marginal costs are applied. Figure 10 shows projected future costs for water main and service line leak/break repair, which are additional system wear-out-related costs over and above the cost of the lost water.

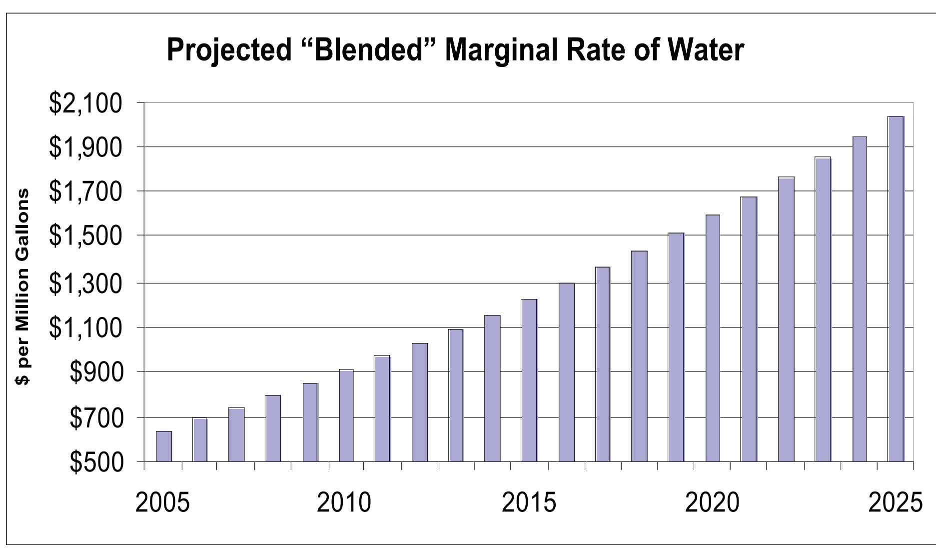

Figure 5. Projected Increase Marginal Rate Unit Cost

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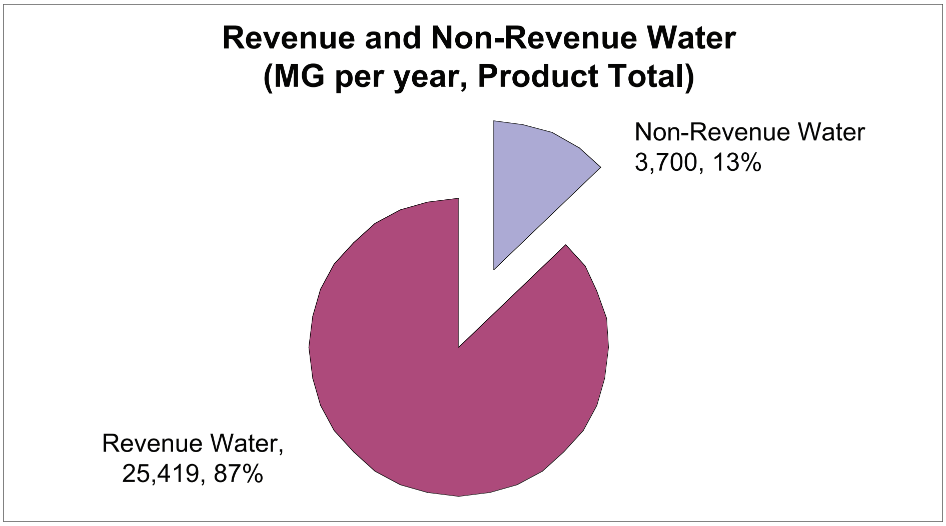

Figure 6. Approximately 87 percent of treated water produces revenue.

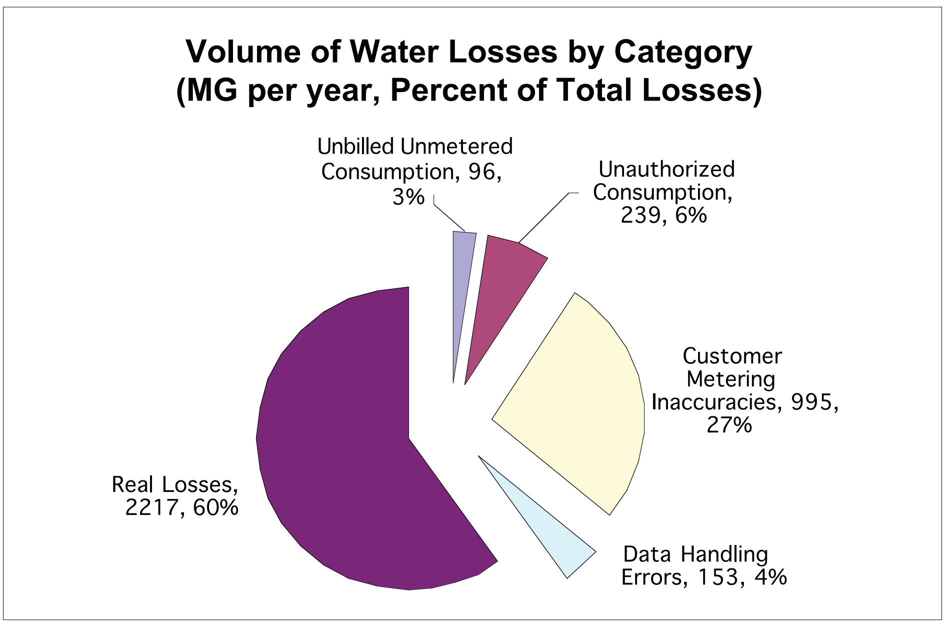

Figure 7. Non-Revenue Water Volume-Based Summary

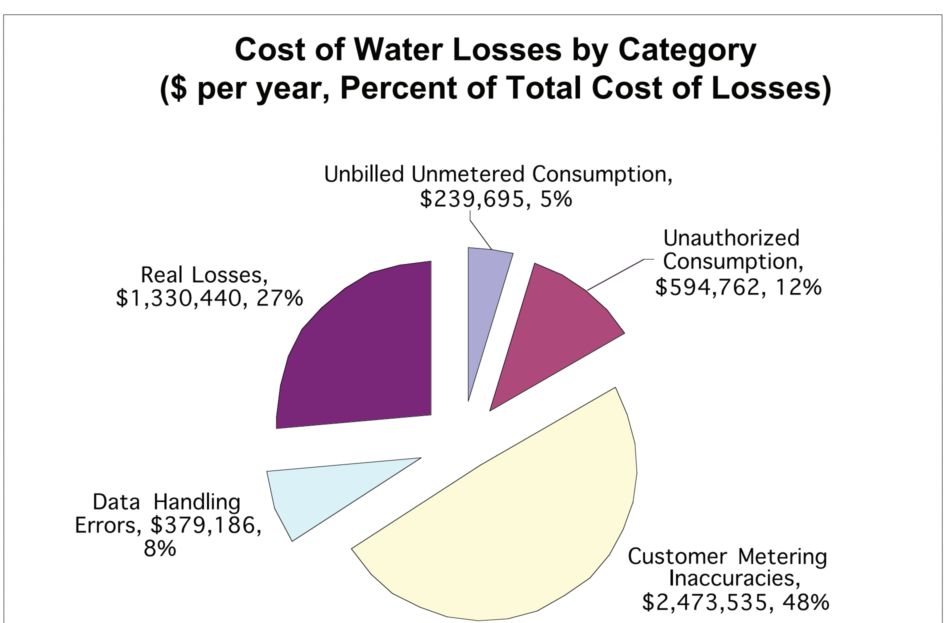

Figure 8. Non-Revenue Water Cost-Based Summary (Baseline)

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Key operational performance indicators for the FY 2005 water balance are shown in Figure 11. The Tampa Water Department's UARL is 1.95 million gallons per day. The calculation of the UARL factors in the length of the water mains, the average water pressure, the number of service connections, and the average length of service connection piping. The UARL represents the technical low level of leakage in a system that could exist if the best management practices for leakage management were applied.

The water balance shows that the ILI for the Tampa Water Department is 3.12. The ILI is a dimensionless ratio of the real losses over the UARL and gives an indication of the actual leakage of the system relative to the lowest level achievable with today's best technology. The value of 3.12 indicates a reasonable control of the leakage in the system.

The ideal level of leakage control, defined as the Economic Level of Leakage (ELL), is derived from the level at which the value of leakage reduction meets the cost saved through investment in aging water main replacement and rehabilitation. Determining the optimal ELL for the Tampa Water Department requires further analysis and depends directly on the marginal cost of water and the annual water main replacement investment.

One of the key advances of the AWWA-IWA methodology is the transition to a business-based analysis. Historically, a non-revenue water percentage of 15 percent was viewed as an acceptable level of performance in systems such as the Tampa Water Department with older water main infrastructure. Under the traditional thinking still prevalent among North American water utilities, a water balance result of 12.7 percent suggests that things are fine. The full accounting principle applied in the AWWA-IWA methodology—all water needs to be accounted for—coupled with the introduction of cost analysis of both lost revenues and increased operating costs, presents a slightly different picture.

Water Loss Reduction Implementation Plan

Subsequent steps toward developing a Tampa Water Department Comprehensive Water Management Program include a comparison of the department's practices with best management practices for reducing NRW and developing a comprehensive NRW reduction implementation plan. This plan was developed applying a business case approach that allows for the comparison of implementation costs, resultant NRW reduction savings, and service level improvements as compared with a no-action baseline.

Meters are a good example of the business case process that was applied by the consultant/water department team. Based on the initial water balance, meter error was identified as the major component of apparent losses.

Large meters (>3") are currently calibrated annually. In contrast, residential meters become replacement candidates when they reach 10 years of age. This policy was developed from a previous study that determined meter under-registration as a function of age. The team looked at the current residential meter population and found that almost 40 percent of the residential meters were older than eight years.

A limited set of recent residential meter calibration data by age was also analyzed to allow some initial conservative estimates of losses to be developed. Figure 12 shows estimated under-registration as the meter ages from the available calibration data. This translates to 767 MG/year for fiscal year 2005, or lost revenues of $1.9 million for water meter under-registration based on the meter calibration data that was available by age for residential meters.

The meter program is clearly a candidate for Phase 1 priority evaluation. A list of activities include:

1. Calibration testing on representative population of large, medium and small meters by size and type.
2. Business case/cost-benefit analysis to determine optimal replacement/overhaul frequency by meter size and type.
3. Analysis and contribution of a fixed-based AMR program in the meter calibration and replacement strategy.
4. Consideration of the maintenance sources required for both meter calibration and more frequent replacement/overhaul.
5. Corrective steps to reduce the backlog of small meters > eight years old, coupled with an analysis and decisions on AMR (e.g., AMR-enable meters with transmitters).

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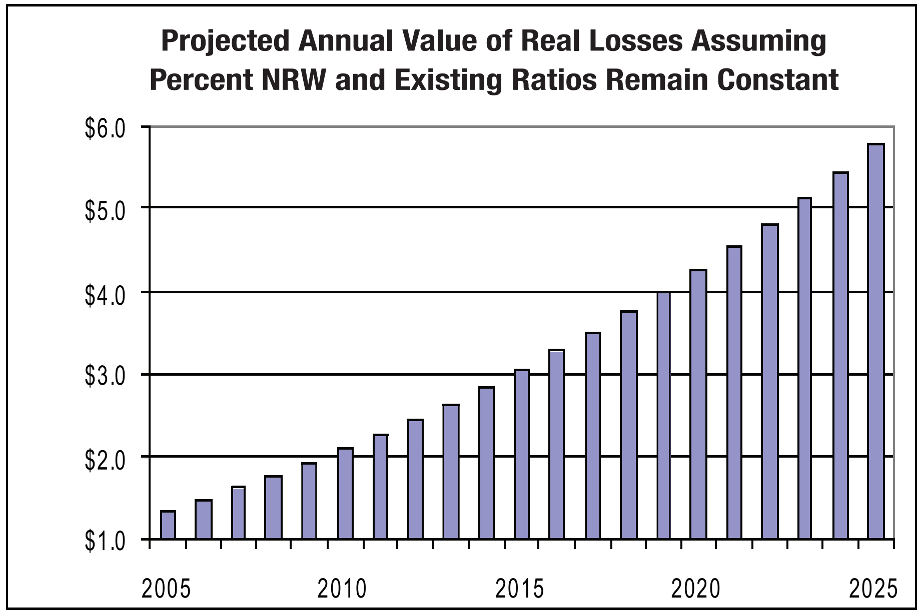
Figure 9: Projected Annual Value of Real Losses



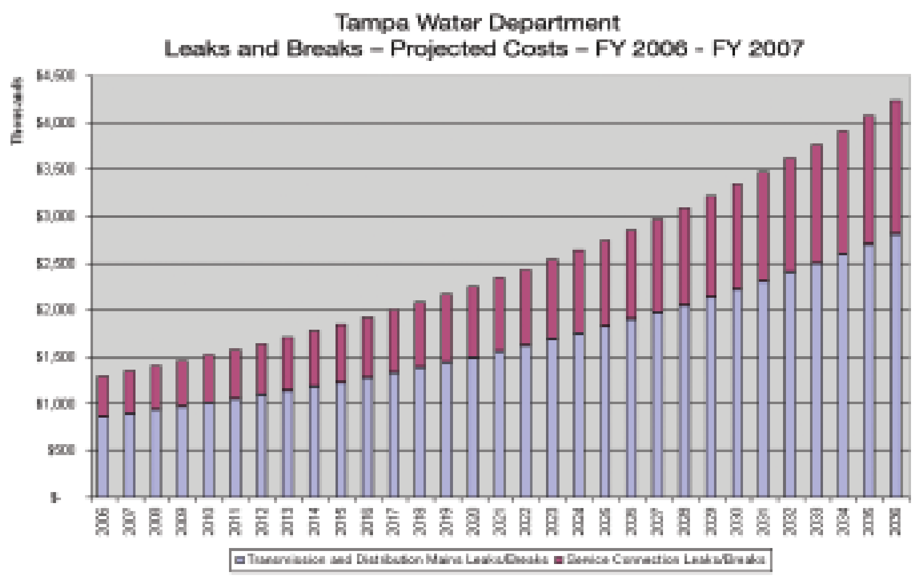
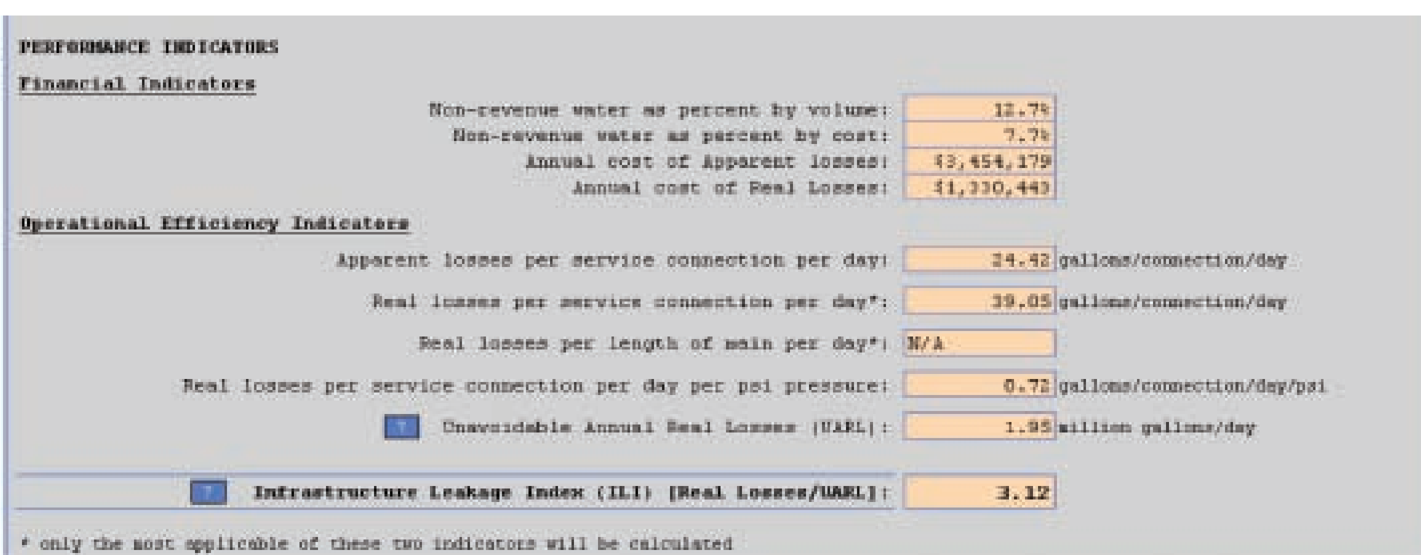


Figure 10. Projected Cost of Water Main/Service Line Leak/Break Repairs


PERFORMANCE INDICATORS

Financial Indicators

Non-revenue water as percent by volume: 12.7%
Non-revenue water as percent by cost: 7.7%
Annual cost of Apparent losses: $3,454,179
Annual cost of Real Losses: $1,330,443

Operational Efficiency Indicators

Apparent losses per service connection per day: 24.42 gallons/connection/day
Real losses per service connection per day*: 39.05 gallons/connection/day
Real losses per length of main per day*: N/A
Real losses per service connection per day per psi pressure: 0.72 gallons/connection/day/psi
Unavoidable Annual Real Losses (UARL): 1.95 million gallons/day

Infrastructure Leakage Index (ILI) [Real Losses/UARL]: 3.12

* only the most applicable of these two indicators will be calculated

Figure 11. Water Balance Performance Indicators for FY 2005

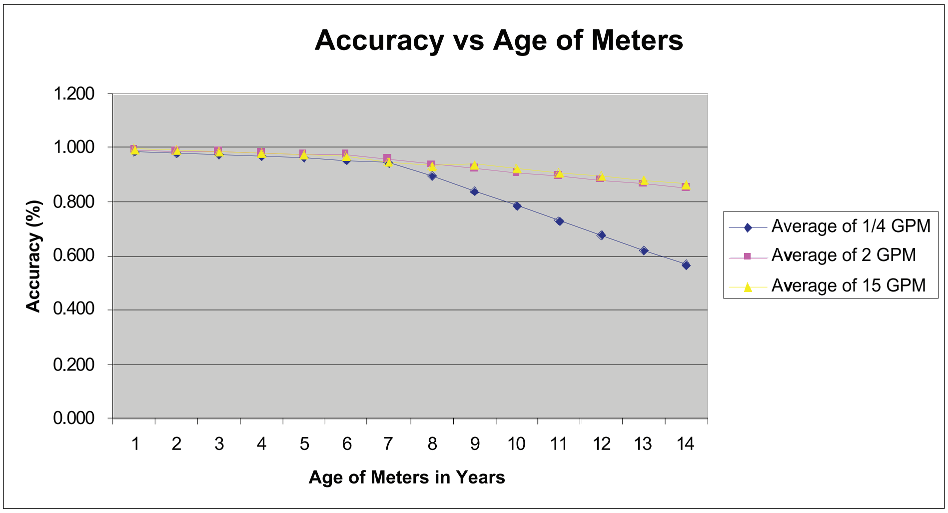


Figure 12. Small Meter Calibration Error

HIGH PRIORITIES

- Continual Improvement Process/Improved Data Quality to Refine Water Balance
- Leakage Management/Asset Management Program
- Short-Term Meter Accuracy Improvements
  1. Formalize master meter calibration schedules
  2. Meter/chamber replacement, calibration optimization by meter size/class
  3. Meter reading and data handling improvements
  4. Convert bimonthly meter reads to monthly

HIGH PRIORITIES (cont'd)

- Long-term Customer Meter Improvements – Automatic Meter Reading (AMR)
- Unauthorized Use (theft) Reduction Initiatives

MEDIUM PRIORITY

- Improve Link Break Data

LOW PRIORITIES

- Synchronize Pumped to Sold Data
- Standardize Flushing/Hydrant Data

Figure 13. TWD Priorities for Water Loss Reduction

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Leak detection is a second example. The Tampa Water Department has been evaluating the feasibility and business case for a formal leak detection program for some time. Based on the water balance for fiscal year 2005, real loss leakage is 2,217 MG per year, or 7.6 percent of the total water production (29,119 MG).

The department has been investigating a formal leak detection program using Fluid Conservation Systems equipment, which includes a network of 7,240 logger units. Using the marginal water cost of $3,140/MG or $2.35 per 100 cubic feet (the department's wholesale rate plus pumping costs) for a small but increasing amount of water annually, the projected five-year return on investment is favorable.

Implementing a formal leak detection program is a high priority in the overall NRW reduction strategy. Steps to implement the leak detection program include:

- Updating the leak detection program plan and costs.
- Conducting a pilot (proof of concept).
- Finalizing the business plan and investment/savings forecast.
- Approval for capital investment and increased operating costs.
- Purchasing.

A process similar to the two examples was applied to all the target areas. Other high priorities include leak reduction/asset management, meter error reduction, and unauthorized consumption reduction. Figure 13 provides a breakdown of the key priorities developed from the business case analysis.

One core principle in the AWWA-IWA methodology is that water loss management is a continual improvement process. The initial top-down water balance using the AWWA WLCC Water Audit Software tool© provides a starting point for completing an initial analysis but the methodology calls for continued refinement of the data and periodic water audits to track progress. The first year implementation includes a number of key initiatives to improve the quality of the water balance data and developing standard procedures for comprehensive annual water balance updates. The monthly NRW tracking will be continued but the process automated and other key performance indicators will be added and evaluated by the water loss reduction committee.

A series of workshops were convened to develop a three-year road map for water loss reduction covering fiscal years 2007, 2008, and 2009. Each year's activities are linked with the continual improvement process and recorded on a recurring Gantt chart for future water department use.