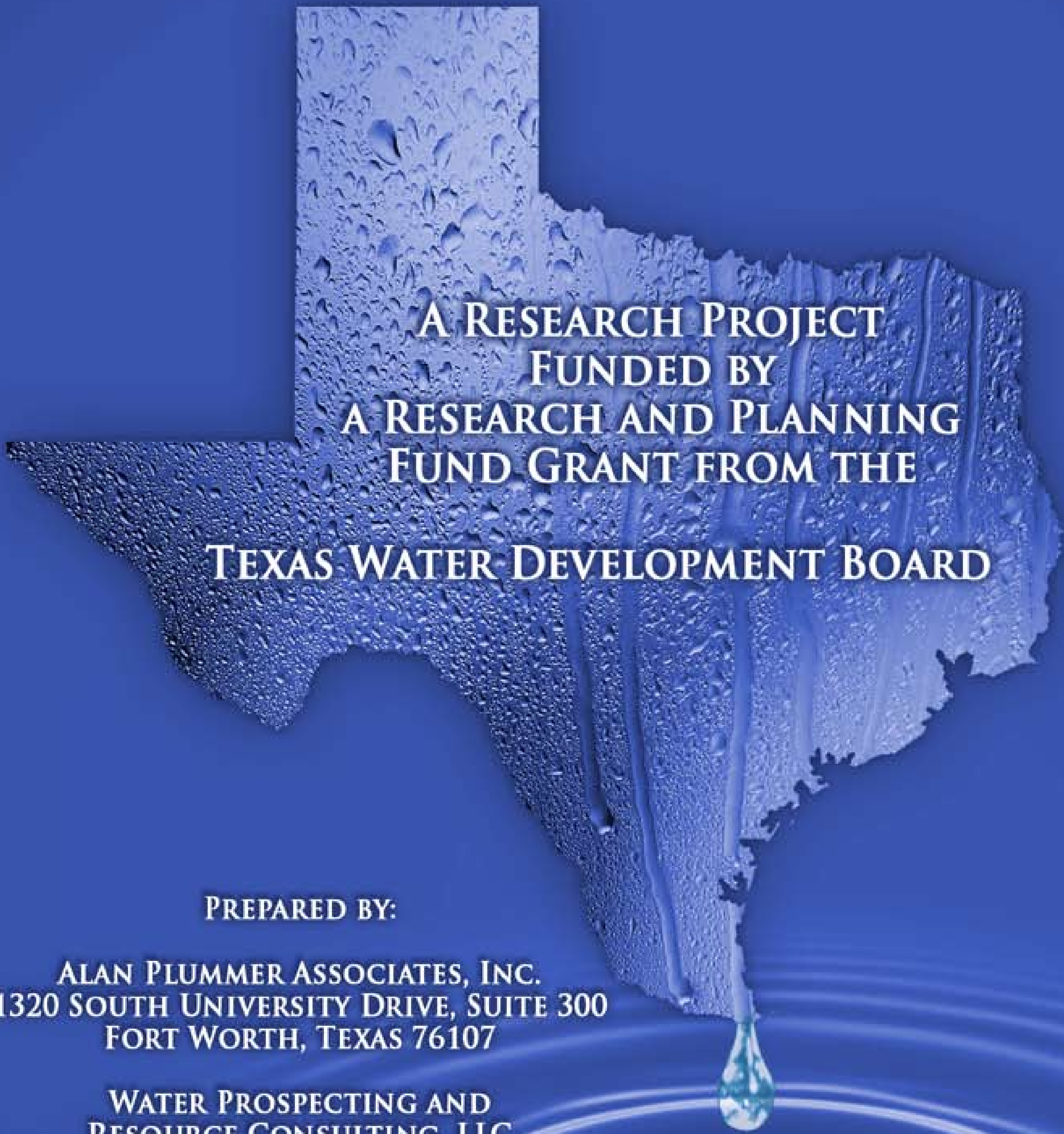
Final Report

An Analysis of Water Loss as Reported by Public Water Suppliers in Texas



A Research Project
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Texas Water Development Board

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1 EXECUTIVE SUMMARY – ANALYSIS OF WATER LOSS

The first broad analysis of water loss for retail public utilities in Texas reveals that:

- Approximately half of retail public utilities in Texas reported their water loss data.
- Reporting utilities serve as much as 84 percent of the state's population.[1]
- A substantial amount of water (the balancing adjustment) was not attributed to any water use category, causing significant uncertainty in estimates of water loss and non-revenue water.
- Reporting utilities experienced total water loss[2] of 212,221 to 464,219 acre-feet per year,[3] or 5.6 to 12.3 percent[3] of all water entering the reporting systems. Based on the 2004 statewide average municipal water use of 150 gallons per capita per day,[A,4] equivalent water volumes could supply between 1.3 million and 2.7 million Texans.[5]
- Reporting utilities experienced non-revenue water[6] of 311,333 to 563,331 acre-feet per year,[3] or 8.3 to 15.0 percent[3] of all water entering the reporting systems.
- When extrapolated to all retail public utilities in Texas, the statewide value of total water loss is estimated to be between $152 million and $513 million per year.
- Reporting utilities may have underestimated their real water loss.

This research provides information necessary for the Texas Water Development Board (TWDB), Regional Water Planning Groups (RWPGs), and retail public utilities to direct planning and funding resources, to recover lost revenue through reduction of non-revenue water, and to achieve water savings through reduction of real loss.

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1 This percentage is uncertain because some utilities reported both retail and wholesale customer populations.

2 Total water loss includes real loss (water that was physically lost from the system, such as main breaks and leaks, customer service line breaks and leaks, and storage overflows) and apparent loss (water that was not accurately measured and billed to a customer, such as unauthorized consumption, customer meter under-registering, and billing adjustment and waivers).

3 The smaller number is the total reported by the utilities. The larger number is based on the assumption that the entire balancing adjustment is water loss.

4 References are denoted with letters and are presented in Chapter 17. Footnotes are denoted with numbers and are presented at the bottom of the same page.

5 However, it is not possible to recover all water loss.

6 Non-revenue water includes real loss, apparent loss, and unbilled authorized consumption. Unbilled authorized consumption includes water used for fire fighting, sewer flushing, etc.

1.A Introduction

Water loss minimization can be an important water conservation strategy for retail water suppliers. Historically, retail public utilities have lacked detailed knowledge about their water loss performance. This is due partially to a lack of careful water auditing and partially to inconsistent water loss reporting using non-uniform statistics, including the use of "unaccounted-for water" percentages to compare performance. As a result, utilities may not know whether their water losses are due to leaks, accounting practices, theft, metering problems, or other factors, and may have difficulty developing water loss minimization strategies.

To address the lack of information on water loss, the 78th Texas Legislature passed House Bill 3338, which required retail public utilities that provide potable water to "perform and file with the [Texas Water Development Board] a water audit computing the utility's most recent annual system water loss"[B] every five years. Under this authority, the Texas Water Development Board (TWDB) instituted new water audit reporting requirements[C] that require retail public utilities to carefully audit their system water use at least once every five years; to estimate system water use in standard, well defined categories; and to report their first set of water loss data to the TWDB by March 31, 2006.

The new water audit reporting requirements follow a methodology that is recommended by the International Water Association (IWA) and the American Water Works Association (AWWA) Water Loss Control Committee. This methodology relies on strictly defined water use categories (Table 1-1) and water loss performance indicators and is becoming the international water loss accounting standard. The IWA Water Loss Task Force (which included AWWA participation) developed this methodology from 1997 through 2000.[D] The first reference to the methodology's performance indicators was published in 2000.[E (cited in D)]

The U.S. Bureau of Reclamation (BOR) has designated a number of "hot spots" in the Western U.S. where existing water supplies are projected to be inadequate to meet the demands of people, farms, and the environment by the year 2025, including six hot spots in Texas.[F] As part of the Water 2025 Program, the BOR offered Challenge Grants to fund projects related to "water conservation, efficiency and markets and collaboration. Recognizing this program as an opportunity to partner with the BOR, to leverage its existing budget, and to enhance conservation technical assistance, the TWDB applied for and received a Challenge Grant for two purposes: 1) to purchase 10 acoustical leak-detection units and make them available to public water suppliers, and 2) to perform an analysis of water loss in Texas, using water loss data provided by public water suppliers. The TWDB solicited proposals for the analysis of water loss and subsequently awarded a Research and Planning Fund Grant to the research team of Alan Plummer Associates, Inc., and Water Prospecting and Resource Consulting, LLC.

This executive summary describes the results of a research project to examine the reported water loss data for consistency, errors, omissions, and other quality control issues; to calculate water loss performance statistics; to compare water loss performance by utility location, type, and size; and to make recommendations for improving the water audit reporting process. The details of the data quality control are discussed in later chapters. A statewide summary of water loss performance, comparative analysis of water loss performance, and recommendations are presented below.

1.B Statewide Summary of Water Loss Performance

For reporting utilities, statewide totals for each water use category are shown in Table 1-1 (acre-feet), Table 1-2 (gallons), and Table 1-3 (percent of corrected input volume). The total reported corrected input volume[7] is 3,761,965 acre-feet over approximately one year. This figure includes retail water sales and wholesale water sales[8] for the reporting utilities.

The balancing adjustment in Table 1-1 through Table 1-3 is the water volume remaining after authorized consumption and total water loss are subtracted from the amount of water that entered the utility system (the corrected input volume). If a utility perfectly accounts for its water use, the balancing adjustment equals zero.

[7] Corrected input volume is the amount of water that was actually delivered to a utility, including water that was not measured by the master meter(s).

[8] A retail water sale is the sale of water to the end user. A wholesale water sale is the sale of water to a utility that resells the water.

Table 1-1: Statewide Totals of Reported Water Loss* (acre-feet)

<table>
<tr><td rowspan="11">Corrected input volume
(3,758,484)</td><td rowspan="4">Authorized consumption
(3,294,265)</td><td rowspan="2">Billed authorized consumption
(3,195,153)</td><td>Billed metered consumption
(3,190,972)</td><td rowspan="2">Revenue water
(3,195,153)</td></tr>
<tr><td>Billed unmetered consumption
(4,181)</td></tr>
<tr><td rowspan="2">Unbilled authorized consumption
(99,112)</td><td>Unbilled metered consumption
(52,698)</td><td rowspan="8">Non-revenue water
(311,333)</td></tr>
<tr><td>Unbilled unmetered consumption
(46,414)</td></tr>
<tr><td rowspan="6">Water losses
(212,221)</td><td rowspan="3">Apparent losses
(109,310)</td><td>Unauthorized consumption
(10,770)</td></tr>
<tr><td>Customer meter under-registering
(87,218)</td></tr>
<tr><td>Billing adjustment and waivers
(11,322)</td></tr>
<tr><td rowspan="3">Real losses
(102,910)</td><td>Main breaks and leaks
(83,529)</td></tr>
<tr><td>Storage overflows
(3,341)</td></tr>
<tr><td>Customer service line breaks and leaks
(16,040)</td></tr>
<tr><td colspan="4">Balancing Adjustment**
(251,998)</td></tr>
</table>

* Over approximately one year. Most utilities reported data for calendar or fiscal year 2005.

** Balancing adjustment is the corrected input volume minus authorized consumption minus total water loss. If all water is fully attributed to the various potential uses, balancing adjustment is zero. Balancing adjustment may consist of underestimated real loss, apparent loss, or authorized consumption. Without further refinement of a utility's water audit, there is no accurate *ad hoc* method for determining the actual water use for water that has been allocated to balancing adjustment.

Table 1-2: Statewide Totals of Reported Water Loss* (gallons)

<table>
<tr><td rowspan="11">Corrected input volume
(1,224,705,675,107)</td><td rowspan="4">Authorized consumption
(1,073,439,695,489)</td><td rowspan="2">Billed authorized consumption
(1,041,143,853,511)</td><td>Billed metered consumption
(1,039,781,485,415)</td><td rowspan="2">Revenue water
(1,041,143,853,511)</td></tr>
<tr><td>Billed unmetered consumption
(1,362,368,096)</td></tr>
<tr><td rowspan="2">Unbilled authorized consumption
(32,295,841,978)</td><td>Unbilled metered consumption
(17,171,730,325)</td><td rowspan="8">Non-revenue water
(101,448,133,344)</td></tr>
<tr><td>Unbilled unmetered consumption
(15,124,111,653)</td></tr>
<tr><td rowspan="6">Water losses
(69,152,291,366)</td><td rowspan="3">Apparent losses
(35,618,824,222)</td><td>Unauthorized consumption
(3,509,318,446)</td></tr>
<tr><td>Customer meter under-registering
(28,420,204,130)</td></tr>
<tr><td>Billing adjustment and waivers
(3,689,301,646)</td></tr>
<tr><td rowspan="3">Real losses
(33,533,467,144)</td><td>Main breaks and leaks
(27,218,129,878)</td></tr>
<tr><td>Storage overflows
(1,088,723,441)</td></tr>
<tr><td>Customer service line breaks and leaks
(5,226,613,826)</td></tr>
<tr><td colspan="4">Balancing Adjustment**
(82,113,688,252)</td></tr>
</table>

* Over approximately one year. Most utilities reported data for calendar or fiscal year 2005.

** Balancing adjustment is the corrected input volume minus authorized consumption minus total water loss. If all water is fully attributed to the various potential uses, balancing adjustment is zero. Balancing adjustment may consist of underestimated real loss, apparent loss, or authorized consumption. Without further refinement of a utility's water audit, there is no accurate *ad hoc* method for determining the actual water use for water that has been allocated to balancing adjustment.

Table 1-3: Statewide Percentages of Reported Water Loss*

<table>
<tr><td rowspan="11">Corrected input volume
(100.0)</td><td rowspan="4">Authorized consumption
(87.6)</td><td rowspan="2">Billed authorized consumption
(85.0)</td><td>Billed metered consumption
(84.9)</td><td rowspan="2">Revenue water
(85.0)</td></tr>
<tr><td>Billed unmetered consumption
(0.1)</td></tr>
<tr><td rowspan="2">Unbilled authorized consumption
(2.6)</td><td>Unbilled metered consumption
(1.4)</td><td rowspan="8">Non-revenue water
(8.3)</td></tr>
<tr><td>Unbilled unmetered consumption
(1.2)</td></tr>
<tr><td rowspan="6">Water losses
(5.6)</td><td rowspan="3">Apparent losses
(2.9)</td><td>Unauthorized consumption
(0.3)</td></tr>
<tr><td>Customer meter under-registering
(2.3)</td></tr>
<tr><td>Billing adjustment and waivers
(0.3)</td></tr>
<tr><td rowspan="3">Real losses
(2.7)</td><td>Main breaks and leaks
(2.2)</td></tr>
<tr><td>Storage overflows
(0.1)</td></tr>
<tr><td>Customer service line breaks and leaks
(0.4)</td></tr>
<tr><td colspan="4">Balancing Adjustment**
(6.7)</td></tr>
</table>

* Over approximately one year. Most utilities reported data for calendar or fiscal year 2005.

** Balancing adjustment is the corrected input volume minus authorized consumption minus total water loss. If all water is fully attributed to the various potential uses, balancing adjustment is zero. Balancing adjustment may consist of underestimated real loss, apparent loss, or authorized consumption. Without further refinement of a utility's water audit, there is no accurate *ad hoc* method for determining the actual water use for water that has been allocated to balancing adjustment.

Some or all of the balancing adjustment is due to underestimation of real and apparent water losses. Without further refinement of a utility's water audit, there is no accurate *ad hoc* method for determining the actual water use for water that has been allocated to balancing adjustment. Therefore, for a given water loss performance indicator, a range of potential values are presented. One end of the range is calculated directly from the reported water loss data, and the other end of the range is based on the assumption that all of the balancing adjustment is unreported water loss (either real or apparent, depending on the performance indicator). The balancing adjustment may be a positive quantity or a negative quantity.

Assuming the real loss is valued at the marginal production water cost and that apparent loss and the balancing adjustment are valued at the retail water cost, the estimated value of total water loss in Texas is between $152 million and $513 million per year.[9] Adding the value of unbilled authorized consumption to these totals gives an estimated value of non-revenue water in Texas between $253 million and $635 million. To increase the reliability and narrow the range of these estimates, the production and retail water costs must be more uniformly reported, and utilities must refine their water accounting, thereby reducing the balancing adjustment.

Statewide median and average water loss performance indicators are shown in Table 1-4. Generally speaking, the balancing adjustment is too large in relation to other quantities to draw reliable conclusions about water loss trends. From all reported data, balancing adjustment was 6.7 percent of total corrected input volume, while real loss was 2.7 percent, and apparent loss was 2.9 percent. On average, therefore, the balancing adjustment is larger than sum of the real and apparent losses. Given similar statistics, an individual utility would not be able to determine whether its best strategy is to reduce real loss or to reduce apparent loss.

The screening-level infrastructure leakage index (SLILI) is the real loss divided by the theoretical unavoidable annual real loss. In theory, the SLILI should not be less than one, because the real loss should not be less than the unavoidable real loss. However, the statewide median SLILI is 0.22 when calculated from reported data. In addition, the statewide median real loss is 3.6 gallons per connection per day, which is only about 23 percent of the lowest identified

[9] This estimate is not fully reliable, because up to 10 percent of the reported production and retail water costs were modified as discussed in Chapters 3.B.13 and 3.B.14. Not all non-revenue water can be recovered.

Table 1-4: Statewide Summary of Reported Water Loss Data

Statistic or Performance Indicator	Units	Median from Reported Data	Median With Balancing Adjustment Assumption	Average from Reported Data	Average With Balancing Adjustment Assumption
Absolute Value of Balancing Adjustment/Corrected Input Volume[10]	%	2.6	2.6	7.1	7.1
Real Loss per Mile of Main Per Day	gal/mi/day	77	233	204	417
Real Loss per Service Connection per Day	gal/conn/day	3.6	18.8	14	51
Apparent Loss per Service Connection per Day	gal/conn/day	6.4	17.5	15	51
Non-Revenue Water/Corrected Input Volume	%	7.3	13.4	8.3	15.0
Value of Real Loss per Mile of Main Per Day	$/mi/day	0.12	0.31	0.24	0.49
Value of Real Loss per Service Connection per Day	$/conn/day	0.004	0.018	0.010	0.040
Value of Apparent Loss per Service Connection per Day	$/conn/day	0.018	0.046	0.042	0.140
Screening-Level Infrastructure Leakage Index (SLILI)[11]	--	0.22	2.04	1.08	4.10

[10] The average of the absolute value balancing adjustment as a percentage of corrected input volume does not match the balancing adjustment percentage shown in Table 9-3, because the balancing adjustment is a negative quantity for some utilities.

[11] Calculation of the Screening-Level Infrastructure Leakage Index was performed only for utilities with 5,000 or more connections and 32 or more connections per mile of main. See discussion in Chapter 5.C.

real loss for a North American system (16 gal/conn/day for Halifax Central, shown in Table 7-1).

Even assuming that the balancing adjustment is unreported real loss, the statewide median SLILI is only 2.04, and the statewide median real loss is 18.8 gal/conn/day. Compared to the American Water Works Association (AWWA) guidelines for ILI goals (Table 7-3) and real loss performance by North American utilities (Table 7-1), these statistics seem to indicate that at least half of reporting utilities have excellent real loss control. However, most utilities in Texas practice real loss control in a reactive way (rather than a proactive way), so it is surprising that half of the reporting utilities have such excellent real loss performance, particularly in comparison to other North American utilities.

Because the actual statewide median SLILI value is so low (somewhere between 0.22 and 2.04), it appears that most reporting utilities have underestimated actual real loss. Furthermore, from comparison to AWWA guidelines and real loss performance by other North American utilities, it appears likely that the actual real loss is underestimated even if the balancing adjustment is treated as real loss. Real loss estimation problems notwithstanding, at least 8 to 30 percent of Texas utilities with more than 5,000 connections and 32 or more connections per mile of main have an SLILI greater than 3.0 (Appendix C).

1.C Comparative Analysis of Water Loss Performance

Water loss performance was also compared on the basis of utility location, type, size, water source, and connection density. The primary findings of the comparative analysis are similar to the findings in the statewide summary: the balancing adjustment is too large to allow identification of trends in the water loss data, and real loss appears to be underestimated. Other findings from the comparative analysis are discussed further in the conclusions and recommendations section (Chapter 1.D).

1.D Recommendations

This report, the first broad analysis of water loss and water loss accounting for retail public utilities in Texas, provides information necessary for the TWDB, RWPGs, and retail public utilities to direct planning and funding resources, to recover lost revenue through reduction of non-revenue water, and to achieve water savings through reduction of real loss. However, the size of the balancing adjustment results in significant uncertainty in the water loss performance indicators. Recommendations for improving water loss performance and water loss accounting are presented below in the following categories: water loss performance, regional water planning, and TWDB actions.

1.D.1 Water Loss Performance

Recommendations regarding balancing adjustment, real loss, connection density, non-revenue water, and the value of total water loss are discussed below.

Balancing Adjustment

Recommendation #1: Utilities should refine their water audits until the balancing adjustment is small in comparison to the other quantities of interest (*e.g.*, real and apparent water loss) so that reliable conclusions about water loss trends can be drawn. It may be tempting to change the volumes in some water use categories for the sole purpose of eliminating the balancing adjustment. This is not a legitimate way to reduce balancing adjustment: it only disguises the real issues, making it harder to identify what strategies a utility should pursue in the future. To legitimately reduce balancing adjustment, a utility should refine its estimates for each water use category by implementing more accurate measurement and/or estimation procedures.

Recommendation #2: Although utilities are only required to report their water audits every five years, utilities should implement annual or biennial programs to develop the data necessary to gradually reduce the uncertainty in their water audits and should review their water audits annually or biennially. Programs should target the water audit categories with the most uncertain water volume estimates.

Real Loss

Recommendation #3: Because it appears that utilities have underestimated real loss, utilities should refine their water audits to better estimate their actual real loss. This may involve confirmation of existing information (*e.g.*, calibration of production and consumption meters), additional analysis of existing information, and collection of new information (*e.g.*, flow monitoring in District Metered Areas).

Recommendation #4: Utilities should determine their economic level of leakage (ELL) and should use the ELL as a goal for real loss. Prior to determining an ELL, utilities should strive for a maximum ILI of 3.0 (Table 7-3). Utilities with an SLILI greater than 3.0 and other utilities with significant real loss in comparison to other North American utilities (Table 7-1) should consider implementing real loss control measures.

Water Loss Performance and Connection Density

Recommendation #5: Average real loss per mile of main per day increases with increasing connection density,[12] and average non-revenue water percentage decreases with increasing connection density (Figure I-2 in Appendix I). Reasons for these trends should be identified. Future analysis of water loss performance should consider connection density as an independent variable, along with utility location, type, and size.

Non-Revenue Water

Recommendation #6: Utilities should determine their economic target level for non-revenue water and strive to reduce their non-revenue water to the economic target level. In particular, utilities in Regions I and J should consider steps to recover lost revenue from unbilled authorized consumption, and utilities in Harris, Hidalgo, Nueces, Tarrant, and Travis Counties should consider steps to reduce non-revenue water.

Statewide Value of Total Water Loss

Recommendation #7: The estimated total value of total water loss in Texas is between $152 million and $513 million per year. To increase the reliability and narrow the range of this estimate, the production and retail water costs should be reported in consistent units, and utilities must refine their water accounting, thereby reducing the balancing adjustment.

[12] The number of service connections per mile of main.

1.D.2 Regional Water Planning

Recommendation #8: RWPGs should use the research results to estimate potential water savings from system water audits and water loss prevention strategies and should update the regional water plans as appropriate.

Recommendation #9: The TWDB should work to align the regional water planning cycle and the water audit reporting cycle so that up-to-date water loss data is used in developing the regional water plans.

1.D.3 TWDB Actions to Enhance Water Loss Accounting and Prevention

The TWDB should consider the following general actions to enhance water loss accounting and prevention in Texas:

Recommendation #10: To provide a more comprehensive picture of water loss in Texas, the TWDB should consider extending water auditing requirements to include wholesale utilities that provide raw or potable water. This may require additional authorization from the Legislature.

Recommendation #11: The TWDB should continue to promote water loss prevention to retail public utilities, focusing on the retail public utilities that have the greatest need for water loss reduction.

Recommendation #12: To make the water loss data more comprehensive, the TWDB should continue to seek water audit data from retail public utilities that have not reported.

Recommendation #13: The TWDB should continue to provide equipment, education, and financial assistance to help retail public utilities achieve improved water loss accounting and water loss performance.

Recommendation #14: To minimize the impact of balancing adjustment on the water loss analysis, the TWDB should consider devoting additional personnel and/or resources to assisting utilities with refinement of their water audits.

Recommendation #15: The TWDB should convey the findings, conclusions, and recommendations of this research effort to stakeholders through workshops or other means of communication.

In addition, the water loss reporting process should be revised to help assure data quality and to make the maximum use of reported water loss data. Additional recommendations regarding data quality control and the water loss reporting process are presented in Chapter 16.

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2 INTRODUCTION

Water loss minimization can be an important water conservation strategy for retail water suppliers. Historically, retail public utilities have lacked detailed knowledge about their water loss performance. This is due partially to a lack of careful water auditing and partially to inconsistent water loss reporting using non-uniform statistics, including the use of "unaccounted-for water" percentages to compare performance. As a result, utilities may not know whether their water losses are due to leaks, accounting practices, theft, metering problems, or other factors. Consequently, utilities may have difficulty developing appropriate water loss minimization strategies.

To address the lack of information on water loss, the 78th Texas Legislature passed House Bill 3338, which required retail public utilities that provide potable water to "perform and file with the [Texas Water Development Board] a water audit computing the utility's most recent annual system water loss"[B] every five years. Under this authority, the Texas Water Development Board (TWDB) instituted new water audit reporting requirements[C] that require retail public utilities to carefully audit their system water use at least once every five years; to estimate system water use in standard, well defined categories; and to report their first set of water loss data to the TWDB by March 31, 2006.

The new water audit reporting requirements follow a methodology that is recommended by the International Water Association (IWA) and the American Water Works Association (AWWA) Water Loss Control Committee. This methodology relies on strictly defined water use categories and water loss performance indicators and is becoming the international water loss accounting standard. The IWA Water Loss Task Force (which included AWWA participation) developed this methodology from 1997 through 2000.[D] The first reference to the methodology's performance indicators was published in 2000.[E (cited in D)]

This report describes the results of a research project to examine the reported water loss data for consistency, errors, omissions, and other quality control issues; to calculate water loss performance statistics; to compare water loss performance by utility location, type, and size; and to make recommendations for improving the water audit reporting process. The project background and funding, scope of work, and deliverables are discussed below.

2.A Project Background and Funding

The U.S. Bureau of Reclamation (BOR) has designated a number of "hot spots" in the Western U.S. where existing water supplies are projected to be inadequate to meet the demands of people, farms, and the environment by the year 2025.[F] These include six hot spots in Texas (Figure 2-1). The BOR rated hot spots by the likelihood of "conflict," or water shortage, by the year 2025. BOR hot spots in Texas include "moderate" potential for conflict in the Dallas area; "substantial" potential for conflict in the El Paso, San Angelo, and San Antonio areas; and "highly likely" potential for conflict along the Gulf Coast and in the Rio Grande Valley.

The BOR Water 2025 Program is designed to help "launch local, collaborative efforts to stretch existing water supplies and solve decades-old water conflicts among states, Indian tribes, farmers and environmental groups."[F] As part of the Water 2025 Program, the BOR offered Challenge Grants to fund projects related to "water conservation, efficiency and markets and collaboration."[F] Recognizing this program as an opportunity to partner with the BOR, to leverage its existing budget, and to enhance conservation technical assistance, the TWDB applied for and received a Challenge Grant in the amount of $154,970 for two purposes: 1) to purchase 10 acoustical leak-detection units and make them available to public water suppliers, and 2) to perform an analysis of water loss in Texas, using water loss data provided by public water suppliers.

Finally, the TWDB solicited proposals for an analysis of water loss as reported by public water suppliers in Texas and subsequently awarded a Research and Planning Fund Grant to the research team of Alan Plummer Associates, Inc., and Water Prospecting and Resource Consulting, LLC (the APAI team).

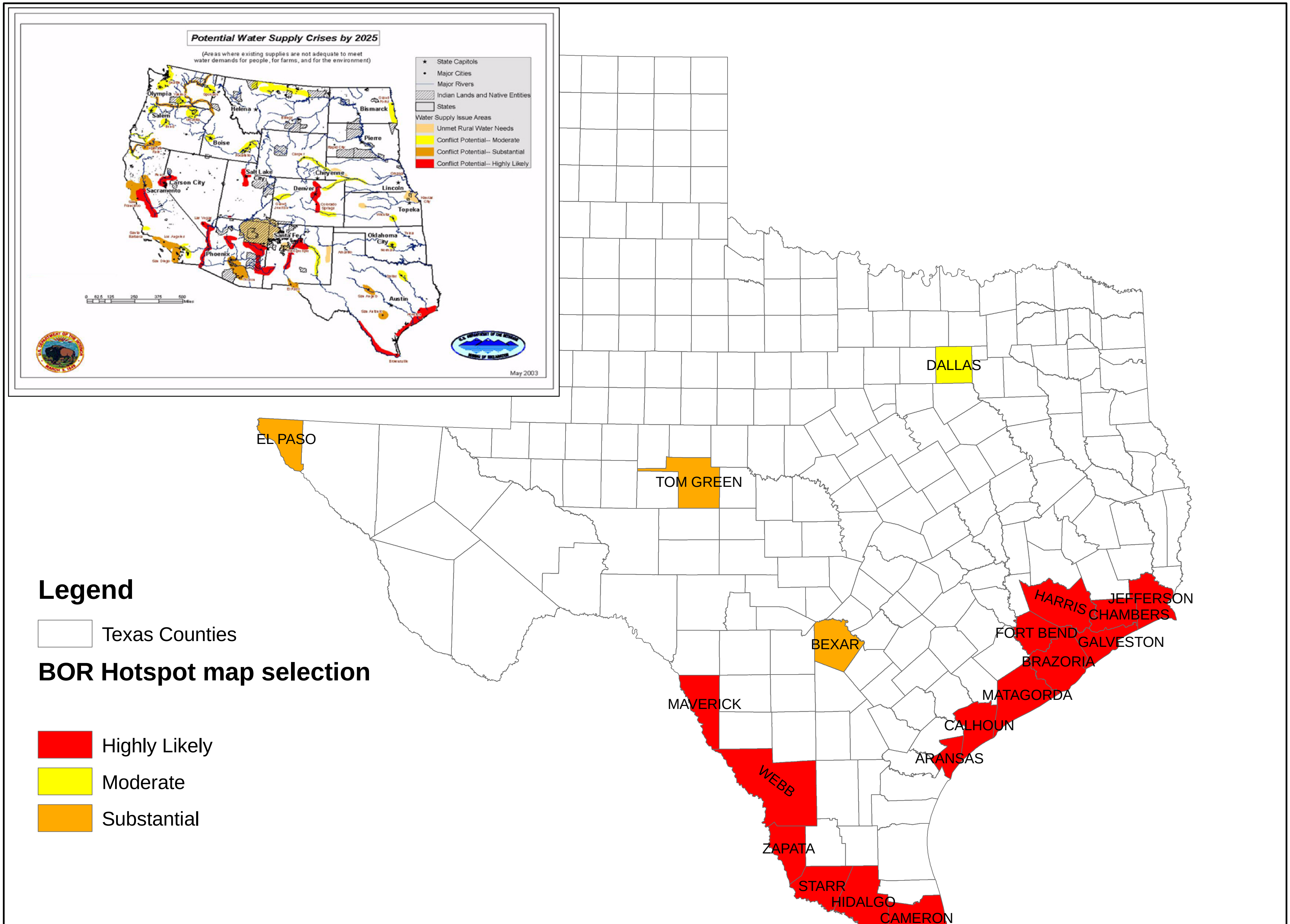

Figure 2-1. Bureau of Reclamation Hotspot Counties in Texas

2.B Scope of Work

The analysis of water loss involved the following technical tasks:

- Acquire the reported water loss data from the TWDB.
- Develop a Microsoft Access database of water loss data reported by the utilities, and design the data structure to facilitate information exchange with GIS mapping software and to allow the input of additional water loss data as they are reported.
- Examine the reported data for consistency, errors, omissions, and other issues, and develop a list of active retail public utilities that have not submitted water loss data.
- Calculate water loss performance indicators.
- Compare water loss data by utility location,[13] type,[14] and size[15] and compare water loss performance statistics with available benchmark data.
- Construct ArcGIS maps as necessary to illustrate the comparative analysis of water audit data by geographic level[13] and to show geographic trends in the data.
- Generate a one-page summary report for each retail public utility that has reported water audit data to the TWDB.
- Prepare a draft report, including charts, maps, and graphs as necessary to illustrate the comparative analysis of water audit data and including recommendations for improving the water audit reporting process; submit it to the TWDB for review and comments; and incorporate TWDB comments into a final report.

2.C Deliverables

The APAI team has provided the TWDB with the following: this report, which summarizes the comparative analysis of water loss; a Microsoft Access database which contains the reported water audit data and associated queries and reports; the ArcGIS shapefiles associated with all

[13] State, Regional Water Planning Area, County, or BOR hot spot.
[14] City, Municipal Utility District, Special Utility District, Water Control and Improvement District, Water Supply Corporation, or Other.
[15] 0-1,100 connections; 1,101-16,666 connections; 16,667-33,333 connections; and 34,333 connections or more.

maps developed and presented from the water audit data; and a one-page summary report[16] for each retail public utility that reported water audit data to the TWDB.

The remainder of this report is divided into the following chapters:

- Chapter 3: Quality control of reported water loss data
- Chapter 4: Definition of calculated water loss quantities
- Chapter 5: Definition of calculated water loss performance indicators
- Chapter 6: Quality control of calculated water loss quantities and water loss performance indicators
- Chapter 7: Review of national and international water loss performance
- Chapter 8: Discussion of comparative analysis of water loss performance indicators
- Chapter 9: Statewide summary of water loss performance indicators
- Chapter 10: Comparative analysis by regional water planning area
- Chapter 11: Comparative analysis by county
- Chapter 12: Comparative analysis by Bureau of Reclamation hot spot
- Chapter 13: Comparative analysis by utility type
- Chapter 14: Comparative analysis by utility size
- Chapter 15: Other comparative analysis
- Chapter 16: Conclusions and recommendations

[16] Transmitted electronically.

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3 QUALITY CONTROL OF REPORTED WATER LOSS DATA

The APAI team acquired available water loss data from the TWDB; implemented quality control procedures to address data consistency, errors, omissions, and other issues; and developed a database of water loss data and associated queries and reports. Each step is discussed in detail below.

3.A Data Acquisition

Public water suppliers reported water loss data to the TWDB either by entering data into a web-based interface or by submitting a completed paper form. (A blank Water Audit Reporting Form is presented in Appendix A). As of July 20, 2006, water loss data had been submitted by a total of 2,098 public water suppliers out of approximately 4,275 active public water suppliers in the state. A list of active retail public utilities that have not submitted water loss data is presented in Appendix B.

TWDB staff entered the data received by paper form, compiled all reported water loss data into an Excel spreadsheet, and transmitted the data to the APAI team. Table 3-1 shows the fields that were present in the water loss spreadsheet.

3.B Quality Control

Data in each field were examined for consistency, errors, omissions, and other issues. The findings of this examination and actions taken to address data deficiencies are discussed below.

3.B.1 Utility_sk

Utility_sk numbers were modified to match the Texas Commission on Environmental Quality (TCEQ) Public Water System identification number as necessary.

Table 3-1: Description of Fields in Water Loss Spreadsheet

Field	Description
Utility_sk	An identifying number that corresponds to the supplier's Texas Commission on Environmental Quality (TCEQ) Public Water Supply identification number or Water District Number.
Utility_name	The name of the supplier.
Utility_type	The supplier type, selected from City, Municipal Utility District (MUD), Special Utility District (SUD), Water Control and Improvement District (WCID), Water Supply Corporation (WSC), or Other.
Region_id	Letter corresponding to one of the 16 Water Planning Regions in Texas.
Region_name	Name of the Water Planning Region.
Person_name	The supplier's contact person.
Phone_number	The supplier's phone number.
Addr_one	The first line of the supplier's address.
Addr_two	The second line of the supplier's address.
City	The supplier's city.
State	The supplier's state.
Zip	The supplier's ZIP Code.
Rpt_period_from	The first date of the period for which water loss data are reported.
Rpt_period_to	The last date of the period for which water loss data are reported.
Surfacewater_used_pct	The percentage of water delivered to the supplier that originated from surface water.
Grdwater_used_pct	The percentage of water delivered to the supplier that originated from groundwater.
Pop_mean_income	The mean income of the population served by the supplier.
Population_served	The population served by the supplier.
Unit_measure	The units used in reporting water quantities, selected from gallons or acre-feet.
Unit_measure_other	Other units used in reporting water quantities.
Water_delivery	The total amount of water pumped, produced, purchased, or obtained through interconnects.
Mstr_meter_accuracy_pct	The accuracy of the production meters.
Billed_metered	The amount of water sold that was metered.
Billed_unmetered	The amount of water sold that was not metered.
Unbilled_metered	The amount of water that was metered but not billed.
Unbilled_unmetered	The amount of authorized water consumption that was neither metered nor billed.
Cust_meter_accuracy_pct	The average accuracy of customer meters.
Billing_adjust_waivers	The amount of water consumption for which billing was adjusted or waived.

Table 3-1 Continued: Description of Fields in Water Loss Spreadsheet

Field	Description
Unauthorized_consump	The amount of water consumption that was not authorized by the supplier.
Main_leaks_breaks	The amount of water lost through water main leaks and breaks.
Cust_leaks_breaks	The amount of water lost through service line leaks and breaks.
Storage_overflows	The amount of water lost through overflows in storage facilities.
Num_service_connections	The number of the supplier's service connections.
Miles_main_lines	The number of miles of water main in the supplier's water system.
Prod_water_cost	The supplier's average unit cost of producing water.
Retail_water_cost	The supplier's average unit price charged to its retail customers.

3.B.2 Utility_type

The following modifications were made to the reported utility types:

1. The utility type was changed to "City" for one utility with "City" in its name.
2. The utility type was changed to "MUD" for five utilities with "MUD" in their names.
3. The utility type was changed to "WCID" for six utilities with "WCID" in their names.
4. The utility type was changed to "Other" for eight water systems that appeared to be miscategorized but for which the appropriate category was unknown.
5. The utility type was changed to "WSC" for four utilities with "WSC" in their names.

3.B.3 Region_id

The supplier's Regional Water Planning Group (RWPG) was identified using the principal county in which the supplier operates. In cases where the principal county is located in more than one planning region, CCN maps and well records were used to identify the *Region_id*.

3.B.4 City, State, and Zip

Blank *city*, *state*, and *zip* fields were populated using data from the TCEQ Water Utility Database.

3.B.5 Rpt_period_from and Rpt_period_to

One water supplier reported water audit data for a period of only two days. Ten other suppliers report water audit data for a period of 31 days. A total of 91 suppliers report water audit data for a period of less than a year. No changes were made.

3.B.6 Population_served

This variable is intended to represent the retail population served by the utility. Some water suppliers reported the total population for their retail and wholesale customers, while other suppliers reported the population only for their retail customers. For this reason, care should be taken when using the reported data to compare per capita water use between water suppliers. In addition, some populations are reported twice: once by the retail water supplier and once by the wholesale water supplier. Therefore, the total population served by reporting utilities is uncertain.

3.B.7 Water_delivery

Ten water suppliers reported water delivery of zero gallons. *Water_delivery* for these entities was set to the null value as if water delivery was not reported. Seven of these utilities reported some combination of billed metered, billed unmetered, unbilled metered, and unbilled unmetered water consumption. No changes were made to these data.

For a wholesale water supplier, the water delivery should include water that is ultimately provided to both retail and wholesale customers. A wholesale water purchase may show up in the following reported quantities:

- Water delivered to the wholesale water supplier,
- Billed metered consumption for the wholesale water supplier, and
- Water delivery to the wholesale water customer.

As shown above, wholesale water sales are counted as reported water deliveries at least twice: once for the wholesale water supplier and once for the wholesale water customer. If the wholesale water customer resells this water to a third utility, the water is counted as delivered water a third time, and so on. Therefore, the sum of reported water delivery for all reporting utilities includes wholesale water sales multiple times.

3.B.8 Mstr_meter_accuracy_pct

This variable quantifies the accuracy of a utility's production, or master, meters. As an example, suppose 100 gallons pass through a master meter. A master meter with accuracy of 95 percent would register 95 gallons, while a master meter with accuracy of 105 percent would register 105 gallons. The customer meter accuracy percentage (Chapter 3.B.9) works the same way.

The master meter accuracy percentages for two water suppliers were reported as decimal values and were modified accordingly. After this modification, reported master meter accuracies ranged from 10 to 165 percent. Twenty-six water suppliers reported a master meter accuracy of less than 90 percent. Fifteen water suppliers reported a master meter accuracy of greater than 110 percent. No other changes were made.

3.B.9 Cust_meter_accuracy_pct

Reported customer meter accuracies ranged from 0 to 120 percent. Fifty-four water suppliers reported a customer meter accuracy of less than 90 percent. One water supplier reported a customer meter accuracy of greater than 110 percent.

The customer meter accuracy for the supplier that reported a value of 0 percent accuracy was changed to 100 percent on the assumption that the report of 0 percent accuracy was in error.

3.B.10 Unauthorized_consump

Two utilities each reported more than ten billion gallons of unauthorized consumption. For the first utility, the reported value is 11.0 percent of corrected input volume[17] and approximately 55 percent of all reported unauthorized consumption in the state. For the second utility, the reported value is 7.8 percent of corrected input volume and about 36 percent of all reported unauthorized consumption in the state. These values are not realistic, and it appears that the utilities may have used this category as a catch-all for unknown water uses.

[17] Corrected input volume is the water entering the system after correcting for master meter accuracy.

Utilities similar to the two described above reported unauthorized consumption of approximately 0.3 percent of corrected input volume. Based on these examples, *unauthorized_consump* for the two utilities mentioned above was changed to equal 0.3 percent of corrected input volume.[18] As a result, the remainder of the water that was originally reported as unauthorized consumption is treated as balancing adjustment.

3.B.11 Num_service_connections

The number of service connections is an important statistic in this report, because many of the water loss performance indicators are normalized by the number of service connections.

Fifty-five utilities reported zero service connections. *Num_service_connections* for these entities was set to the null value as if the number of service connections was not reported.

For some utilities, the number of wholesale connections is significant compared to the number of retail connections. One hundred twelve utilities report more than four people per service connection. For example, one utility reported one service connection but reported serving 2,200 people. Although the inclusion of wholesale connections does not necessarily represent a data quality issue, it should be carefully considered during analysis of water loss performance indicators that are normalized by the number of connections.

3.B.12 Miles_main_lines

The number of miles of main line is an important statistic in this report, because many of the water loss performance indicators are normalized by miles of main line.

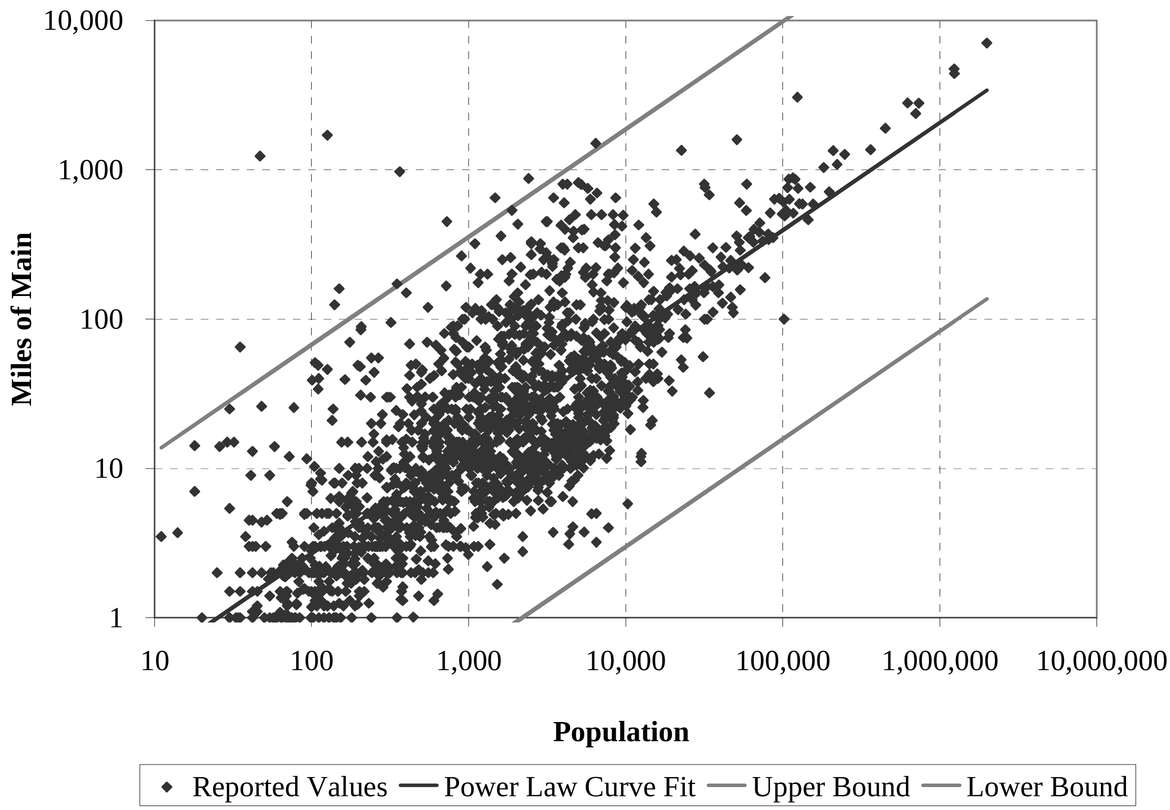
One hundred eight utilities reported zero miles of main lines. *Miles_main_lines* for these entities was set to the null value as if the length of main lines was not reported.

Figure 3-1 shows a plot of miles of main line versus population served. Some of the reported miles of main are not credible. For example, two utilities that serve a population of fewer than 150 people report more than 1,000 miles of main. To filter out the most unlikely reported miles

[18] This assumption compares reasonably well with a recommendation of the AWWA Water Loss Control Committee. In the absence of other information, the Committee recommends assuming that unauthorized consumption is 0.25 percent of water supplied.

of main, a power law curve[19] was fitted to the data, and upper and lower bounds were drawn within a factor of 25 of the power law curve. All reported values outside these generous bounds (there were 10) were rejected as not credible, and *miles_main_lines* for these entities was set to the null value as if the length of main lines was not reported.

Figure 3-1: Reported Population Versus Miles of Main



3.B.13 Prod_water_cost

Reported production water costs ranged from 0.0000 to 220,519.52. Unfortunately, the units for this field are not well defined. For the eight suppliers that reported water quantities in acre-feet, it appears that production water costs were reported in units of dollars per acre-foot, and no changes have been made.

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[19] Of the form (Miles of Main) = C1 * Population^{C2}, where C1 and C2 are constants.

For suppliers that reported water quantities in gallons:

- 223 suppliers reported a production cost of zero. The production cost for these suppliers was set to the null value as if the production cost was not reported.
- It has been assumed that quantities greater than or equal to 0.0001 and less than 0.01 were reported in units of dollars per gallon, and no changes have been made (1,682 suppliers).
- For quantities greater than or equal to 0.01 and less than 0.1, the units were unclear, and *prod_water_cost* was set to the null value so that these values would not be used (38 suppliers).
- It has been assumed that quantities greater than or equal to 0.1 and less than or equal to 10 were reported in units of dollars per thousand gallons, and such quantities were divided by one thousand (125 suppliers).
- For quantities greater than 10, the units were unclear, and *prod_water_cost* was set to the null value so that these values would not be used (22 suppliers).

3.B.14 Retail_water_cost

Reported retail water costs ranged from 0.0000 to 52,889. Unfortunately, the units for this field are not well defined. For the eight suppliers that reported water quantities in acre-feet, it appears that retail water costs were reported in units of dollars per acre-foot (although two suppliers did not report a retail water cost), and no changes were made.

For suppliers that reported water quantities in gallons:

- 245 suppliers reported a retail cost of zero. The retail cost for these suppliers was set to the null value as if the retail cost was not reported.
- It has been assumed that quantities greater than or equal to 0.0001 and less than 0.01 were reported in units of dollars per gallon, and no changes were made (1,673 suppliers).
- For quantities greater than or equal to 0.01 and less than 0.1, the units were unclear, and *retail_water_cost* was set to the null value so that these values would not be used (47 suppliers).

- It has been assumed that quantities greater than or equal to 0.1 and less than or equal to 10 were reported in units of dollars per thousand gallons, and such quantities were divided by one thousand (117 suppliers).
- For quantities greater than 10, the units were unclear, and *retail_water_cost* was set to the null value so that these values would not be used (eight suppliers).

After the modifications described above, reported production costs are greater than reported retail costs for 169 suppliers.

3.C Database Development

Reported water loss data were placed into a Microsoft Access database for processing and analysis. Original water loss data were imported into a table. Additional tables were generated to allow quality control modifications as discussed above. These additional tables generally consist of three fields: *utility_sk*, to allow cross-referencing with the original water loss data table; the field for which quality control modifications are being made (*e.g.*, *retail_water_cost*); and *mod*, a field to identify records that have been modified.

Data queries were written that allow quality control modifications, addition of primary county names, exclusion of outlier data (discussed in Chapter 6.B), calculation of water loss performance indicators, calculation of average and median summary statistics, and ranking of statistics by location, utility type, and utility size. Data reports were written to generate one-page summary reports for each reporting utility and to generate graphs of water loss performance indicators for utilities by location, type, and size.

The database structure, data queries, and data reports in the Access database will allow the TWDB to update the original water loss data, analyze updated water loss data, and generate revised water loss statistics.

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4 DEFINITION OF CALCULATED WATER LOSS QUANTITIES

Key water loss quantities were calculated from the reported water loss data. These quantities are defined below and are used extensively in this report. Table 4-1 shows the relationship between water loss quantities.

Table 4-1: International Standard Water Audit Format[G]

<table>
<tr><td rowspan="10">Corrected input volume</td><td rowspan="4">Authorized consumption</td><td rowspan="2">Billed authorized consumption</td><td>Billed metered consumption</td><td rowspan="2">Revenue water</td></tr>
<tr><td>Billed unmetered consumption</td></tr>
<tr><td rowspan="2">Unbilled authorized consumption</td><td>Unbilled metered consumption</td><td rowspan="8">Non-revenue water</td></tr>
<tr><td>Unbilled unmetered consumption</td></tr>
<tr><td rowspan="6">Water loss</td><td rowspan="3">Apparent losses</td><td>Unauthorized consumption</td></tr>
<tr><td>Customer meter under-registering</td></tr>
<tr><td>Billing adjustment and waivers</td></tr>
<tr><td rowspan="3">Real losses</td><td>Main breaks and leaks</td></tr>
<tr><td>Storage overflows</td></tr>
<tr><td>Customer service line breaks and leaks (up to the customer meter)</td></tr>
</table>

4.A Production Meter Adjustment

Production meter adjustment is water delivered divided by master meter accuracy minus water delivered. This quantity represents the amount of delivered water that was not measured by the master meter.

4.B Corrected Input Volume

Corrected input volume is water delivered divided by master meter accuracy. This quantity represents the amount of water that was actually delivered to the utility, including water that was not measured by the master meter(s).

4.C Authorized Consumption

Authorized consumption is the sum of billed metered, billed unmetered, unbilled metered, and unbilled unmetered water.

4.D Customer Meter Under-Registering

Customer meter under-registering is billed metered water divided by customer meter accuracy minus billed metered water. This quantity represents the amount of billed metered water that was not measured by the customer meters.

4.E Apparent Loss

Apparent loss is the sum of customer meter under-registering, billing adjustment and waivers, and unauthorized consumption. Apparent loss represents water that was used but not paid for, resulting in lost revenue. Revenue loss from apparent water loss has been estimated using the retail unit water cost.

4.F Real Loss

Real loss is the sum of main breaks and leaks, customer service line breaks and leaks, and storage overflows. Real loss represents water that was physically lost from the water system prior to use, resulting in lost revenue. Revenue loss from real water loss has been estimated using the production unit water cost. (See Chapter 9.B for more discussion regarding the value of real loss.)

4.G Total Water Loss

Total water loss is the sum of apparent loss and real loss. This quantity represents the total amount of water that was not consumed by authorized users (Table 4-1).

4.H Non-Revenue Water

Non-revenue water is the sum of unbilled authorized consumption and total water loss. Non-revenue water represents all water for which the utility does not receive compensation.

4.I Balancing Adjustment

Balancing adjustment is the corrected input volume minus authorized consumption minus total water loss. If all water is fully attributed to the various potential uses, the balancing adjustment is zero. In reality, there is always some inherent uncertainty in the audit data. Once a utility has made its best effort to analyze and categorize all of its water uses, any remaining water is allocated to balancing adjustment by default.

Balancing adjustment may consist of underestimated real loss, apparent loss, or authorized consumption. Without further refinement of a utility's water audit, there is no accurate *ad hoc* method for determining the actual water use for water that has been allocated to balancing adjustment.

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5 DEFINITION OF CALCULATED WATER LOSS PERFORMANCE INDICATORS

Water loss performance indicators allow retail public utilities to assess their water loss performance in comparison to other utilities and to target their resources more efficiently to improve the areas of their system that will yield the greatest benefit. There are three principal types of water loss performance indicators: water resources, operational, and financial.[H] For this analysis, the APAI team has also devised a water loss accounting precision indicator. Each of these is discussed below.

5.A Water Loss Accounting Precision Indicator

The ratio of the absolute value of the balancing adjustment to the corrected input volume represents the percentage of water use that is either unattributed to any water use category or overattributed (double-counted) to one or more water use categories. This is a measure of the precision, though not necessarily the accuracy, of the water loss accounting. High balancing adjustment indicates that a utility has not correctly identified the magnitude of water use in each category. A utility that reports zero balancing adjustment, although it has precisely reported the magnitude of water use in each category, may still have inaccuracies in the reported amounts, particularly in those categories that are difficult to estimate, such as real and apparent water losses.

5.B Water Resource Performance Indicator

The ratio of real loss to corrected input volume, or the percentage of water entering a utility's system that is not used by the utility's customers, indicates the efficiency of a utility's use of water resources.

5.C Operational Performance Indicators

Operational performance indicators reveal the efficiency of a utility's operations. Operational performance indicators include:

- Real loss per mile of main per day,
- Real loss per service connection per day,

- Apparent loss per service connection per day,
- Real loss as a percentage of corrected input volume,
- Apparent loss as a percentage of corrected input volume, and
- Infrastructure Leakage Index (ILI, defined below).

Direct comparison of total water loss between utilities is not meaningful without taking into account the number of customers and the extent of the service area. To allow comparison between utilities, water loss should be normalized by the number of service connections and/or the miles of main. This is the purpose of performance indicators such as real loss per service connection per day, real loss per mile of main per day, and apparent loss per service connection per day.

For utilities that have a low density of service connections in relation to miles of main (fewer than 32 connections per mile[D]), real losses are normalized by miles of main. These utilities tend to be more rural, with long stretches of main lines, and a majority of real loss generally originates from main breaks and leaks. For utilities that have a higher density of service connections in relation to miles of main (32 or more connections per mile[D]), real losses are normalized by the number of service connections. These utilities tend to be more urban, and a majority of real loss generally originates from customer line breaks and leaks.

Real and apparent losses as percentages of corrected input volume, along with the screening-level infrastructure leakage index (SLILI) and financial performance indicators (discussed below), indicate the degree to which a utility should prioritize its resources toward reducing real losses or toward reducing apparent losses.

The ILI is the dimensionless ratio of total real loss to unavoidable annual real loss (UARL). UARL is the theoretical minimum level of real water loss that would exist after successful implementation of water loss best management practices. A utility with a low ILI is experiencing a relatively low level of real losses compared to a utility with a high ILI.

The International Water Association (IWA) recommends a formula to estimate UARL using miles of main, number of service connections, average length of service connections from curb-stop to meter, and average system water pressure.[H] Unfortunately two of these parameters (the average length of service connections from curb-stop to meter and the average system water pressure) are not reported on the Water Audit Reporting Form. Therefore, the UARL (and the ILI) for a given utility is estimated using assumed values for service connection length from curb-stop to meter (0 feet) and system water pressure (60 pounds per square inch). The resulting screening-level infrastructure leakage index (SLILI) is not a precise measurement but may be a useful screening tool regarding the real loss performance of utilities and whether further investigation of the level of real losses is warranted. According to the AWWA, the actual ILI is the best indicator for comparison of real losses between systems.[D]

The UARL formula is intended for utilities with more than 5,000 service connections, average pressure greater than 35 pounds per square inch, and a density of more than 32 service connections per mile.[I] Therefore, SLILI was not estimated for utilities with fewer than 5,000 connections or fewer than 32 service connections per mile.

5.D Financial Performance Indicators

Financial performance indicators reveal a utility's efficiency in being compensated for the water it produces. Financial performance indicators include:

- Non-revenue water as a percentage of corrected input volume,
- Value of real loss per mile of main per day,
- Value of real loss per service connection per day,
- Value of apparent loss per service connection per day, and
- Value of non-revenue water as a percentage of the total annual cost of running the water system.

Non-revenue water as a percentage of corrected input volume shows the percentage of water entering the distribution system for which the utility does not receive any compensation. This indicator measures financial efficiency in terms of water produced.

The value of non-revenue water as a percentage of the total annual cost of running the water system measures financial efficiency in dollar terms. Unfortunately, the total annual cost of running the water system is not reported on the Water Audit Reporting Form, so this performance indicator cannot be calculated.

6 QUALITY CONTROL OF CALCULATED WATER LOSS QUANTITIES AND PERFORMANCE INDICATORS

As discussed in Chapter 3, the reported water loss data were analyzed for consistency, errors, omissions, and other issues. This analysis eliminated obvious reporting errors but did not address whether the reported water loss data are reasonable. For example, if a public water supplier reported that no water was lost from main breaks and leaks, this value was accepted, though it may not be correct. A further quality control step is necessary to assess the credibility of results calculated from the reported water loss data.

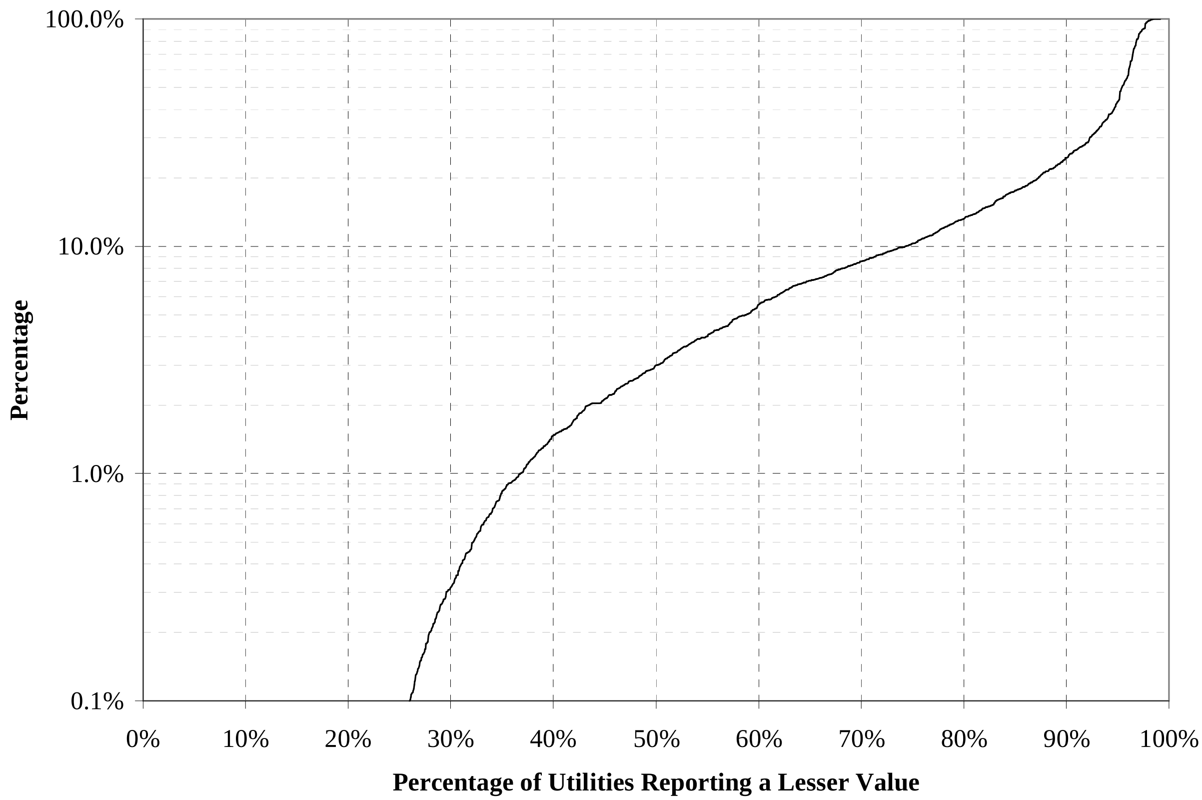
After review of the calculated water loss quantities and performance indicators, two quality control issues were identified: balancing adjustments and outlier values could significantly affect the analysis of water loss. Approaches taken to improve the results are discussed below.

6.A Balancing Adjustment

As discussed in Chapter 4.I, if water is perfectly accounted for, there is no balancing adjustment. Some of the accounting quantities (e.g., corrected input volume, billed metered consumption, unbilled metered consumption, customer meter under-registering, and billing adjustments/waivers) are calculated from measured quantities and may be relatively accurate, depending on the quality of the data. However, many of the quantities involved in water loss accounting (e.g., billed unmetered consumption, unbilled unmetered consumption, unauthorized consumption, leakage from mains, leakage from customer service lines, and storage tank overflows) are often not measured and must be estimated, which can cause significant balancing adjustment.

Figure 6-1 shows the frequency with which various magnitudes of balancing adjustment are reported. Approximately 26.1 percent of reporting utilities reported a balancing adjustment of less than 0.1 percent of corrected input volume. The median reported balancing adjustment was about 3 percent of corrected input volume. Approximately 26 percent of utilities reported a balancing adjustment of more than 10 percent of corrected input volume.

Figure 6-1: Absolute Value of Balancing Adjustment as a Percentage of Corrected Input Volume



Some or all of the balancing adjustment is due to underestimation of water losses. Without further refinement of a utility's water audit, there is no accurate *ad hoc* method for determining the actual water use for water that has been allocated to balancing adjustment. Therefore, for a given water loss performance indicator, a range of potential values will be presented. One end of the range is calculated directly from the reported water loss data, and the other end of the range is based on the assumption that all of the balancing adjustment is unreported water loss (either real or apparent, depending on the performance indicator). The balancing adjustment may be a positive quantity or a negative quantity.

6.B <u>Outliers</u>

An outlier is a value that is unusually high or low compared to other data. For the water loss data, an outlier could result from a data error, or it could be a valid observation resulting from unusual events or situations. Outliers resulting from data errors can distort average values and other statistical measures and can lead to erroneous conclusions.

To accurately represent water loss in Texas, it is necessary to remove outliers that result from data errors while retaining outliers that represent unusual, but valid, situations. To this end, data from a retail public utility were removed from the analysis if the following conditions existed:

- <u>The absolute value of the balancing adjustment is more than 50 percent of the corrected input volume or cannot be calculated</u>. Balancing adjustment of this size represents poor water loss accounting or unreported water delivery and is likely to provide misleading water loss performance indicators. This constraint removes 97 retail public utilities, or 4.6 percent of reporting utilities, from the analysis.
- <u>The corrected input volume is less than 65 gallons per connection per day</u>. Very low corrected input volume per connection per day probably indicates misreported input volume or misreported reporting period. A misreported input volume may distort performance indicators that compare water losses to the corrected input volume. A misreported reporting period may distort performance indicators that normalize water losses per day. This constraint removes an additional 40 retail public utilities, or 1.9 percent of reporting utilities, from the analysis.
- <u>The storage overflow volume is more than 50 percent of corrected input volume</u>. This constraint removes two additional retail public utilities from the analysis. The reported storage overflow volumes appear unlikely and unnecessarily skew the performance indicators.

The cutoff values used above are arbitrary and are designed to filter out the most obvious outliers. Other outlier data may still be present, but it is not feasible within the scope of this project to inspect and provide quality control for every reported value. Instead, recommendations are made in Chapter 16 regarding procedural reporting improvements that will lead to improved data quality in the future.

6.C Water Loss Summary Reports

After quality control, a one-page summary report was created for each public water supplier for which water loss data are being analyzed. The summary report contains all data reported on the Water Audit Reporting Form (subject to quality control modifications) and calculated water loss performance indicators. For various performance indicators, the summary report also shows how each utility ranks in comparison to other utilities of similar location, type, and size.

Due to the number of water utilities for which summary reports were created (1,959), the one-page summary reports are not presented in this document but were transmitted to the TWDB electronically.

7 REVIEW OF NATIONAL AND INTERNATIONAL WATER LOSS PERFORMANCE

The current analysis of Texas water loss data represents the first comprehensive effort to assess water loss performance in Texas using data reported in a uniform manner. Because there are no previous data with which to compare the Texas results, a brief summary of national and international water loss performance indicators and water loss performance targets is presented in the following sections. This information provides context for evaluating the Texas results presented in later chapters and for utilities to consider when setting their water loss goals.

7.A Water Loss Performance

Available water loss performance statistics for individual North American utilities are briefly summarized in Table 7-1. The entries are generally sorted by normalized real loss where statistics were available. These statistics encompass many different types of utilities with different characteristics (connection density, system pressure, soil types, etc.) and show a wide range of potential water loss performance.

Non-revenue water as a percentage of corrected input volume ranged from 8.5 percent in Salt Lake City to 35.4 percent in Philadelphia. Apparent loss ranged from four gallons per connection per day (gal/conn/day) in Charlotte County, Florida, to 54.8 gal/conn/day in Cleveland. Real loss ranged from 16 gal/conn/day in the central portion of the Halifax, Nova Scotia, system to 172 gal/conn/day in the western portion of the Halifax system. Finally, infrastructure leakage index (ILI) ranged from 0.9 in the central portion of the Halifax system to 12.2 in Philadelphia.

There is a strong correlation between real loss and ILI, but utilities with similar real loss performance indicators can have very different ILI values, depending on the characteristics of their systems. For example, Philadelphia has about twice as many service connections per mile of main as Fort Worth does. Philadelphia’s real loss (gal/conn/day) is approximately 19 percent greater than Fort Worth’s, but Philadelphia’s ILI is more than twice Fort Worth’s. Therefore, although their normalized real losses are somewhat similar, Fort Worth is currently faring better in relation to its unavoidable annual real loss than Philadelphia.

Table 7-1: Summary of North American Water Loss Performance for Individual Utilities

Year	Location	State/ Province	Performance Indicator				Reference
			Non-Revenue Water (%)	Apparent Loss (gal/conn/day)	Real Loss (gal/conn/day)	ILI (-)	
2001	Halifax Central	NS			16	0.9	J
NA	Seattle	WA			28		K
2003	Orlando	FL		17	32	2.2	J
2002	Anonymous	ON			39		J
1999	Anonymous	KY			42	2.7	J
2004	Los Angeles	CA		36	46	2.2	J
2003	Salt Lake City	UT	8.5	26	48	2.0	L
2003	Anonymous	AZ		20	58	3.3	J
NA	El Dorado Irrigation District	CA			66		K
2002	Anonymous	TX		13	68	4.6	J
2003	Anonymous	UT		26	68	2.8	J
NA	Halifax	NS			83		K
2004	Cleveland	OH	28.6	54.8	84.5	4.2	M
NA	Dallas	TX			91		K
2002	Nashville	TN		42	93	5.2	J
2001	Halifax East	NS			95	2.9	J
NA	Birmingham	AL			98		K
2001	Fort Worth	TX		17	108	5.4	J
2003	Philadelphia	PA		24	129	11.8	J
2004	Philadelphia	PA	35.4	20.3	132.6	12.2	N
NA	Philadelphia	PA			151		K
2001	Boston	MA		24	160	9.0	J
1999	Anonymous	FL			165	11.6	J

Table 7-1 Continued: Summary of North American Water Loss Performance for Individual Utilities

Year	Location	State/ Province	Performance Indicator				Reference
			Non-Revenue Water (%)	Apparent Loss (gal/conn/day)	Real Loss (gal/conn/day)	ILI (-)	
2001	Halifax West	NS			172	11.5	J
NA	Halifax	NS				4	M
NA	Fort Worth	TX	14.0			5.4	M
2004	Fort Worth	TX				5.5	O
2001	Charlotte County	FL		4.0			J
2003	Halifax	NS		6.4			J
2002	Anonymous	ON		37		2.9	J

Water loss performance statistics are summarized for groups of international and North American utilities in Table 7-2. Entries are generally sorted by average value for non-revenue water, apparent loss, real loss, and ILI. Generally speaking, little information is available regarding how long each utility has been refining its water audit and how reliable the reported data are.

For individual utilities, the following ranges of water loss performance are noted:

- Non-revenue water as a percentage of corrected input volume: 4 percent (Asia) to 77 percent (Portugal).
- Apparent loss: 8 gal/conn/day to 77 gal/conn/day for relatively small utilities in Colombia.
- Real loss: 1 to 66 gal/conn/day and 270 to 211,262 gallons per mile of main per day for relatively small utilities in Colombia.
- ILI: 0.6 for an urban California utility to 79 for a utility in an international data set.

7.B Water Loss Performance Goals

Based on Texas water loss performance results presented in later chapters, retail public utilities, regional water planning groups, governmental agencies, and legislators may decide that they need to set water loss performance goals. Because there has been little experience with setting water loss performance goals in Texas, it is appropriate to consider what goals other utilities and agencies, both nationally and internationally, have set. These goals are summarized below.

7.B.1 ILI Goals

The most common water loss performance goal is to reduce a utility's ILI, which involves reducing the normalized real loss (gal/conn/day or gal/mile/day). The American Water Works Association (AWWA) Water Loss Control Committee recommends that the goal for an individual utility should be to reduce water loss to the "economic level of leakage," defined as "the level at which the cost of leakage reduction activities meets the cost of water saved through leakage reduction."[H] The economic level of leakage will change as the local economics of water supply change.

Table 7-2: Summary of North American and International Water Loss Performance

Year	Location	Number of Utilities	Minimum	Maximum	Median	Average	Reference
Non-revenue water (% of corrected input volume)							
2001	Asia	18	4	65	36	30	P
2003/04	Portugal	50	15	56		31	Q
2003	Portugal	300	7	77		36	Q
NA	Italy		15	60		42	R
Apparent loss (gal/conn/day)							
2004	Colombia	40	8	77		38	S
Real loss (gal/conn/day)							
2004	Colombia	40	1	666		69	S
NA	International	27	8	220	53	73	T
NA	North America	10	16	177	100		U
2003	Korea	84	29	539		157	V
Real loss (gal/mile of main/day)							
2005	California	9	750	7,900	3,000		W
2004	Colombia	40	270	211,262		13,991	S

Table 7-2 Continued: Summary of North American and International Water Loss Performance

Year	Location	Number of Utilities	Minimum	Maximum	Median	Average	Reference
Infrastructure Leakage Index							
2005	California	6	0.6	4.4	1.8		W
NA	Australia	22	1.1	13.1	2.2		J
NA	Northwest England	1 (34 Districts)	1.1	3.2	2.2	2.4	X
2002/03	England/Wales	22	1.1	6.3	2.4		J
NA	International	27	0.7	10.9	2.9	4.4	T
NA	Canada	13	0.5	18.1	3.6		Y
NA	North America	17 US, 3 Canada	0.8	11.9	4.3	4.9	Z
NA	South Africa	26	2.0	19.8	4.3		J
NA	North America	10	0.9	13.1	5.0		U
NA	Italy	14	4.2	15.8	6.1		R
2004	Colombia	9	2.1	15.7	7.2	8.7	S
2003	Korea	84	2.3	46.1		12.5	V
NA	International	55	1.2	79.0	9.0	15.8	AA

Most Texas utilities have not yet conducted a system-specific study to determine their economic level of leakage. The AWWA Water Loss Control Committee has published general guidelines (Table 7-3) to help utilities set an intermediate target ILI until a system-specific economic level of leakage can be determined. These guidelines are based on raw water availability, existing treatment and distribution infrastructure, and the cost of developing new water sources. In locations where undeveloped water is scarce and expensive, the AWWA guidelines would justify an ILI goal of 1 to 3. Conversely, in locations where undeveloped water is plentiful and inexpensive, the AWWA guidelines may justify an ILI goal of 5 to 8.[20]

The Fort Worth Water Department has set a goal of reducing its ILI by approximately 1 percent per year through 2015.[O] The Halifax Regional Water Commission, which serves a population of more than 300,000 in Halifax, Nova Scotia, has set an ILI goal of 3.

Internationally, minimum leakage management actions based on ILI have recently been proposed for utilities in Australia (Table 7-4). Although this table does not specifically set numerical ILI goals, it does classify ranges of ILI values as “excellent,” “reasonable,” “unacceptable,” etc., and proposes management actions that include leak detection and pressure management. Presumably, use of the proposed management actions will minimize ILI.

Compared to leakage levels in the rest of the world, Australian water supply systems experience relatively low leakage; therefore, the ILI bands in Table 7-4 are narrow, and the overall ILI values are relatively low.[AA] Table 7-5 shows a “more comprehensive and flexible” set of proposed ILI categories intended for worldwide use.[AA] The proposed ILI categories were presented to the International Water Association in 2005, where they were “considered appropriate for use in both developed as well as developing countries.”[AA] The proposed ILI categories fall somewhere between the Australian proposal (Table 7-4) and the AWWA guidelines (Table 7-3).

[20] As discussed in Chapter 5.C, the methodology for calculating ILI does not necessarily apply to utilities with fewer than 5,000 connections or fewer than 32 service connections per mile. Therefore, it is especially important that such utilities determine a system-specific economic level of leakage.

Table 7-3: AWWA General Guidelines for Setting a Target Infrastructure Leakage Index (ILI) for Utilities That Have Not Determined Their System-Specific Economic Level of Leakage[H]

Target ILI Range	Water Resources Considerations	Operational Considerations	Financial Considerations
1.0-3.0	Available resources are greatly limited and are very difficult and/or environmentally unsound to develop.	Operating with system leakage above this level would require expansion of existing infrastructure and/or additional water resources to meet the demand.	Water resources are costly to develop or purchase; ability to increase revenues via water rates is greatly limited because of regulation or low ratepayer affordability.
3.0-5.0	Water resources are believed to be sufficient to meet long-term needs, but demand management interventions (leakage management, water conservation) are included in the long-term planning.	Existing water supply infrastructure capability is sufficient to meet long-term demand as long as reasonable leakage management controls are in place.	Water resources can be developed or purchased at reasonable expense; periodic water rate increases can be feasibly imposed and are tolerated by the customer population.
5.0-8.0	Water resources are plentiful, reliable, and easily extracted.	Superior reliability, capacity, and integrity of the water supply infrastructure make it relatively immune to supply shortages.	Cost to purchase or obtain/treat water is low, as are rates charged to customers.
Greater than 8.0	Although operational and financial considerations may allow a long-term ILI greater than 8.0, such a level of leakage is not an effective utilization of water as a resource. Setting a target level greater than 8.0 (other than as an incremental goal to a smaller long-term target) is discouraged.		

ILI guidelines for the German water industry are shown in Table 7-6. These guidelines suggest that an ILI greater than about 3 requires real loss reduction.

The state of Sao Paulo, Brazil, where the current average ILI is 6, has set an ILI goal of 3.[J] In South Africa, the average ILI value is about 6, an ILI above 10 is considered to be very poor and worthy of attention, and a value of 4 or less is currently considered to be acceptable.[J]

Table 7-4: Proposed Minimum Leakage Activities for Australian Utilities[BB (cited in AA)]

	Management Action	ILI < 1.5 Excellent	1.5 < ILI < 2.0 Good	2.0 < ILI < 2.5 Reasonable	2.5 < ILI < 3.0 Fair	3.0 < ILI < 3.5 Poor	ILI > 3.5 Unacceptable
Do You Need This Action?	Economic Pressure Management	Yes	Yes	Yes	Yes	Yes	Yes
	Repair Policy Statement	Yes	Yes	Yes	Yes	Yes	Yes
	Single Detection Intervention			Yes	Yes	Yes	Yes
	Regular Detection Intervention				Yes	Yes	Yes
	Peer Review of Leak Management Activities				Yes	Yes	Yes
	Formulate and Implement Action Plan						Yes

Notes:

1. Determine the utility's ILI classification.
2. Look down chart to determine management actions required.
3. Wherever the word "Yes" appears, the utility must, as a minimum, implement these management actions.

Table 7-5: Proposed Use of ILI as a Performance Indicator in Developed and Developing Countries[CC (cited in AA)]

Technical Performance Category		ILI	Real Loss (gal/conn/day) when the system is pressurized at an average pressure of:				
			14 psi	**28 psi**	**43 psi**	**57 psi**	**71 psi**
Developed Countries	A	1-2		<13	<20	<26	<33
	B	2-4		13-26	20-40	26-53	33-66
	C	4-8		26-53	40-79	53-106	66-132
	D	>8		>53	>79	>106	>132
Developing Countries	A	1-2	<13	<26	<40	<53	<66
	B	4-8	13-26	26-53	40-79	53-106	66-132
	C	8-16	26-53	53-106	79-159	106-211	132-264
	D	>16	>53	>106	>159	>211	>264

Notes:

1. Units converted from metric.
2. Category A: Further loss reduction may be uneconomic unless there are shortages; careful analysis needed to identify cost effective improvement.
3. Category B: Potential for marked improvements; consider pressure management; better active leakage control practices, and better network maintenance.
4. Category C: Poor leakage record; tolerable only if water is plentiful and cheap; even then, analyze level and nature of leakage and intensify leakage reduction efforts.
5. Category D: Inefficient use of resources; leakage reduction programs imperative and high priority.

Table 7-6: German Leakage Level Guidelines[DD (cited in J)]

Category	Network Structure		
	Urban, Large Cities	**Urban**	**Rural**
Infrastructure Leakage Index (ILI)			
Low	< 1.38	< 1.17	< 0.97
Medium	1.38-2.76	1.17-2.50	0.97-1.95
High	> 2.76	> 2.50	> 1.95
Real Loss (gal/mile/day)			
Low	< 1,020	< 714	< 510
Medium	1,020-2,041	714-1,530	510-1,020
High	> 2,041	> 1,530	> 1,020
Real Loss (gal/conn/day)			
Low	< 13	< 12	< 13
Medium	13-25	12-25	13-25
High	> 25	> 25	> 25

Notes:
Assumed 80 connections per mile in urban, large cities network structure; 60 connections per mile in urban network structure; and 40 connections per mile in rural network structure.

Low level of real losses: According to the German definition, the low level of losses can nearly be considered as unavoidable real losses.

Medium level of real losses: Normally, real losses should not exceed the upper range given in this category, meaning that they should not be more than two times the unavoidable real losses.

High level of real losses: Real losses at these levels require special attention, efforts and loss reduction measures to be taken.

7.B.2 Real Loss Goals

In the United Kingdom, the national goal for real losses is 30 gal/conn/day.[J]

The state of Sao Paulo, Brazil, has set a real loss goal of 40 gal/conn/day.[J]

Real loss guidelines for the German water industry are shown in Table 7-6. These guidelines suggest that real loss greater than about 2,000 gal/mile/day or 25 gal/conn/day requires real loss reduction.

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8 DISCUSSION OF COMPARATIVE ANALYSIS OF WATER LOSS PERFORMANCE INDICATORS

This chapter introduces the comparative analysis of water loss performance indicators through a discussion of the statistics that will be presented, an introduction to the results that are presented in the appendices, and a discussion of the interpretation of results.

8.A Statistics

Comparisons of water loss performance indicators can be made using entire statistical distributions, percentile values, median values, and/or average values. Eight different water loss performance indicators are summarized in this chapter for different geographic areas, utility types, and utility sizes. Because of the tremendous amount of data, it is not feasible to show the entire distribution of each performance indicator for each geographic area, utility type, and utility size.

In addition, the balancing adjustment assumption discussed in Chapter 6.A complicates the reporting somewhat, resulting in upper and lower bounds for each water loss performance indicator rather than a single estimate. Therefore, although percentile values (*e.g.*, 25th and 75th percentiles) can be used to convey additional information about the statistical distribution, reporting percentile values will also result in too much information for concise summary and comparison of water loss.

Therefore, the feasible options for summarizing and comparing water loss performance indicators are the median values and average values of the distributions of each indicator. The median of a distribution depends on the number of reporting utilities, while the average depends on the magnitudes of the values in the distribution. Therefore, the median is much less sensitive than the average to an individual value.

In some cases, it may not be appropriate for an individual value to disproportionately influence the characterization of water loss. If an individual value is an outlier that is still present in the data even after quality control, then the median may characterize water loss in a given region or county better than the average. In other cases, however, it may be appropriate for an individual value to disproportionately influence the characterization of water loss. If the individual value is an accurate value reported by a utility that is responsible for most of the water use in a region or county, then the average may characterize water loss in the region or county better than the median.

Total water loss or the total value of water loss for a given geographic area, utility type, or utility size may also be of interest. Totals and averages are inextricably linked, because the average is the total divided by a normalizing factor (e.g., number of utilities, number of service connections, or miles of main). Totals are subject to the same issues with outliers and large water providers as averages.

Where the amount of available information is too voluminous to report distributions, percentiles, medians, and averages for each water loss performance indicator, average values have been used to characterize water loss performance by geographic unit, utility type, and utility size.

8.B Results Presented in Appendices

Distributions of water loss performance indicators (statewide) and average values for water loss performance indicators (by utility location, type, and size) are presented in Appendix C through Appendix H. In each of these appendices, graphs are presented for the following quantities:

- Absolute value of balancing adjustment,
- Real loss per mile of main per day,
- Real loss per service connection per day,
- Screening-level ILI (SLILI),
- Apparent loss per service connection per day,
- Value of real loss per mile of main per day,
- Value of real loss per service connection per day, and
- Value of apparent loss per service connection per day.

Where real loss or the value of real loss is normalized by miles of main, results are presented only for utilities with fewer than 32 service connections per mile of main.[D] Where real loss or the value of real loss is normalized by the number of service connections, results are presented only for utilities with 32 or more service connections per mile of main.[D] SLILI results are presented only for utilities with 5,000 or more connections and 32 or more connections per mile of main. If there are no utilities within a geographic unit (region, county, BOR hot spot), utility type, or utility size that meet these conditions, then a null value is shown in the graphs.

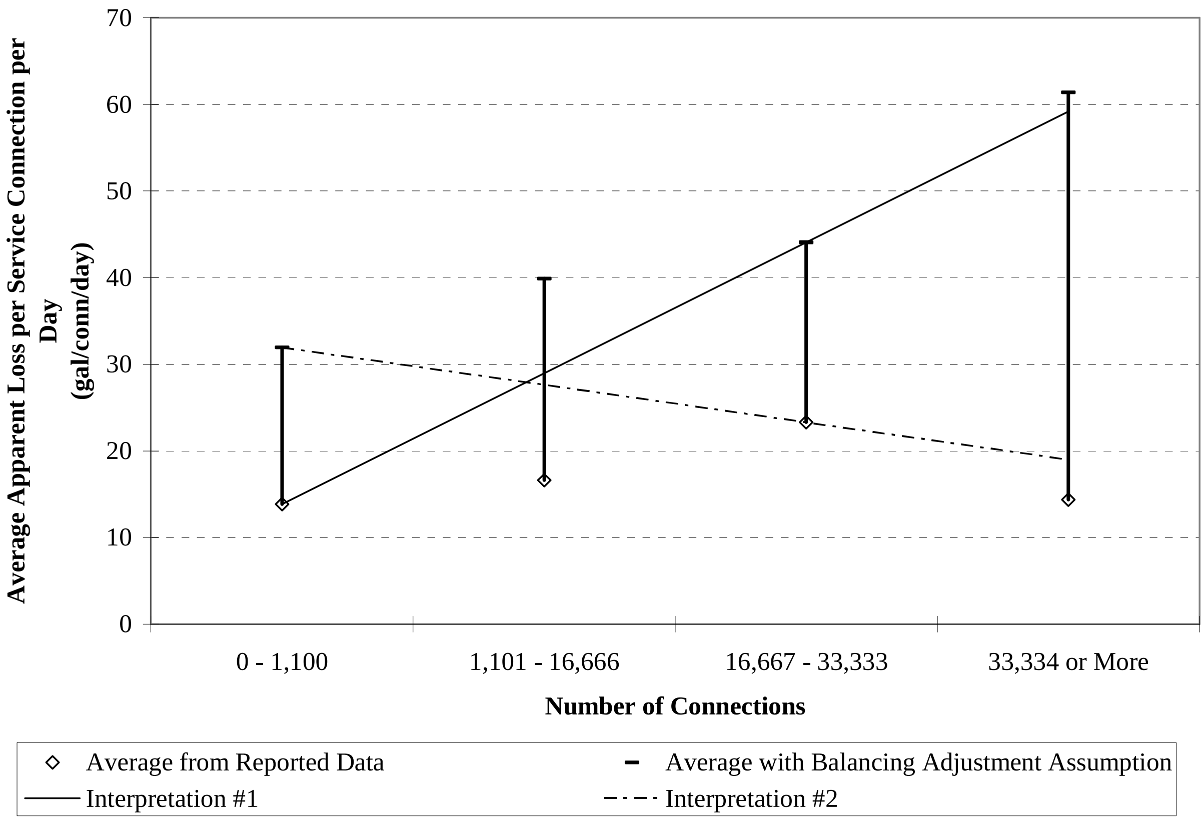
For each parameter in Appendix D through Appendix H (with the exception of the absolute value of the balancing adjustment), two points are shown on the graph for each utility location, type, or size. The first point shows the average value as calculated from the reported water loss data. The second point shows the average value if it is assumed that the balancing adjustment is unreported real or apparent loss. The line connecting the two points defines a range of possible values for a given parameter. The actual value experienced by the utility should be located somewhere within this range.

For the vast majority of utilities, the balancing adjustment is positive, and the second point will generally be higher than the first point. However, balancing adjustment is negative for utilities that have over-allocated their water to the different categories. If the average balancing adjustment is negative, then the second point is lower than the first point.

8.C Interpretation of Results

Because the balancing adjustments are so large in many cases, it can be difficult to interpret the results properly, and trends in the results may not be as clear-cut as they seem. As an example, consider the average apparent loss per service connection per day for utilities of various sizes (Figure 8-1). As discussed above, a diamond point shows the average calculated from the data as reported, and a bar point assumes that all balancing adjustment is unreported apparent loss. In other words, a diamond point represents a lower bound, a bar point represents an upper bound, and the actual average apparent loss per service connection per day is somewhere within the range of possible values as shown by the line connecting the two points. At first glance, it may appear that there is a trend of increasing apparent loss per service connection per day with increasing number of service connections (Interpretation #1), primarily because the bar points (the upper bound) do increase with increasing number of service connections. However, one could also argue that the apparent loss per service connection per day decreases with increasing

Figure 8-1: Interpretation of Results



number of service connections (Interpretation #2). In fact, one can draw an infinite number of lines that pass between the upper and lower bounds for each grouping of utility sizes.

Given the balancing adjustment assumption, each of these hypothetical interpretations might represent the actual average apparent loss experienced by the utilities. Therefore, without refinement of the water loss data, it is not possible to say whether apparent loss per service connection per day is correlated to the number of service connections. Sizable balancing adjustments are present in most of the graphs in the appendices, and the reader should use caution in attempting to identify trends in water loss performance.

8.D Introduction to Comparative Analysis

In the following chapters, a statewide summary of water loss and a comparative analysis of water loss performance indicators by utility location, type, and size are reported. Discussion focuses on non-revenue water, the value of non-revenue water, balancing adjustment, and screening-level ILI.

In general, normalizing non-revenue water or water loss by corrected input volume is the least robust method of normalization. It is difficult to compare non-revenue water or water loss percentages between utilities because they have different characteristics (miles of main, service connections, etc.). In addition, a change in corrected input volume from year to year causes a change in the percentage, even if the volume of non-revenue water or water loss has not changed. It is more robust to normalize non-revenue water or water loss by miles of main or number of service connections, because both of these are characteristics of a utility system and can be directly related to non-revenue water and water loss.

Nonetheless, it is difficult to normalize non-revenue water by miles of main or number of service connections in a meaningful way for this analysis. In the following chapters, it is desirable to present a single non-revenue water statistic by utility location, type, and size. However, real loss should be normalized by miles of main for utilities with fewer than 32 connections per mile of main and should be normalized by number of service connections for utilities with 32 or more connections per mile of main.[D] Therefore, it is not possible to produce a single, meaningful non-revenue water statistic by utility location, type, and size unless non-revenue water is normalized by corrected input volume. As a concession to this difficulty, non-revenue water is presented as a percentage of corrected input volume in the following chapters.

Real and apparent losses have been normalized using miles of main and number of service connections, as appropriate.

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9 STATEWIDE SUMMARY OF WATER LOSS PERFORMANCE INDICATORS

This chapter provides a summary of water loss performance in Texas. In the following sections, statewide estimates for water loss and the value of the lost water are presented, statewide average and median values of water loss performance indicators are presented, and possible correlations between demographic factors and water loss performance are analyzed.

9.A Statewide Totals

After quality control, the 1,959 reporting utilities reported serving 19,147,421 people through 6,310,826 service connections and 143,647 miles of main.[21] The total of the reported population served contains the population of some wholesale customers (possibly more than once), so the actual total retail population served is less than the total of the reported population served. Using 2005 Census estimates of 22,859,968 people and 9,026,011 total housing units in Texas[EE] and assuming one service connection per housing unit, there could be as few as 2.53 people per service connection statewide, which would indicate a total retail population for reporting utilities of as few as 15,966,390. Therefore, it is estimated that water loss data have been reported for between 70 and 84 percent of the state population.

The total number of retail service connections should be close to the total of the reported number of service connections, because a wholesale customer would only be reported as a single connection. It has been assumed that miles of main have been reported for the retail service area only. Therefore, normalization of water loss by the number of service connections and miles of main should give water loss performance indicators that can be fairly compared between utilities.

Water loss totals for reporting utilities are shown in Table 9-1 (acre-feet), Table 9-2 (gallons), and Table 9-3 (percent of corrected input volume). The total reported corrected input volume is 3,761,965 acre-feet over approximately one year. This figure includes retail water sales and wholesale water sales for the reporting utilities (see Chapter 3.B.7 for discussion).

[21] 35 utilities did not report the number of service connections, and 81 utilities did not report miles of main. For a given quantity, the average value was calculated based only on the utilities that reported a value for that quantity. For example, the average real loss per mile of main was calculated based on data from 1,878 utilities.

Table 9-1: Statewide Totals of Reported Water Loss* (acre-feet)

<table>
<tr><td rowspan="11">Corrected input volume
(3,758,484)</td><td rowspan="4">Authorized consumption
(3,294,265)</td><td rowspan="2">Billed authorized consumption
(3,195,153)</td><td>Billed metered consumption
(3,190,972)</td><td rowspan="2">Revenue water
(3,195,153)</td></tr>
<tr><td>Billed unmetered consumption
(4,181)</td></tr>
<tr><td rowspan="2">Unbilled authorized consumption
(99,112)</td><td>Unbilled metered consumption
(52,698)</td><td rowspan="8">Non-revenue water
(311,333)</td></tr>
<tr><td>Unbilled unmetered consumption
(46,414)</td></tr>
<tr><td rowspan="6">Water losses
(212,221)</td><td rowspan="3">Apparent losses
(109,310)</td><td>Unauthorized consumption
(10,770)</td></tr>
<tr><td>Customer meter under-registering
(87,218)</td></tr>
<tr><td>Billing adjustment and waivers
(11,322)</td></tr>
<tr><td rowspan="3">Real losses
(102,910)</td><td>Main breaks and leaks
(83,529)</td></tr>
<tr><td>Storage overflows
(3,341)</td></tr>
<tr><td>Customer service line breaks and leaks
(16,040)</td></tr>
<tr><td colspan="4">Balancing Adjustment**
(251,998)</td></tr>
</table>

* Over approximately one year. Most utilities reported data for calendar or fiscal year 2005.

** Balancing adjustment is the corrected input volume minus authorized consumption minus total water loss. If all water is fully attributed to the various potential uses, balancing adjustment is zero. Balancing adjustment may consist of underestimated real loss, apparent loss, or authorized consumption. Without further refinement of a utility's water audit, there is no accurate *ad hoc* method for determining the actual water use for water that has been allocated to balancing adjustment.

Table 9-2: Statewide Totals of Reported Water Loss* (gallons)

Corrected input volume (1,224,705,675,107)	Authorized consumption (1,073,439,695,489)	Billed authorized consumption (1,041,143,853,511)	Billed metered consumption (1,039,781,485,415)	Revenue water (1,041,143,853,511)
			Billed unmetered consumption (1,362,368,096)	
		Unbilled authorized consumption (32,295,841,978)	Unbilled metered consumption (17,171,730,325)	Non-revenue water (101,448,133,344)
			Unbilled unmetered consumption (15,124,111,653)	
	Water losses (69,152,291,366)	Apparent losses (35,618,824,222)	Unauthorized consumption (3,509,318,446)	
			Customer meter under-registering (28,420,204,130)	
			Billing adjustment and waivers (3,689,301,646)	
		Real losses (33,533,467,144)	Main breaks and leaks (27,218,129,878)	
			Storage overflows (1,088,723,441)	
			Customer service line breaks and leaks (5,226,613,826)	
	Balancing Adjustment** (82,113,688,252)			

* Over approximately one year. Most utilities reported data for calendar or fiscal year 2005.

** Balancing adjustment is the corrected input volume minus authorized consumption minus total water loss. If all water is fully attributed to the various potential uses, balancing adjustment is zero. Balancing adjustment may consist of underestimated real loss, apparent loss, or authorized consumption. Without further refinement of a utility's water audit, there is no accurate *ad hoc* method for determining the actual water use for water that has been allocated to balancing adjustment.

Table 9-3: Statewide Percentages of Reported Water Loss*

<table>
<tr><td rowspan="11">Corrected input volume
(100.0)</td><td rowspan="4">Authorized consumption
(87.6)</td><td rowspan="2">Billed authorized consumption
(85.0)</td><td>Billed metered consumption
(84.9)</td><td rowspan="2">Revenue water
(85.0)</td></tr>
<tr><td>Billed unmetered consumption
(0.1)</td></tr>
<tr><td rowspan="2">Unbilled authorized consumption
(2.6)</td><td>Unbilled metered consumption
(1.4)</td><td rowspan="8">Non-revenue water
(8.3)</td></tr>
<tr><td>Unbilled unmetered consumption
(1.2)</td></tr>
<tr><td rowspan="6">Water losses
(5.6)</td><td rowspan="3">Apparent losses
(2.9)</td><td>Unauthorized consumption
(0.3)</td></tr>
<tr><td>Customer meter under-registering
(2.3)</td></tr>
<tr><td>Billing adjustment and waivers
(0.3)</td></tr>
<tr><td rowspan="3">Real losses
(2.7)</td><td>Main breaks and leaks
(2.2)</td></tr>
<tr><td>Storage overflows
(0.1)</td></tr>
<tr><td>Customer service line breaks and leaks
(0.4)</td></tr>
<tr><td colspan="4">Balancing Adjustment**
(6.7)</td></tr>
</table>

* Over approximately one year. Most utilities reported data for calendar or fiscal year 2005.

** Balancing adjustment is the corrected input volume minus authorized consumption minus total water loss. If all water is fully attributed to the various potential uses, balancing adjustment is zero. Balancing adjustment may consist of underestimated real loss, apparent loss, or authorized consumption. Without further refinement of a utility's water audit, there is no accurate *ad hoc* method for determining the actual water use for water that has been allocated to balancing adjustment.

Because statewide municipal water use data for 2005 are not yet available, it is not possible to estimate how much of the total corrected input volume is retail water use.

Reporting utilities experienced total water loss of 212,221 to 464,219 acre-feet per year,[3] or 5.6 to 12.3 percent[3] of the water entering their systems. Based on the 2004 statewide average municipal water use of 150 gallons per capita per day,[A] equivalent water volumes could supply between 1.3 million and 2.7 million Texans. However, not all water loss can be recovered.

From the reported data, the following additional statewide average quantities can be derived:

- Master meter accuracy: 99.1 percent
- Customer meter accuracy: 97.7 percent
- Production water cost: $0.84 per thousand gallons
- Retail water cost: $2.72 per thousand gallons
- Service connections per mile of main: 43.5
- Reporting period: 365.2 days

Non-revenue water, for which utilities are not compensated, consists of real loss, apparent loss, and unbilled authorized consumption. Statewide, the largest contributor to real loss is main leaks and breaks, the largest contributor to apparent loss is customer meter under-registering, and unbilled authorized consumption is roughly split between unbilled metered and unbilled unmetered consumption (Table 9-3). The reported real loss (2.7 percent of corrected input volume), apparent loss (2.9 percent), and unbilled authorized consumption (2.6 percent) all have similar magnitudes. However, at 6.7 percent of corrected input volume, the balancing adjustment is larger than the reported real and apparent losses added together.

9.B Statewide Value of Non-Revenue Water

In determining the value of non-revenue water, apparent loss and unbilled authorized consumption were valued at the retail unit water cost, and real loss was valued at the production unit water cost. Apparent loss and unbilled authorized consumption were valued at the retail unit water cost, because these categories represent water that could have been billed at retail rates but was not. Real loss was valued at the production unit water cost, [22] because it represents water that was produced but was lost from the system before it could be sold.

Note that the production unit water cost requested on the Water Audit Reporting Form (Appendix A) is actually the marginal production unit water cost, or the cost of producing the last units of water. Production costs can be divided into fixed costs (e.g., personnel salaries and debt service) that are independent of how much water is produced and variable costs (e.g., power, chemicals, and raw or treated water purchase cost) that depend on how much water is produced. The marginal production unit water cost includes only the variable costs.

Although the water volumes associated with real loss, apparent loss, and unbilled authorized consumption are similar (Table 9-3), the dollar values of apparent loss and unbilled authorized consumption are greater than the dollar value of real loss, because the retail water cost is greater than the production water cost (Table 9-4).

The value associated with the balancing adjustment is more difficult to determine, because the sources of balancing adjustment can be difficult to identify and may be different for each utility. Balancing adjustment could be valued in the following ways:

- If the balancing adjustment results from misreading of the production meter, then the balancing adjustment is not non-revenue water and should not be included in the value of non-revenue water.
- If the balancing adjustment is underestimated real water loss, then it should be valued at the production unit water cost (Table 9-4).
- If the balancing adjustment is underestimated apparent water loss, then it should be valued at the retail unit water cost (Table 9-4).

[22] Another potential value of real water is the cost of a new water supply source. If a water loss control strategy will defer the need for a new water supply source, the value of the recovered water could be considered as the cost of the new water supply source. In such a case, the retail water cost may be a better approximator of the value of real loss. However, for generic calculations, the marginal production water cost is the most appropriate value for real loss, because it is the cost that is actually incurred.

Table 9-4: Total Annual Value of Non-Revenue Water for All Utilities That Reported Water Loss Data

Quantity	Total Annual Value	Annual Average Value Per Connection
Real Loss	$28,005,356	$4.57
Apparent Loss	$96,790,656	$15.61
Unbilled Authorized Consumption	$83,462,236	$13.46
Lower Bound Value	*$208,258,248*	*$33.65*
Balancing Adjustment (Production Cost)	$66,858,043	$10.92
Balancing Adjustment (Retail Cost)	$226,734,116	$36.57
Upper Bound Value[23]	*$434,992,365*	*$70.22*

For the utilities that reported water loss data, the total annual value of non-revenue water (including the value of reported real loss, apparent loss, and unbilled authorized consumption) may be as low as $208 million (Table 9-4). This lower bound value corresponds to an average of $33.75 per connection per year. If the balancing adjustment is valued at the retail water cost, the total annual value of non-revenue water for utilities that reported water loss data may be as high as $435 million. This upper bound value corresponds to an average of $70.43 per connection per year.

Similar bounds can be estimated for the value of the reported total water loss. The value of the reported total water loss may be as low as $125 million (or $20.19 per connection per year) and as high as $351 million (or $56.76 per connection per year).

Assuming that non-reporting utilities experience similar water losses and costs and serve from 16.2 to 30.4 percent of the state population (Chapter 9.A), the estimated total value of non-revenue water in Texas is between $253 million and $635 million per year, which includes an estimated total water loss value between $152 million and $513 million.[9] To increase the reliability and narrow the range of this estimate, the production and retail water costs must be more uniformly reported, and utilities must refine their water accounting, thereby reducing the balancing adjustment.

[23] To identify the upper bound value of non-revenue water, it has been assumed that balancing adjustment is valued at the retail water cost.

9.C Strategies for Reducing Non-Revenue Water

To reduce non-revenue water, a utility can reduce unbilled authorized consumption, apparent loss, and/or real loss. Reducing unbilled authorized consumption and apparent loss recovers lost revenue but does not reduce water use. Reducing real loss recovers lost revenue and reduces water use, so reducing real loss is also a water conservation measure.

A utility cannot completely eliminate non-revenue water. There will always be unavoidable annual real loss and apparent loss (see discussion in Chapter 5.C), and it may not be economical to reduce non-revenue water beyond a certain economic target level.[24] To reduce non-revenue water beyond the economic target level, the utility would spend more money than it would recover. Although this may not be advisable from a purely economic standpoint, there may be valid non-monetary reasons to reduce non-revenue water beyond the economic target level.

The economic target level for an individual utility depends on its marginal production water cost and retail water cost. If water resources are limited, the economic target level will also depend on the cost of developing new water sources. All other factors being the same, a utility for which these costs are relatively high can justify spending more money to reduce its non-revenue water than a utility for which these costs are relatively low. In addition, it is generally more valuable to a utility to recover revenue from a gallon of apparent loss or a gallon of unbilled authorized consumption than from a gallon of real loss.

The distribution of non-revenue water among the different categories and the economic target level is unique to each individual utility. Therefore, strategies for reducing non-revenue water must be evaluated at the utility level: What might be a cost-effective strategy for one utility may not be cost-effective for another.

9.D Other Water Loss Performance Indicators

Distributions of other calculated water loss performance indicators for all reporting water utilities (after quality control) are presented in Appendix C. A summary of median and average values

[24] This is similar to the economic level of leakage discussed in Chapter 7.B. Determining the economic level of leakage is part of determining the economic target level for non-revenue water.

for each indicator is shown in Table 9-5. In general, the average values are greater than the median values, indicating that a minority of utilities is responsible for a majority of the water loss.

Averages calculated from the reported data are limited by the number of utilities reporting zero water loss: 195 utilities reported zero real water loss, 260 utilities reported zero apparent water loss, and 76 utilities reported zero real and apparent water loss. This is at least partially addressed by the balancing adjustment assumption, where it is assumed that the balancing adjustment is unreported water loss.

The balancing adjustment assumption makes a significant difference in the water loss performance indicators. For example, based on reported data, the median real loss per connection per day for utilities with 32 or more connections per mile of main is 3.6 gallons, which is only about 23 percent of the lowest identified real loss for a North American system (16 gal/conn/day for Halifax Central, shown in Table 7-1).

However, if it is assumed that the balancing adjustment is unreported real water loss, the median real loss per connection per day increases to 18.8 gallons (which is still quite low compared to North American utilities in Table 7-1). Therefore, for utilities with 32 or more connections per mile of main, it is projected that the actual statewide median real loss per connection per day is somewhere between 3.6 and 18.8 gallons. Similarly, the median and average values calculated with and without the balancing adjustment assumption represent the upper and lower bounds for the true median and average values for other water loss performance indicators (Table 9-5).

The range of potential average real loss per service connection per day (14 to 51 gal/conn/day) is higher than the range of potential median values. Although individual utilities may experience much greater levels of real loss, the potential range of average real loss is in the lower half of the range of real loss reported by North American utilities (Table 7-1).

The range of potential average apparent loss per service connection per day (15 to 51 gal/conn/day) is similar to the range of apparent loss reported by North American utilities (Table 7-1).

Table 9-5: Statewide Summary of Reported Water Loss Data

Statistic or Performance Indicator	Units	Median from Reported Data	Median With Balancing Adjustment Assumption	Average from Reported Data	Average With Balancing Adjustment Assumption
Absolute Value of Balancing Adjustment/Corrected Input Volume[10]	%	2.6	2.6	7.1	7.1
Real Loss per Mile of Main Per Day	gal/mi/day	77	233	204	417
Real Loss per Service Connection per Day	gal/conn/day	3.6	18.8	14	51
Apparent Loss per Service Connection per Day	gal/conn/day	6.4	17.5	15	51
Non-Revenue Water/Corrected Input Volume	%	7.3	13.4	8.3	15.0
Value of Real Loss per Mile of Main Per Day	$/mi/day	0.12	0.31	0.24	0.49
Value of Real Loss per Service Connection per Day	$/conn/day	0.004	0.018	0.010	0.040
Value of Apparent Loss per Service Connection per Day	$/conn/day	0.018	0.046	0.042	0.140
Screening-Level Infrastructure Leakage Index (SLILI)[11]	--	0.22	2.04	1.08	4.10

The median SLILI (the ratio of real loss to unavoidable real loss) for utilities with 5,000 or more connections and a connection density of 32 or more connections per mile of main is between 0.22 and 2.04. In theory, it is not possible for the actual real loss to be less than the UARL (resulting in an SLILI less than 1.00), indicating that the reported real loss has been underestimated by many utilities.

Even assuming that the balancing adjustment is unreported real loss, the statewide median SLILI is only 2.04, and the statewide median real loss is 18.8 gal/conn/day. Compared to the AWWA guidelines for ILI goals (Table 7-3) and real loss performance by North American utilities (Table 7-1), these statistics seem to indicate that at least half of reporting utilities have excellent real loss control. However, most utilities in Texas practice real loss control in a reactive way (rather than a proactive way), so it is surprising that half of the reporting utilities have such excellent real loss performance, particularly in comparison to other North American utilities.

Because the actual statewide median SLILI value is so low (somewhere between 0.22 and 2.04), it appears from the water loss performance indicators that most reporting utilities have underestimated actual real loss. Furthermore, from comparison to AWWA guidelines and real loss performance by other North American utilities, it appears likely that the actual real loss is underestimated even if the balancing adjustment is treated as real loss.

Comparing the upper bound of the statewide average SLILI (4.10) to the guidelines in Table 7-3 suggests that utilities in Texas may need to do more to control real loss. If real loss is indeed being underestimated, then the actual average SLILI may be greater than 4.10. Real loss estimation problems notwithstanding, at least 8 to 30 percent of Texas utilities with more than 5,000 connections and 32 or more connections per mile of main have an SLILI greater than 3.0 (Appendix C) and might benefit from real loss control measures, according to AWWA guidelines (Table 7-3).

The statewide median non-revenue water percentage is between 7.4 and 13.5 percent of corrected input volume. The average non-revenue water percentage is slightly higher, at 8.3 to 15.0 percent of corrected input volume.

9.E Correlation Coefficients

Correlation coefficients were calculated between all reported non-water-volume quantities (e.g., number of service connections) and normalized water loss performance indicators (e.g., real loss per mile of main per day) to identify possible relationships between variables.

Although many of the variables are strongly correlated, no unexpected or insightful relationships were identified. The strongly correlated variables were those where a relationship is obvious, such as number of service connections and miles of main, or real loss percentage and non-revenue water percentage.

10 COMPARATIVE ANALYSIS BY REGIONAL WATER PLANNING AREA

Water loss results were compared across the 16 regional water planning areas in Texas (Figure 10-1). The distribution of reporting utilities and the total corrected input volume is shown by region in Figure 10-2. As discussed in the previous chapter, wholesale water sales are included in the corrected input volume multiple times, so the total corrected input volume does not necessarily reflect total retail water use.

Regional statistics and water loss performance indicators are presented in the following sections.

10.A Regional Statistics

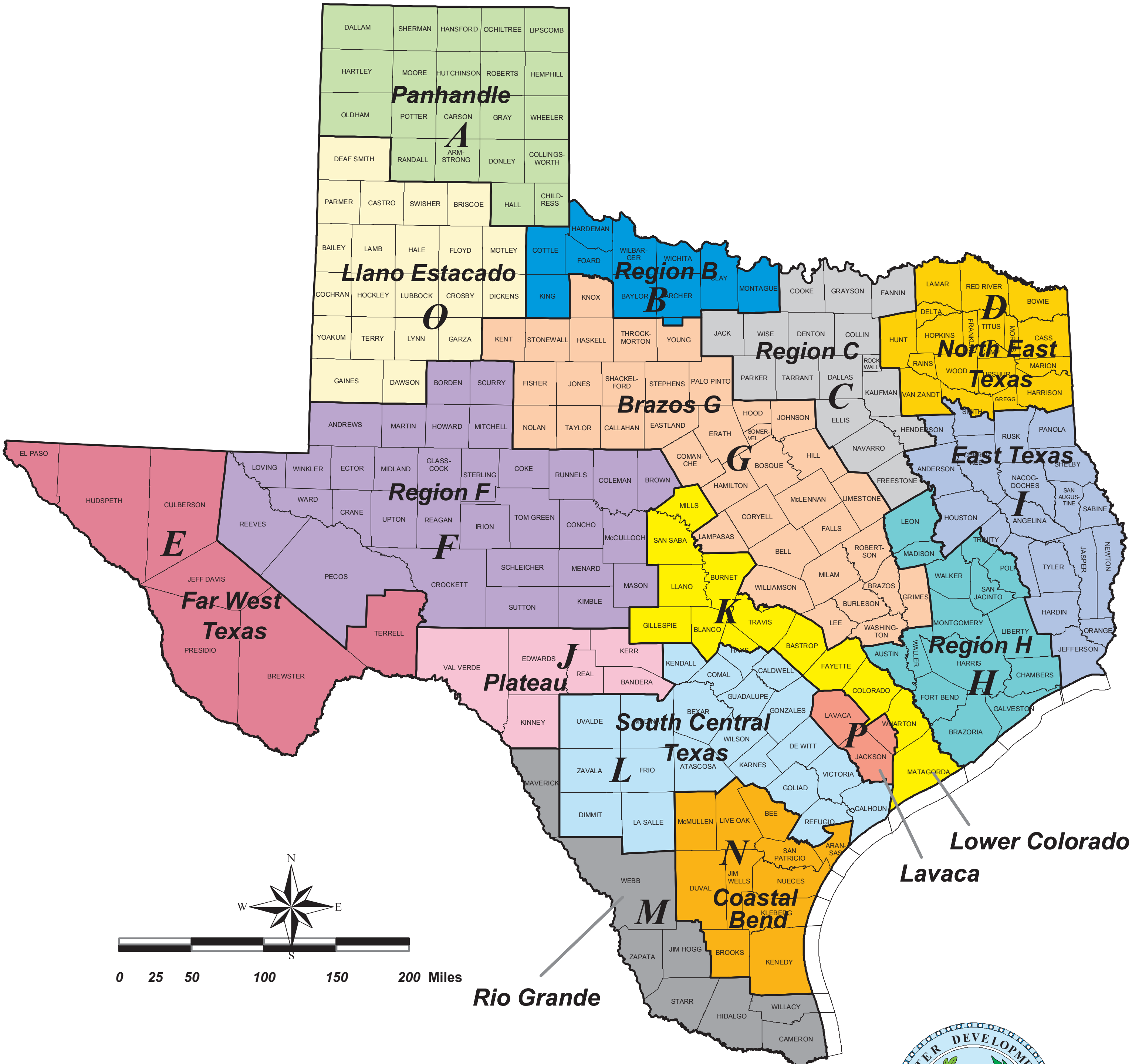
Several additional regional average quantities can be derived from the reported data (Table 10-1). The ranges of the regional averages are:

- Master meter accuracy: 95.7 – 100.3 percent
- Customer meter accuracy: 94.1 – 99.5 percent
- Production water cost: $0.34 – $2.02 per thousand gallons
- Retail water cost: $0.94 – $5.13 per thousand gallons
- Service connections per mile of main: 14.6 – 89.6
- Reporting period: 346.7 – 383.5 days

10.B Regional Water Loss Performance Indicators

The average reported non-revenue water as a percentage of corrected input volume for each region is shown in Figure 10-3. Regions I and J have the highest average non-revenue water percentage (ranging from approximately 19 percent to as much as 27 percent). These regions also had the highest reported average unbilled authorized water use, at 5.5 percent and 9.4 percent of corrected input volume, respectively, compared to the statewide reported average of 2.6 percent. Utilities in Regions I and J should consider steps to recover lost revenue from unbilled authorized consumption. This will reduce the non-revenue water percentage in these regions.

*Figure 10-1: Regional Water Planning Areas in Texas**



* Texas Water Development Board,
Available URL: http://www.twdb.state.tx.us/mapping/maps/pdf/sb1_groups_8x11.pdf,
accessed November 2006.

Figure 10-2: Distribution of Reporting Utilities by Regional Water Planning Area

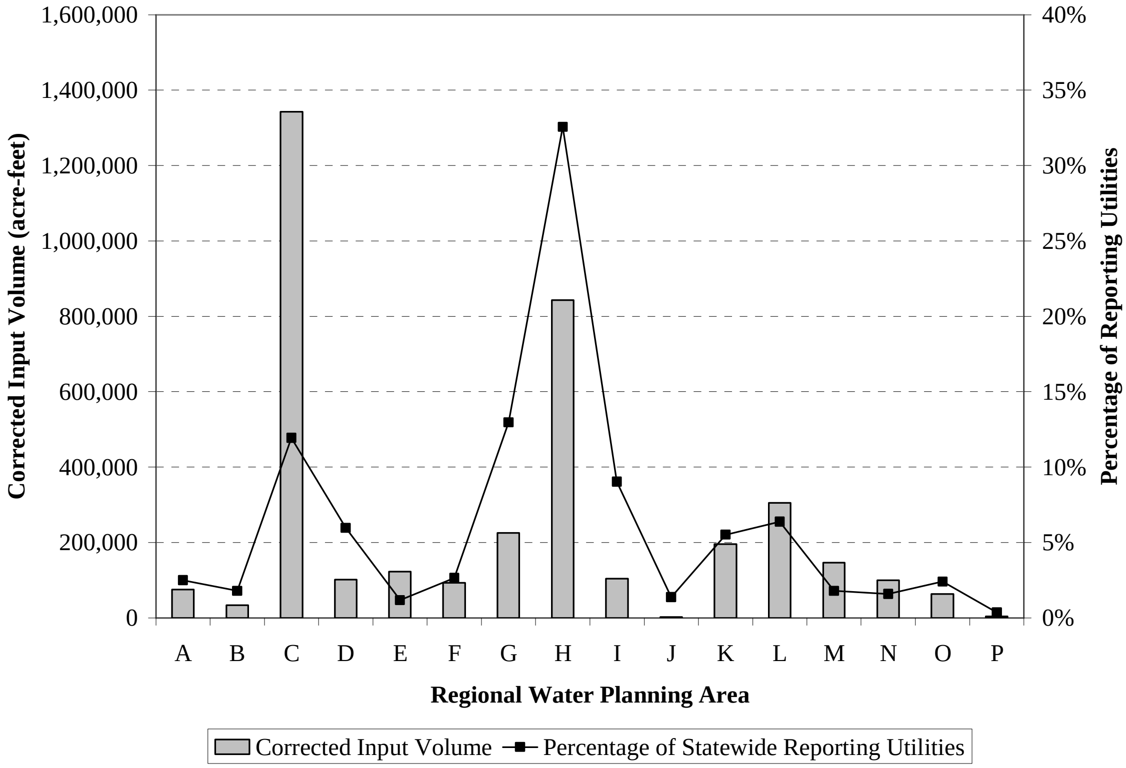
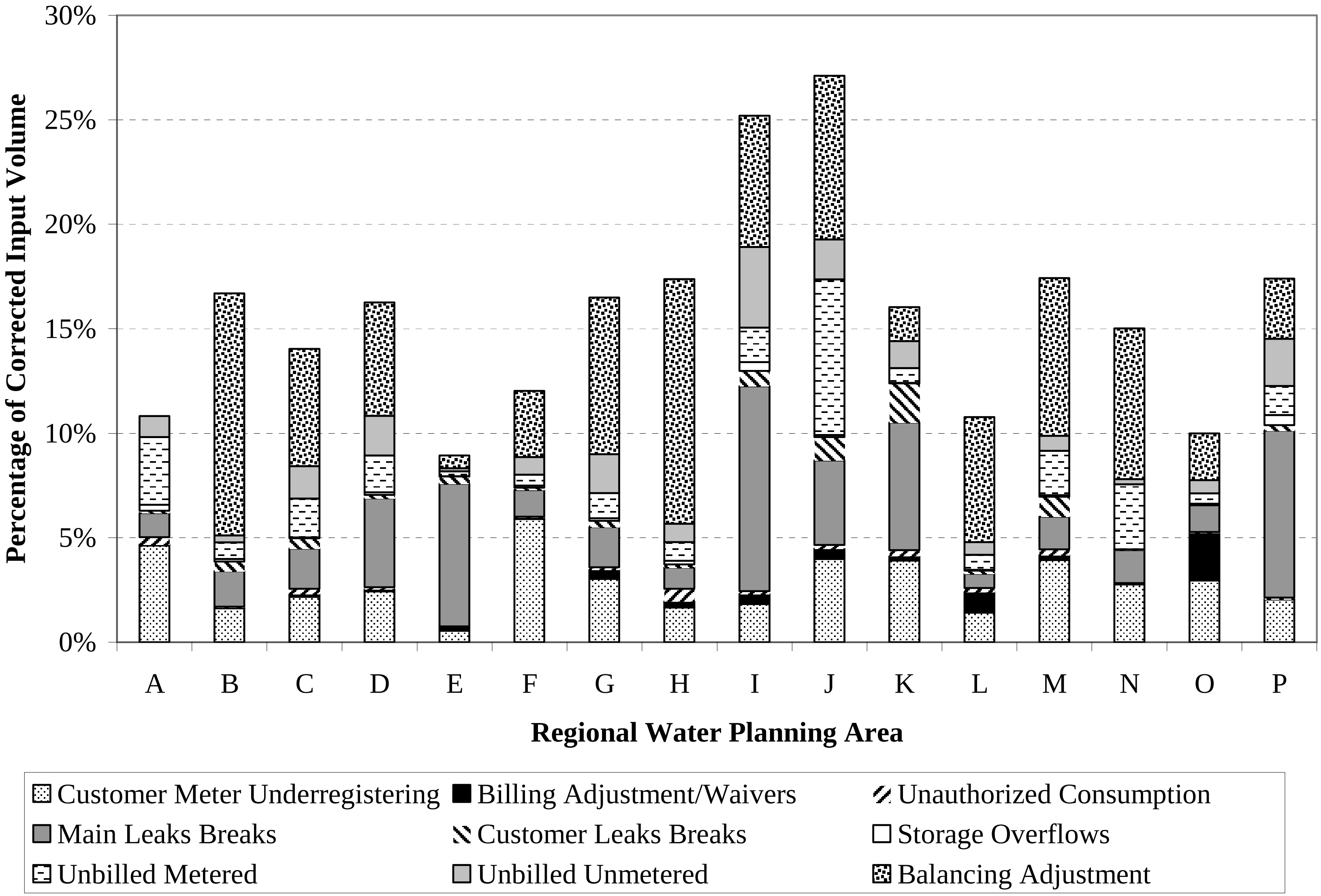


Table 10-1: Regional Average Quantities

Region	Master Meter Accuracy	Customer Meter Accuracy	Production Water Cost ($/1,000 gallons)	Retail Water Cost ($/1,000 gallons)	Service Connections per Mile of Main	Reporting Period
A	98.0%	95.4%	$0.70	$1.89	40.2	362.8
B	98.4%	98.4%	$1.70	$3.11	22.3	365.4
C	99.7%	97.8%	$0.90	$2.60	51.2	366.0
D	99.0%	97.6%	$1.51	$3.96	14.6	383.5
E	99.4%	99.5%	$0.61	$2.52	73.9	346.7
F	99.1%	94.1%	$2.02	$2.66	29.6	372.1
G	98.5%	97.0%	$1.42	$2.85	19.5	363.0
H	98.4%	98.3%	$0.80	$2.38	89.6	363.4
I	99.8%	98.2%	$0.34	$2.68	19.2	363.5
J	97.9%	96.0%	$0.91	$3.09	27.9	360.7
K	100.3%	96.1%	$0.57	$2.89	38.8	360.0
L	99.6%	98.6%	$1.20	$5.13	50.0	364.6
M	99.3%	96.1%	$0.72	$1.81	38.2	364.2
N	95.7%	97.2%	$1.62	$2.46	38.7	364.1
O	98.5%	97.0%	$0.86	$1.64	49.0	380.4
P	98.3%	98.0%	$0.36	$0.94	47.0	365.0
TOTAL	99.1%	97.7%	$0.84	$2.72	43.5	365.2

Figure 10-3: Average Annual Non-Revenue Water by Region



The average annual value of non-revenue water per connection is shown by region in Figure 10-4.[9] On a per-connection basis, utilities in Region E report the lowest average value of non-revenue water (approximately $14 per connection per year), and utilities in Regions D and K report the highest average value of non-revenue water (more than $50 per connection per year). Reported values include real loss, apparent loss, and unbilled authorized consumption. However, after accounting for the balancing adjustment, the average value of non-revenue water in Regions B, C, D, G, L, and N may be more than $80 per connection per year. The total balancing adjustment for Region A is negative, which causes the balancing adjustment assumption to reduce the average value of non-revenue water.

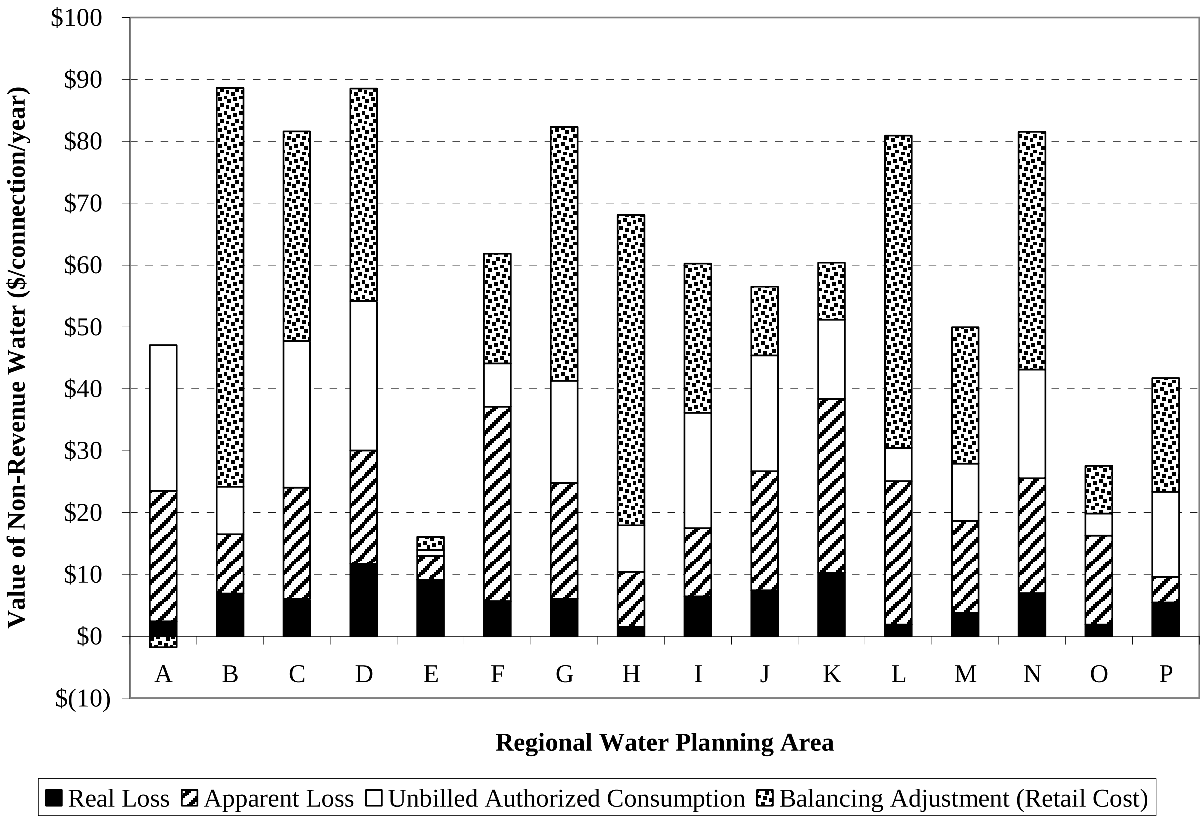
Graphs showing other average water loss performance indicators by region for all reporting water utilities (after quality control) are presented in Appendix D. These graphs present the performance indicators with and without the balancing adjustment assumption discussed in Chapter 6.A. The ranges of average real loss and average SLILI are on the low end of the ranges of real loss and ILI reported by North American utilities (Table 7-1), while the range of average apparent loss is similar to, or perhaps somewhat greater than, the range of apparent loss reported by North American utilities.

Regions B, H, and M each have an average balancing adjustment (absolute value) that is more than 10 percent of the corrected input volume (Figure D-1). With the balancing adjustment assumption, this results in a relatively wide range of upper and lower bounds for water loss performance indicators for these regions. This suggests that utilities in these regions should refine their water accounting procedures to more accurately quantify water use in each category.

Three regions (A, F, and O) have average SLILI values that range from 0.36 to 0.71 as calculated from the reported data and range from 0.71 to 1.77 with the balancing adjustment assumption (Figure D-4). As discussed in Chapter 5.C, the theoretical minimum SLILI is 1. These observations suggest that the larger utilities[25] in these regions may be underestimating real loss. It is interesting to note that these regions are contiguous and are located in West Texas and the Panhandle (Figure D-12). It is not known whether there is a common geographic or system factor that would result in low levels of real loss in these regions.

[25] Utilities having 5,000 connections or more and 32 or more connections per mile of main.

Figure 10-4: Average Annual Value of Non-Revenue Water per Connection by Region



The average SLILI values for Regions I and K suggest that the larger utilities[25] in these regions might benefit from real loss control measures.

11 COMPARATIVE ANALYSIS BY COUNTY

In this section, water loss performance is analyzed by county. Many counties have only one or two reporting utilities, and the resulting average water loss performance indicators may not accurately characterize water loss in the entire county. Therefore, although results are presented in Appendix E for every county with reporting utilities, analysis in this section is focused primarily on the ten counties that have the highest reported corrected input volumes (Figure 11-1). The top ten counties have a substantial number of reporting utilities and account for 70 percent of the statewide total corrected input volume. Five of these counties are also located in five different BOR hot spots (Chapter 12): Bexar County (San Antonio hot spot), Dallas County (Dallas), El Paso County (El Paso), Harris County (Gulf), and Hidalgo County (Border).

11.A County Statistics

Water loss results were compared across the 254 counties of Texas (Figure 10-1). Additional county statistics and water loss performance indicators are presented in the sections that follow.

From the reported data, several additional county average quantities can be derived. The ranges of the county averages are:

- Master meter accuracy: 87.4 – 110.6 percent
- Customer meter accuracy: 67.3 – 100.0 percent
- Production water cost: $0.00 – $7.35 per thousand gallons
- Retail water cost: $0.00 – $9.49 per thousand gallons
- Service connections per mile of main: 0.2 – 551.7
- Reporting period: 274 – 548 days

The distribution of reporting utilities in the ten counties reporting the highest corrected input volume is shown in Figure 11-2. Again, wholesale water sales are included in the corrected input volume multiple times, so the total corrected input volume does not necessarily reflect total retail water use.

Figure 11-1: Ten Counties with the Highest Corrected Input Volume

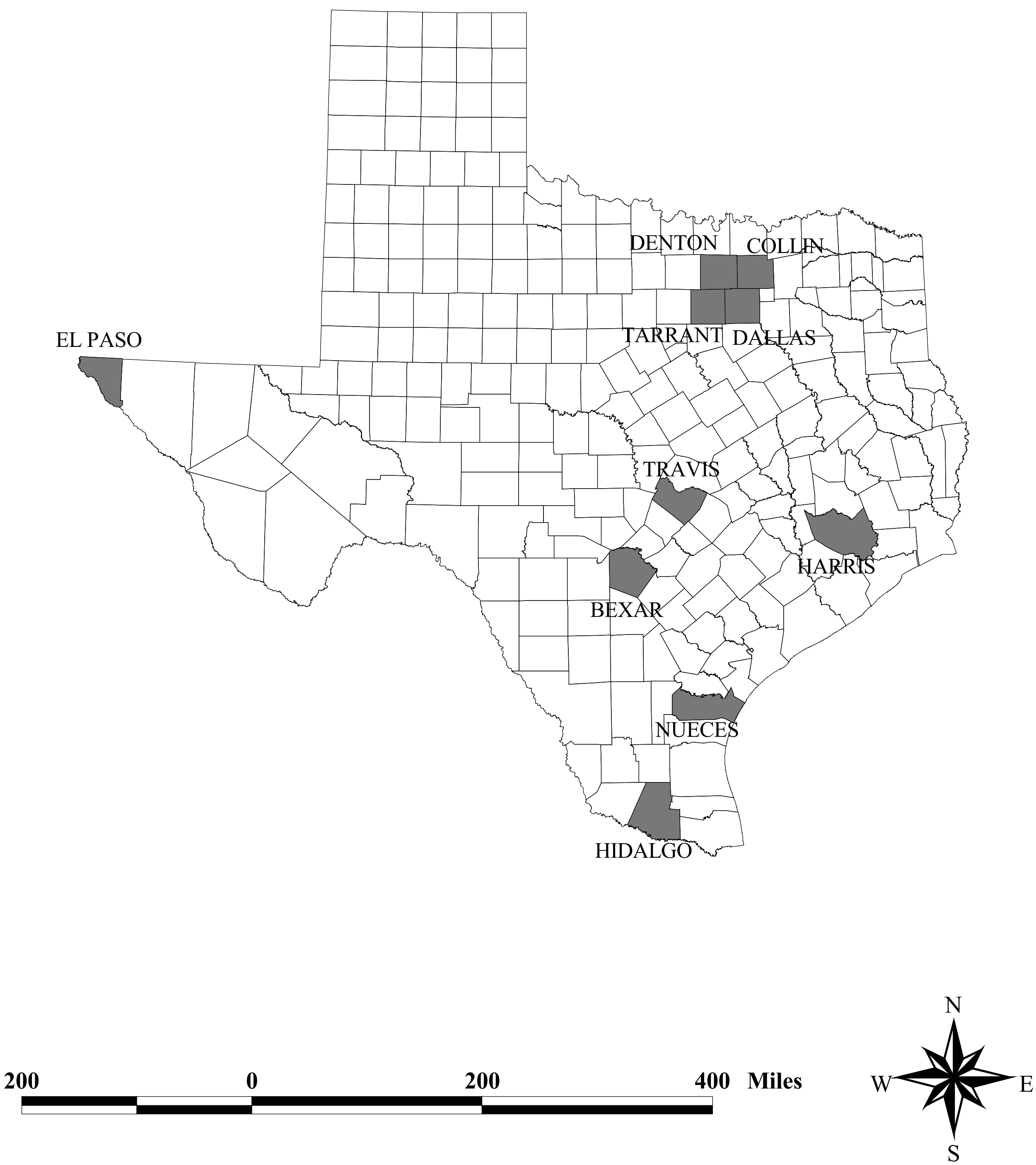
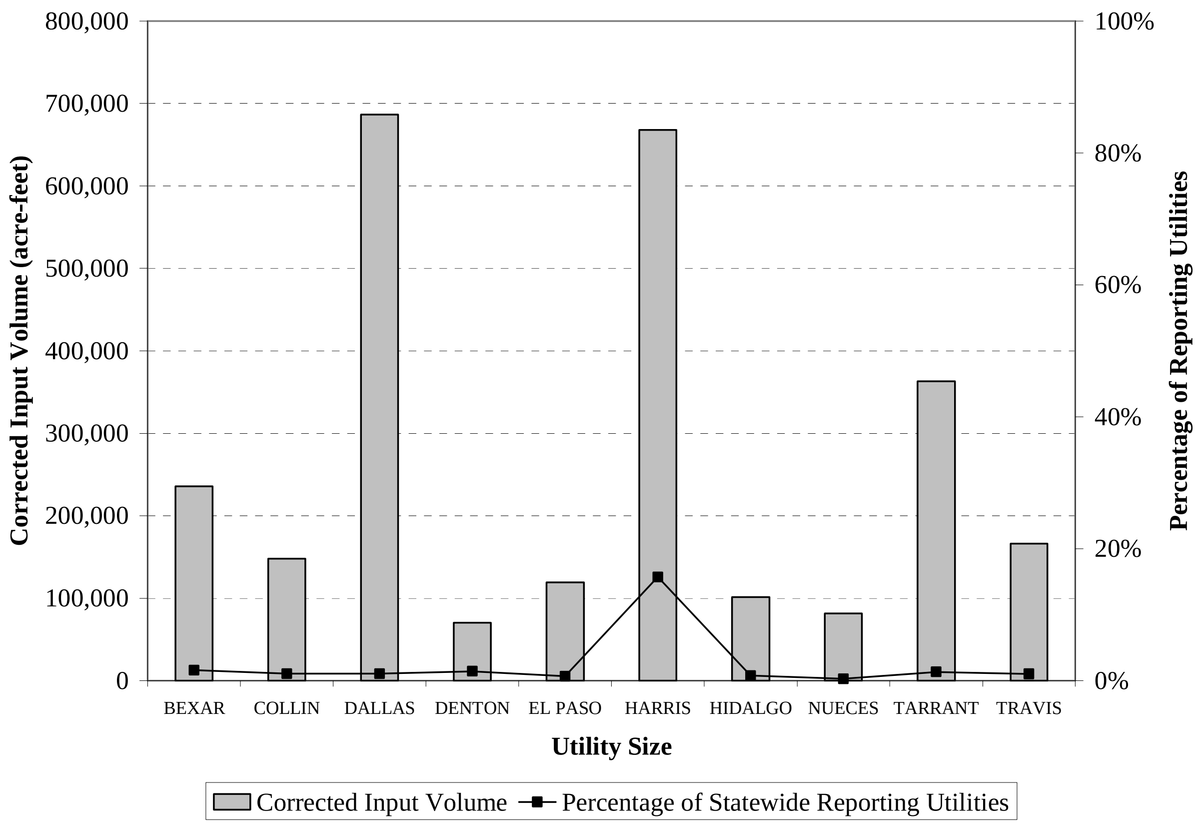


Figure 11-2: Distribution of Reporting Utilities by Counties with Highest Reported Corrected Input Volume

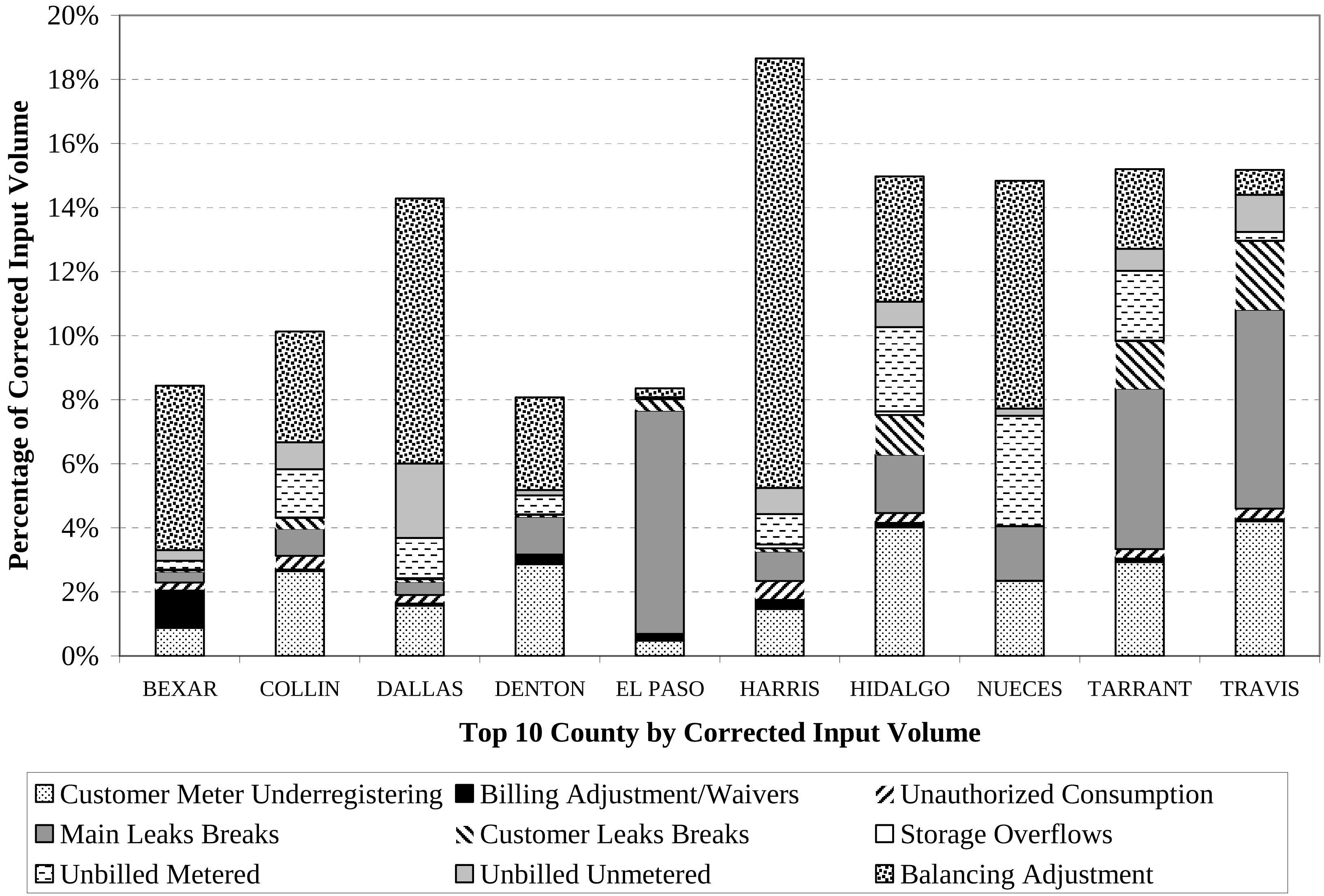


11.B County Water Loss Performance Indicators

For the ten counties with the greatest reported corrected input volume, the ranges of average real loss and average SLILI are on the low end of the ranges of real loss and ILI reported by North American utilities (Table 7-1), while the range of average apparent loss is similar to, or perhaps somewhat greater than, the range of apparent loss reported by North American utilities.

The average reported non-revenue water as a percentage of corrected input volume for the ten counties with the greatest reported corrected input volume is shown in Figure 11-3. Denton and El Paso Counties have the lowest maximum non-revenue water percentage at just over 8 percent. The average non-revenue water percentage may be as high as 18.7 percent in Harris County and may be as high as about 15 percent in Hidalgo, Nueces, Tarrant, and Travis Counties. Utilities in these counties should consider steps to recover lost revenue from non-revenue water.

Figure 11-3: Average Annual Non-Revenue Water by County



Of the ten counties, El Paso, Tarrant, and Travis Counties have the highest percentage of real loss from main leaks and breaks, and Hidalgo and Travis Counties have the highest percentage of apparent loss from customer meter under-registering. The balancing adjustment is greater than the sum of the other non-revenue water components in Bexar, Dallas, and Harris Counties, indicating that additional work is needed to refine water accounting in these counties.

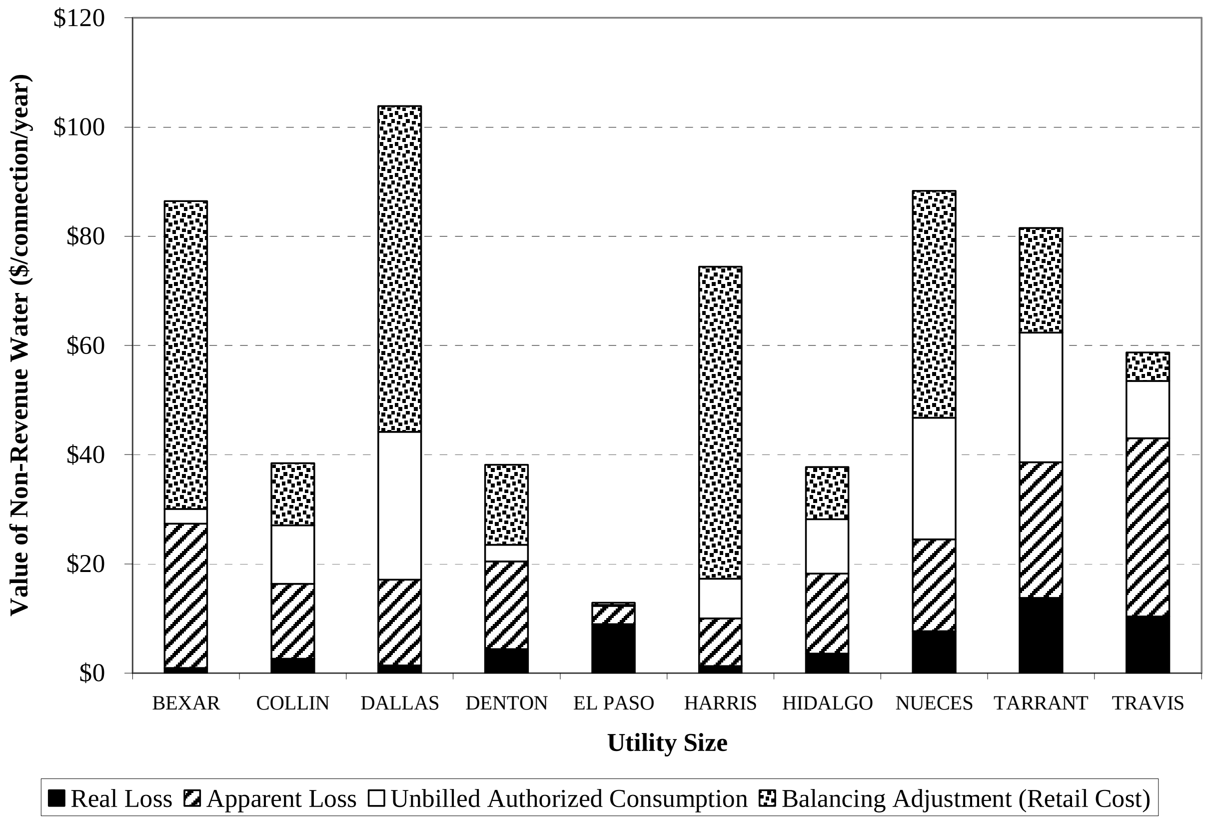
The average annual value of non-revenue water per connection is shown in Figure 11-4[9] for the ten counties with the highest reported corrected input volume. On a per-connection basis, utilities in El Paso County report the lowest average value of non-revenue water ($12.46 per connection per year), and utilities in Tarrant County report the highest average value of non-revenue water ($62.36 per connection per year). Reported values include real loss, apparent loss, and unbilled authorized consumption. However, after accounting for the balancing adjustment, the average value of non-revenue water in Bexar, Dallas, Nueces, and Tarrant Counties may be more than $80 per connection per year.

Graphs showing county average water loss performance indicators for all reporting water utilities (after quality control) are presented in Appendix E. These graphs present the performance indicators with and without the balancing adjustment assumption discussed in Chapter 6.A. Water loss performance results for the ten counties with the highest corrected input volumes are discussed below.

Harris County has the highest average balancing adjustment of 13.6 percent of corrected input volume. Using the balancing adjustment assumption, water loss performance indicators for Harris County will likely have upper and lower bounds that are further apart than the other counties. El Paso County has the lowest average balancing adjustment (0.4%).

Travis County has the highest average SLILI as calculated from the reported data (4.22), but the actual average SLILI in Dallas, Harris, Nueces, and Tarrant Counties may also be more than 4. Utilities in six of the 10 counties (Bexar, Collin, Dallas, Denton, Harris, and Nueces) reported real losses that result in an average SLILI of less than 1, indicating that the larger utilities[25] in these counties are probably underestimating their real losses. Because of the magnitude of the

Figure 11-4: Average Annual Value of Non-Revenue Water per Connection by County



balancing adjustment, it is difficult to determine the actual average SLILI for several counties, particularly Dallas, Harris, and Nueces.

Among all counties (Figure E-12), the average value of the SLILI with the balancing adjustment assumption is greatest in the following areas:

- Several counties along the Gulf Coast,
- Several counties in Central Texas,
- Several counties in North Central Texas,
- Two counties along the Red River, and
- El Paso County.

12 COMPARATIVE ANALYSIS BY BUREAU OF RECLAMATION HOT SPOT

The U.S. Bureau of Reclamation (BOR) has designated six hot spots in Texas (Figure 12-1). A hot spot is an area where the BOR has projected that existing supplies are not adequate to meet the demands of people, farms, and the environment by the year 2025.[F] The BOR rated hot spots by the likelihood of "conflict," or water shortage, by the year 2025. BOR hot spots in Texas include "moderate" potential for conflict in the Dallas area; "substantial" potential for conflict in the El Paso, San Angelo, and San Antonio areas; and "highly likely" potential for conflict along the Gulf Coast and in the Rio Grande Valley.

The distribution of reporting utilities and total corrected input volume by hot spot is shown in Figure 12-2. Again, wholesale water sales are included in the corrected input volume multiple times, so the total corrected input volume does not necessarily reflect total retail water use.

Additional BOR hot spot statistics and water loss performance indicators are presented in the sections that follow.

12.A BOR Hot Spot Statistics

From the reported data, several additional hot spot average quantities can be derived (Table 12-1). The ranges of the hot spot averages are:

- Master meter accuracy: 95.1 – 99.9 percent
- Customer meter accuracy: 89.9 – 99.5 percent
- Production water cost: $0.52 – $1.19 per thousand gallons
- Retail water cost: $1.79 – $6.48 per thousand gallons
- Service connections per mile of main: 37.9 – 108.6
- Reporting period: 354.2 – 365.0 days

12.B BOR Hot Spot Water Loss Performance Indicators

For the BOR hot spots, the ranges of average real loss and average SLILI are on the low end of the ranges of real loss and ILI reported by North American utilities (Table 7-1), while the range

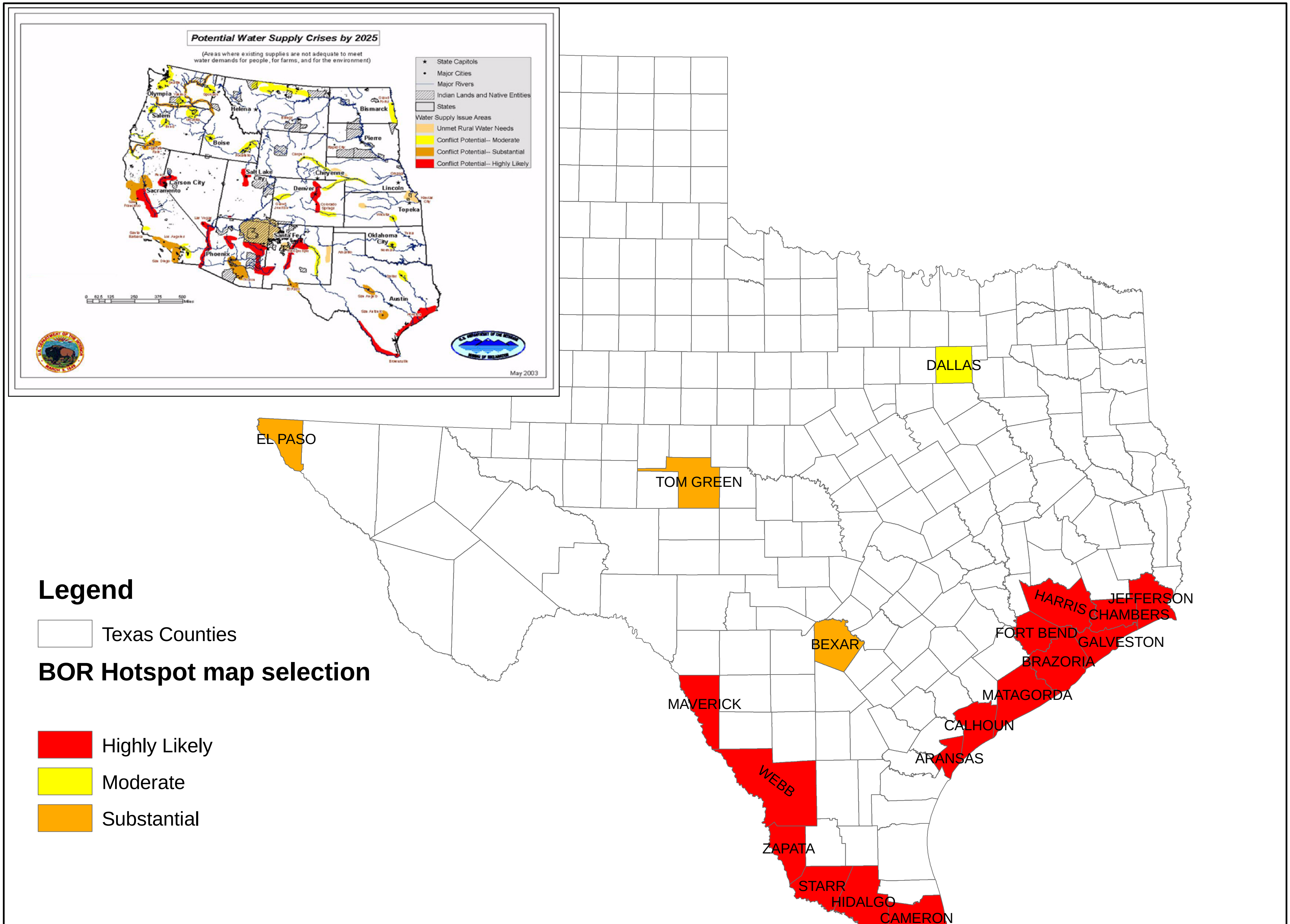


Figure 12-1. Bureau of Reclamation Hotspot Counties in Texas

Figure 12-2: Distribution of Reporting Utilities by BOR Hot Spot

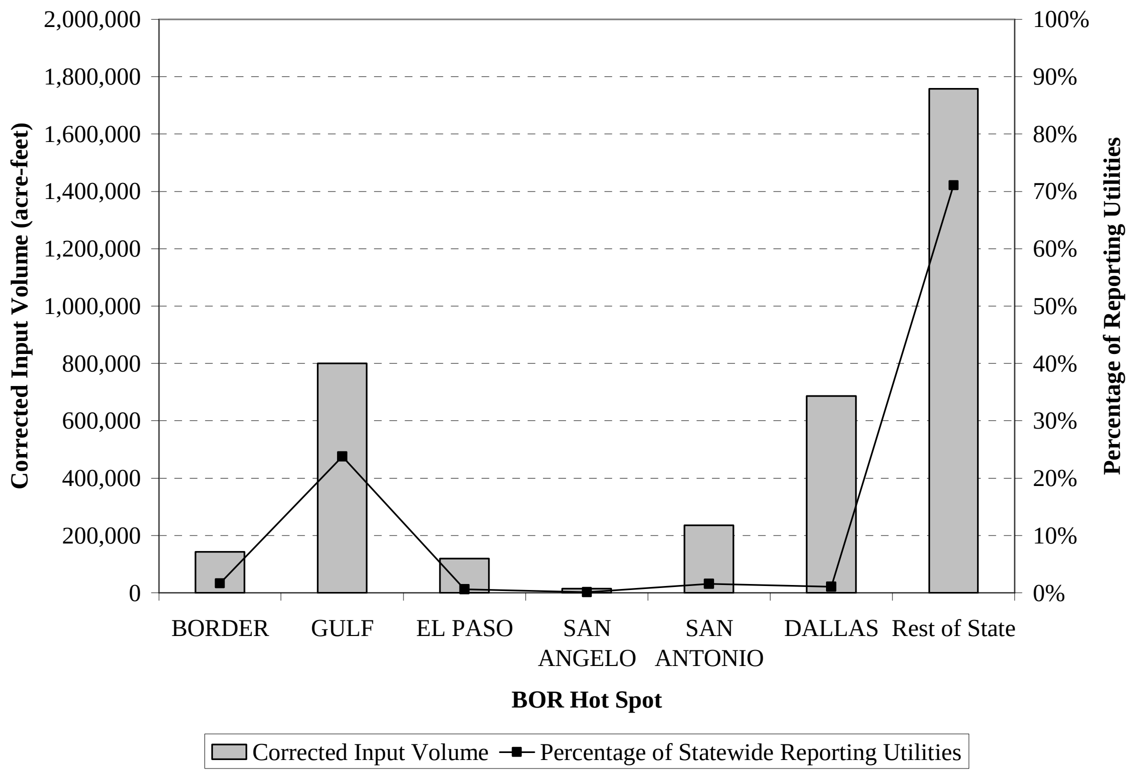


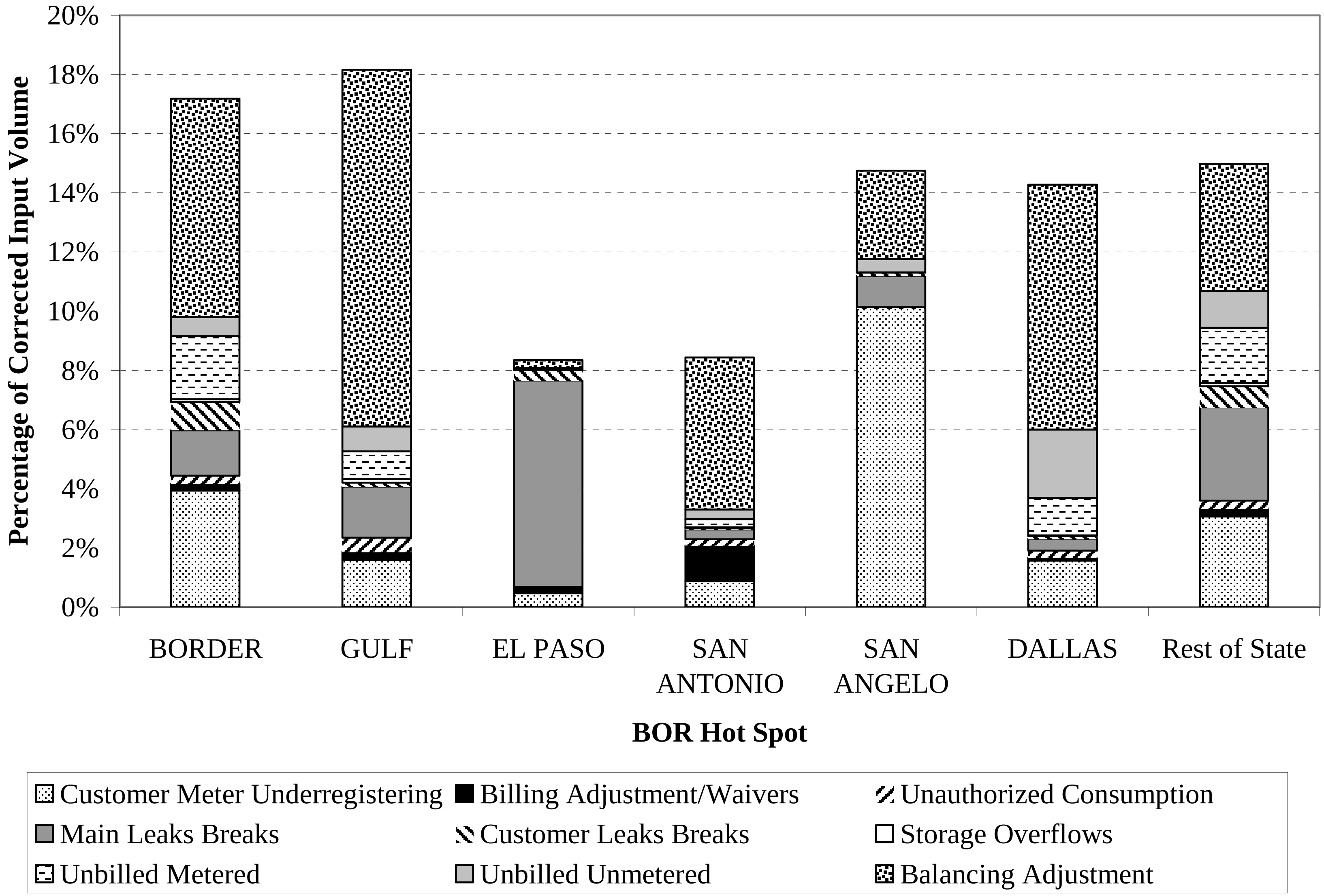
Table 12-1: BOR Hot Spot Average Quantities

BOR Hot Spot	Master Meter Accuracy	Customer Meter Accuracy	Production Water Cost ($/1,000 gallons)	Retail Water Cost ($/1,000 gallons)	Service Connections per Mile of Main	Reporting Period
Border	99.3%	96.1%	$0.72	$1.79	37.9	364.2
Gulf	98.5%	98.4%	$0.52	$2.55	108.7	364.2
El Paso	99.5%	99.5%	$0.60	$2.55	78.7	360.5
San Angelo	95.1%	89.9%	$1.17	$2.80	48.4	365.0
San Antonio	99.7%	99.1%	$1.19	$6.48	80.0	354.2
Dallas	99.9%	98.4%	$0.81	$2.40	69.9	364.7
Rest of State	99.0%	96.9%	$0.94	$2.60	28.0	365.9
TOTAL	99.1%	97.7%	$0.84	$2.72	43.5	365.2

of average apparent loss is similar to, or perhaps somewhat greater than, the range of apparent loss reported by North American utilities.

The average reported non-revenue water as a percentage of corrected input volume for each BOR hot spot is shown in Figure 12-3. The El Paso and San Antonio hot spots have the lowest

Figure 12-3: Average Annual Non-Revenue Water by BOR Hot Spot



maximum non-revenue water percentage at 8.4 percent. The El Paso hot spot's non-revenue water is dominated by real loss from main leaks and breaks. The San Angelo hot spot's non-revenue water is dominated by apparent loss from customer meter under-registering. The balancing adjustment is greater than the sum of the other non-revenue water components in the Gulf, San Antonio, and Dallas hot spots, indicating that additional work is needed to refine water accounting in these areas.

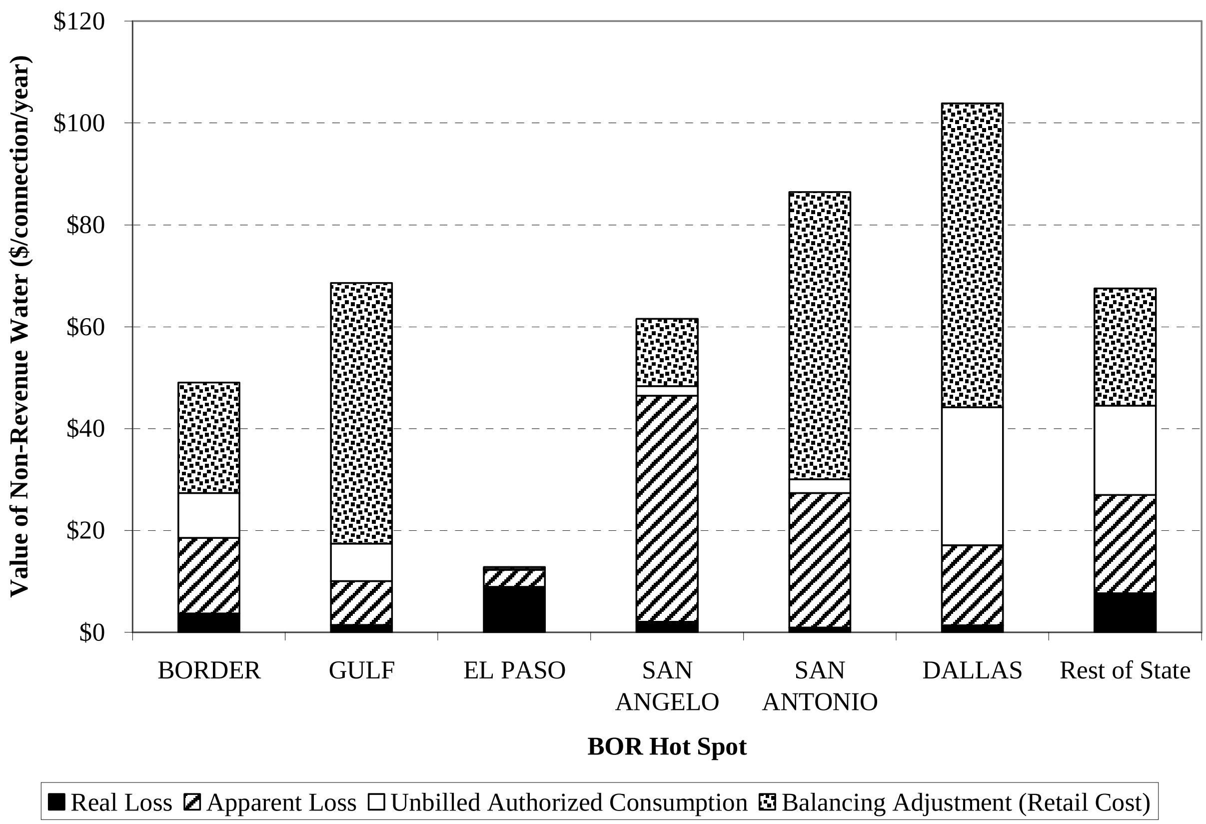
The average annual value of non-revenue water per connection is shown by hot spot in Figure 12-4.[9] On a per-connection basis, utilities in the El Paso hot spot report the lowest average value of non-revenue water (approximately $12.40 per connection per year), and utilities in the San Angelo hot spot report the highest average value of non-revenue water (more than $48 per connection per year). Reported values include real loss, apparent loss, and unbilled authorized consumption. However, after accounting for the balancing adjustment, the average value of non-revenue water in the Dallas and San Antonio hot spots may be as high as $104 and $86 per connection per year, respectively.

Graphs showing average water loss performance indicators for reporting water utilities (after quality control) in each hot spot are presented in Appendix F. These graphs present the performance indicators with and without the balancing adjustment assumption discussed in Chapter 6.A.

Utilities in the Gulf and Border hot spots have an average balancing adjustment (absolute value) of more than 10 percent of corrected input volume (Figure F-1). These are the two hot spots that the BOR rates as "highly likely" to experience water conflict. With the balancing adjustment assumption, this results in a relatively wide range of upper and lower bounds for water loss performance indicators for these hot spots. This suggests that utilities in these hot spots should refine their water accounting procedures to quantify water use more accurately in each category.

The San Angelo hot spot has an average SLILI value of 0.31 from the reported data and 1.16 with the balancing adjustment assumption (Figure F-4). As discussed in Chapter 5.C, the theoretical minimum SLILI is 1. These observations suggest that the larger utilities[25] in the San Angelo hot spot may be underestimating real loss.

Figure 12-4: Average Annual Value of Non-Revenue Water per Connection by BOR Hot Spot

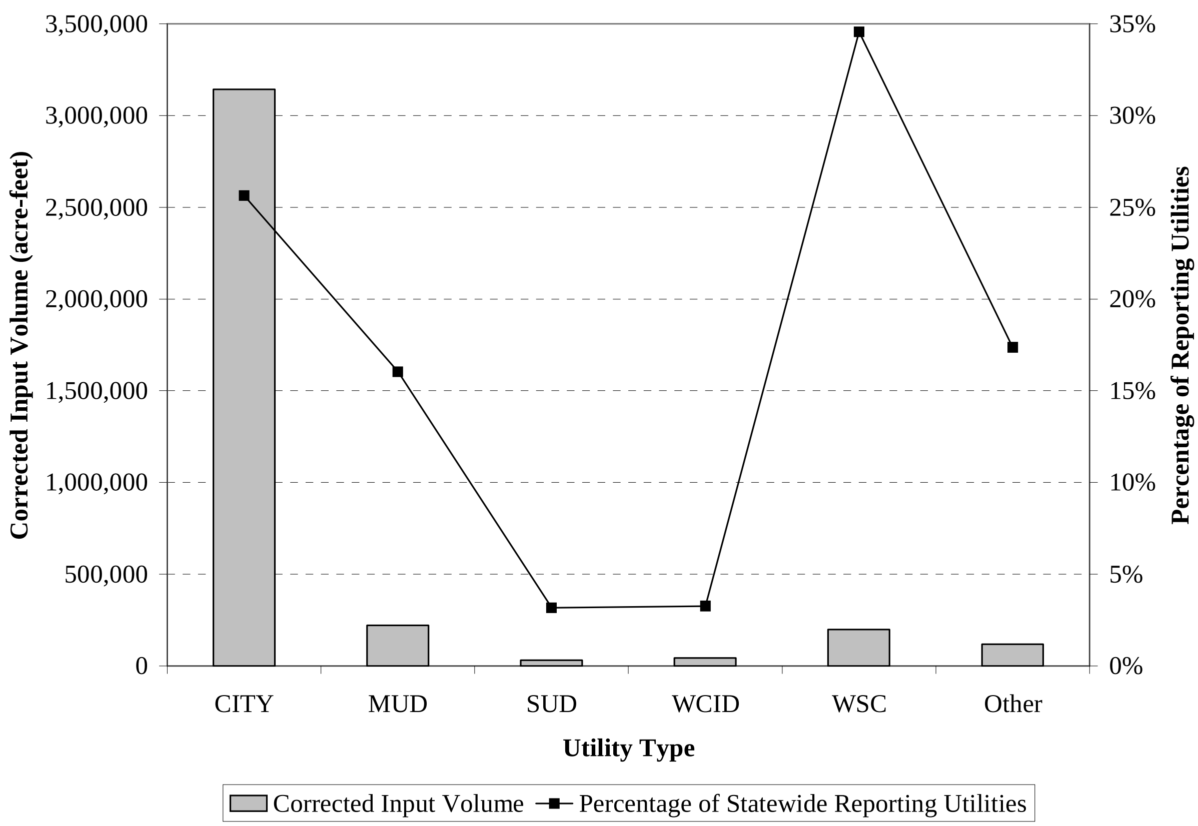


Because of the magnitude of the balancing adjustment, it is difficult to determine the actual average SLILI for the Border, Gulf, and Dallas hot spots. If the balancing adjustment is underestimated real loss, then the larger utilities[25] in these hot spots should consider real loss control measures.

13 COMPARATIVE ANALYSIS BY UTILITY TYPE

Water loss results were compared across the following utility types: cities, Municipal Utility Districts (MUDs), Special Utility Districts (SUDs), Water Control and Improvement Districts (WCIDs), Water Supply Corporations (WSCs), and other suppliers. Figure 13-1 shows the distribution of reporting utilities and the total corrected input volume by utility type. Additional statistics and water loss performance indicators by utility type are presented in the sections to follow.

Figure 13-1: Distribution of Reporting Utilities by Utility Type



13.A <u>Utility Type Statistics</u>

From the reported data, several additional utility type average quantities can be derived (Table 13-1). The ranges of the utility type averages are:

- Master meter accuracy: 98.4 – 99.2 percent
- Customer meter accuracy: 96.9 – 98.1 percent
- Production water cost: $0.75 – $1.37 per thousand gallons
- Retail water cost: $1.77 – $2.82 per thousand gallons
- Service connections per mile of main: 10.0 – 80.0
- Reporting period: 359.3 – 370.7 days

Table 13-1: Utility Type Average Quantities

Utility Type	Master Meter Accuracy	Customer Meter Accuracy	Production Water Cost ($/1,000 gallons)	Retail Water Cost ($/1,000 gallons)	Service Connections per Mile of Main	Reporting Period
City	99.2%	97.7%	$0.75	$2.82	67.6	368.6
MUD	99.2%	97.8%	$0.77	$1.77	80.0	362.8
SUD	98.7%	98.1%	$1.05	$2.69	10.7	370.7
WCID	98.8%	96.9%	$0.76	$2.40	47.2	359.3
WSC	98.9%	96.9%	$1.37	$2.53	10.0	364.6
Other	98.4%	98.0%	$1.18	$2.42	27.5	363.9
TOTAL	99.1%	97.7%	$0.86	$2.72	43.5	365.2

13.B Utility Type Water Loss Performance Indicators

For the different utility types, the ranges of average real loss and average SLILI are on the low end of the ranges of real loss and ILI reported by North American utilities (Table 7-1), while the range of average apparent loss is similar to the range of apparent loss reported by North American utilities.

The average reported non-revenue water as a percentage of corrected input volume for each utility type is shown in Figure 13-2. MUDs have the lowest maximum non-revenue water percentage at 10.6 percent. Each utility type has similar reported percentages of customer meter under-registering. SUDs and WSCs have higher reported percentages of non-revenue water from main leaks and breaks than the other utility types, while SUDs, WCIDs, and WSCs have greater reported percentages of unbilled unmetered water.

The average annual value of non-revenue water per connection is shown by utility type in Figure 13-3.[9] On a per-connection basis, MUDs report the lowest average value of non-revenue water

Figure 13-2: Average Annual Non-Revenue Water by Utility Type

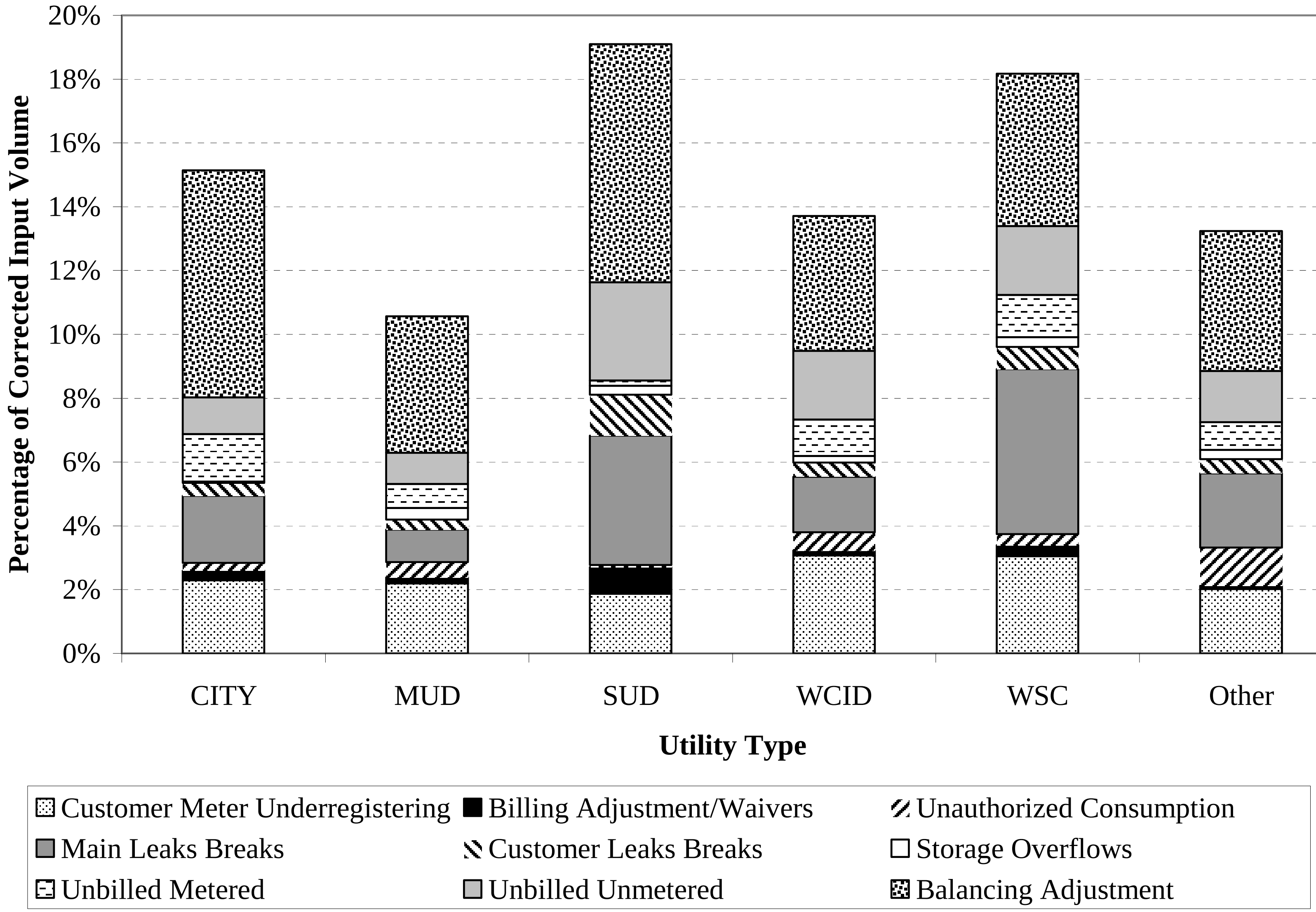
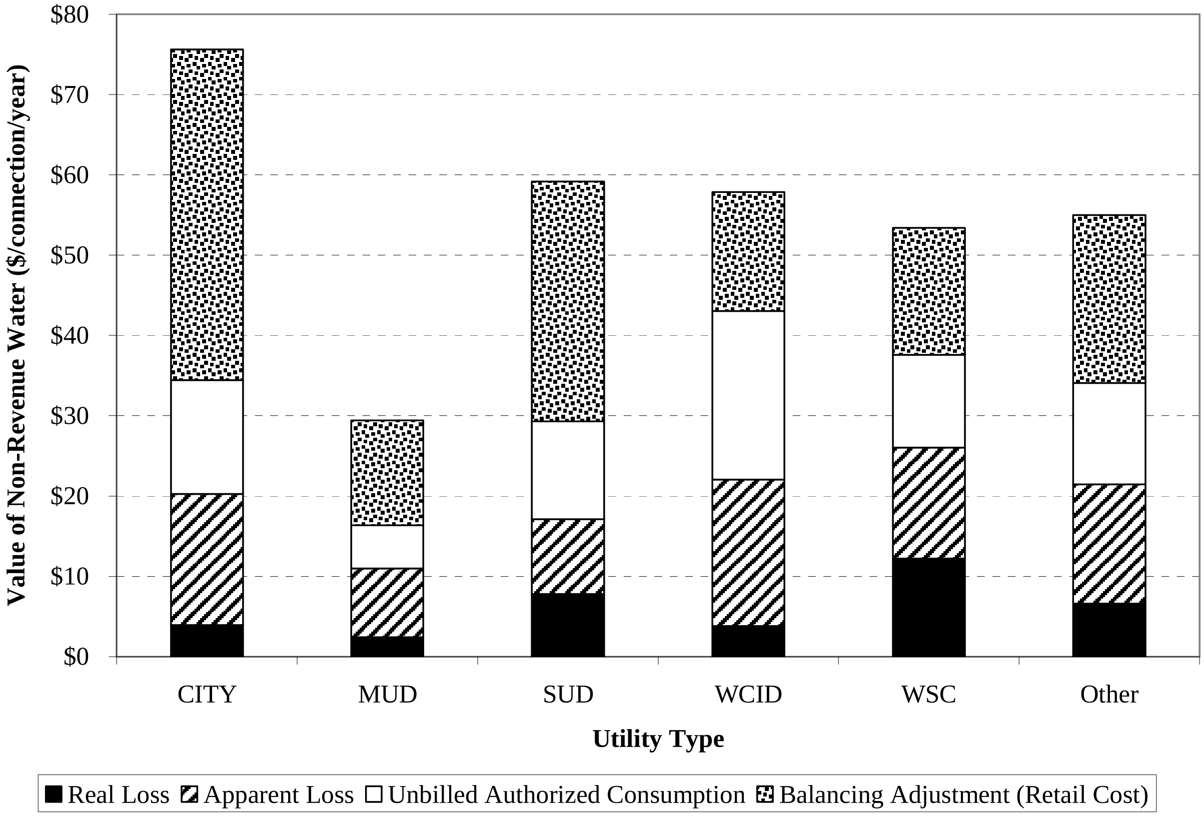


Figure 13-3: Average Annual Value of Non-Revenue Water per Connection by Utility Type



($16.35 per connection per year), and WCIDs report the highest average value of non-revenue water ($43.06 per connection per year). Reported values include real loss, apparent loss, and unbilled authorized consumption. However, if the balancing adjustment is included and valued using the retail water cost, the average value of non-revenue water in cities may be as high as $76 per connection per year.

Graphs showing average water loss performance indicators for reporting water utilities (after quality control) in each hot spot are presented in Appendix G. These graphs present the performance indicators with and without the balancing adjustment assumption discussed in Chapter 6.A.

Each utility type has an average balancing adjustment (absolute value) between 4.6 and 7.5 percent (Figure G-1). As shown by the other figures in Appendix G, reduced balancing adjustment is necessary to determine the actual real and apparent losses.

SUDs and other utilities have average SLILI values of 0.38 and 0.67 as calculated from the reported data and 0.67 and 1.43 with the balancing adjustment assumption (Figure F-4). As discussed in Chapter 5.C, the theoretical minimum SLILI is 1. These observations suggest that the larger SUDs[25] and other utilities may be underestimating real loss.

Because of the magnitude of the balancing adjustment, it is difficult to determine the actual average SLILI for cities and MUDs. If the balancing adjustment is underestimated real loss, then the larger cities and MUDs[25] should consider real loss control measures.

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14 COMPARATIVE ANALYSIS BY UTILITY SIZE

House Bill 3338 required the TWDB to develop water audit methodologies and reporting dates for retail public utilities that serve the following ranges of population: 0 to 3,299 people; 3,300 to 49,999 people; 50,000 to 99,999 people; and 100,000 people or more. An initial goal of this research project was to analyze water loss for the same population ranges. However, reported populations may include the population of wholesale customers, which could cause a utility to be placed in the wrong category. The reported number of connections, even if wholesale connections are included, is likely to be a much better indicator of the size of the utility. Therefore, based on an assumption of three people per connection, water loss results were compared across the following utility size categories: 0 to 1,100 connections; 1,101 to 16,666 connections; 16,667 to 33,333 connections; and 33,334 connections or more.

Figure 14-1 shows the distribution of reporting utilities and total corrected input volume by utility size. Additional statistics and water loss performance indicators by utility size are presented in the sections to follow.

14.A Utility Size Statistics

Several additional utility size average quantities can be derived from the reported data (Table 14-1). The ranges of the utility size averages are:

- Master meter accuracy: 98.8 – 99.2 percent
- Customer meter accuracy: 96.6 – 98.1 percent
- Production water cost: \$0.63 – \$1.36 per thousand gallons
- Retail water cost: \$2.24 – \$2.94 per thousand gallons
- Service connections per mile of main: 14.1 – 82.9
- Reporting period: 354.2 – 365.5 days

14.B Utility Size Water Loss Performance Indicators

For the different utility sizes, the ranges of average real loss and average SLILI are on the low end of the ranges of real loss and ILI reported by North American utilities (Table 7-1), while the

Figure 14-1: Distribution of Reporting Utilities by Utility Size

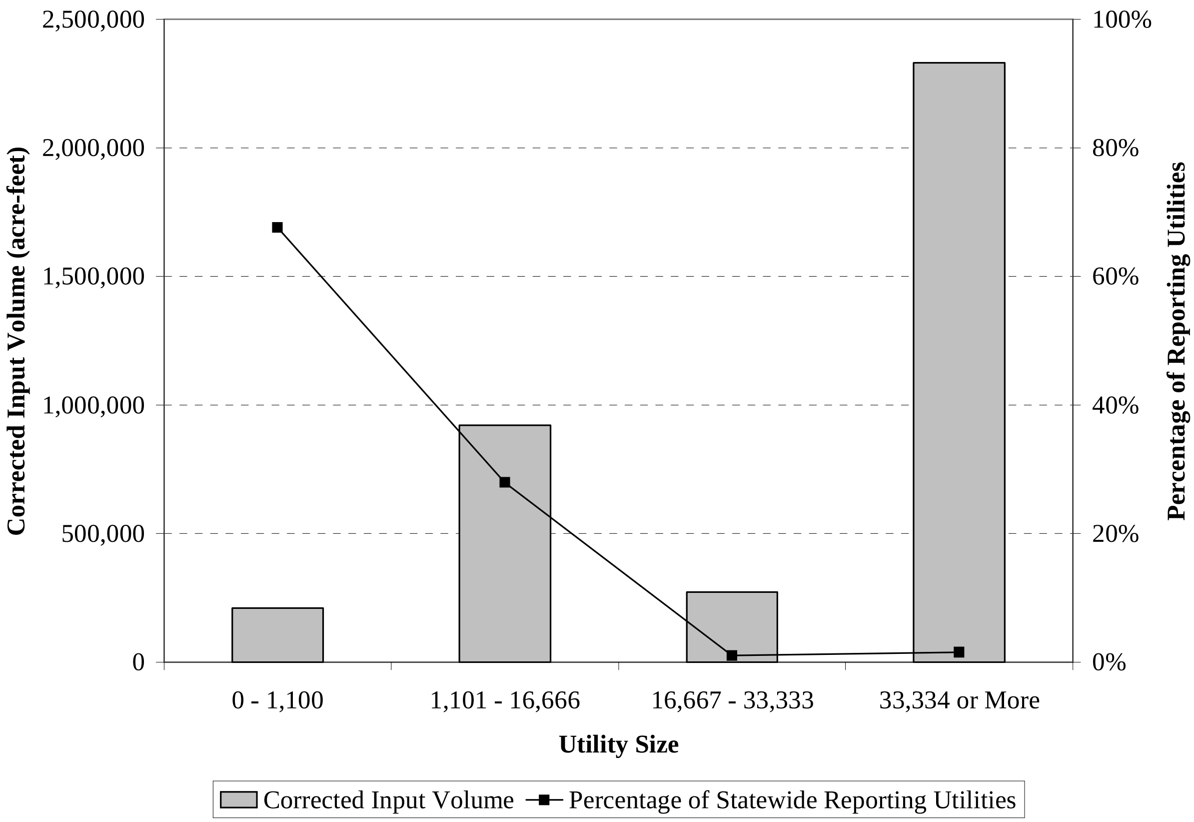


Table 14-1: Utility Size Average Quantities

Connections	Master Meter Accuracy	Customer Meter Accuracy	Production Water Cost ($/1,000 gallons)	Retail Water Cost ($/1,000 gallons)	Service Connections per Mile of Main	Reporting Period
0 – 1,100	98.8%	97.2%	$1.36	$2.54	14.1	365.5
1,101 – 16,666	99.1%	97.0%	$1.17	$2.61	30.0	365.4
16,667 – 33,333	98.9%	96.6%	$0.71	$2.24	44.1	362.2
33,334 or more	99.2%	98.1%	$0.63	$2.94	82.9	354.2
TOTAL	99.1%	97.7%	$0.84	$2.72	43.5	365.2

range of average apparent loss is similar to the range of apparent loss reported by North American utilities.

The average reported non-revenue water as a percentage of corrected input volume for each utility size is shown in Figure 14-2. For each utility size, the maximum non-revenue water percentage is between 13 and 15.5 percent. The largest utilities have lower reported percentages of customer meter under-registering and unbilled water (metered and unmetered) than the other sizes. The smallest utilities have the highest reported percentages of real loss from main leaks and breaks.

The average annual value of non-revenue water per connection is shown by utility size in Figure 14-3.[9] On a per-connection basis, the largest utilities report the lowest average value of non-revenue water (about $30 per connection per year), and utilities with 1,101 to 16,666 connections report the highest average value of non-revenue water (about $43 per connection per year). Reported values include real loss, apparent loss, and unbilled authorized consumption. However, after accounting for the balancing adjustment, the average value of non-revenue water for the largest utilities may be as high as $78 per connection per year.

Graphs showing average water loss performance indicators for reporting water utilities (after quality control) for each utility size range are presented in Appendix H. These graphs present the performance indicators with and without the balancing adjustment assumption discussed in Chapter 6.A.

Each utility type has an average balancing adjustment (absolute value) between 5.4 and 7.8 percent (Figure H-1). As shown by the other figures in Appendix H, reduced balancing adjustment is necessary to determine the actual real and apparent losses.

Average SLILI values for utilities with 1,101 to 33,333 connections appear to be less than 2.36, which is within the lowest range of values recommended by the AWWA (Table 7-3). Because of the magnitude of the balancing adjustment, it is difficult to determine the actual average SLILI for the largest utilities. If the balancing adjustment is underestimated real loss, then the largest utilities should consider real loss control measures.

Figure 14-2: Average Annual Non-Revenue Water per Connection by Utility Size

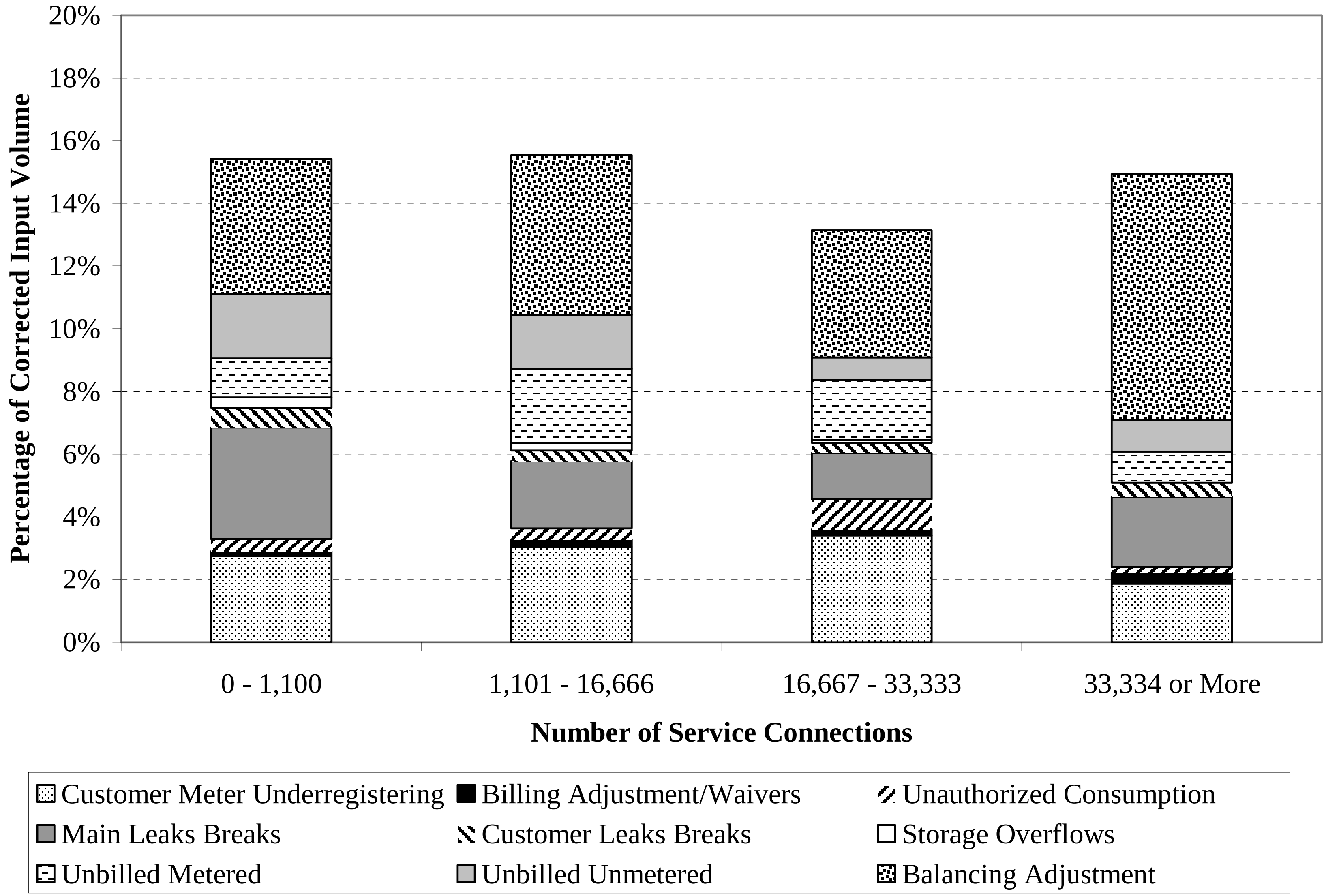
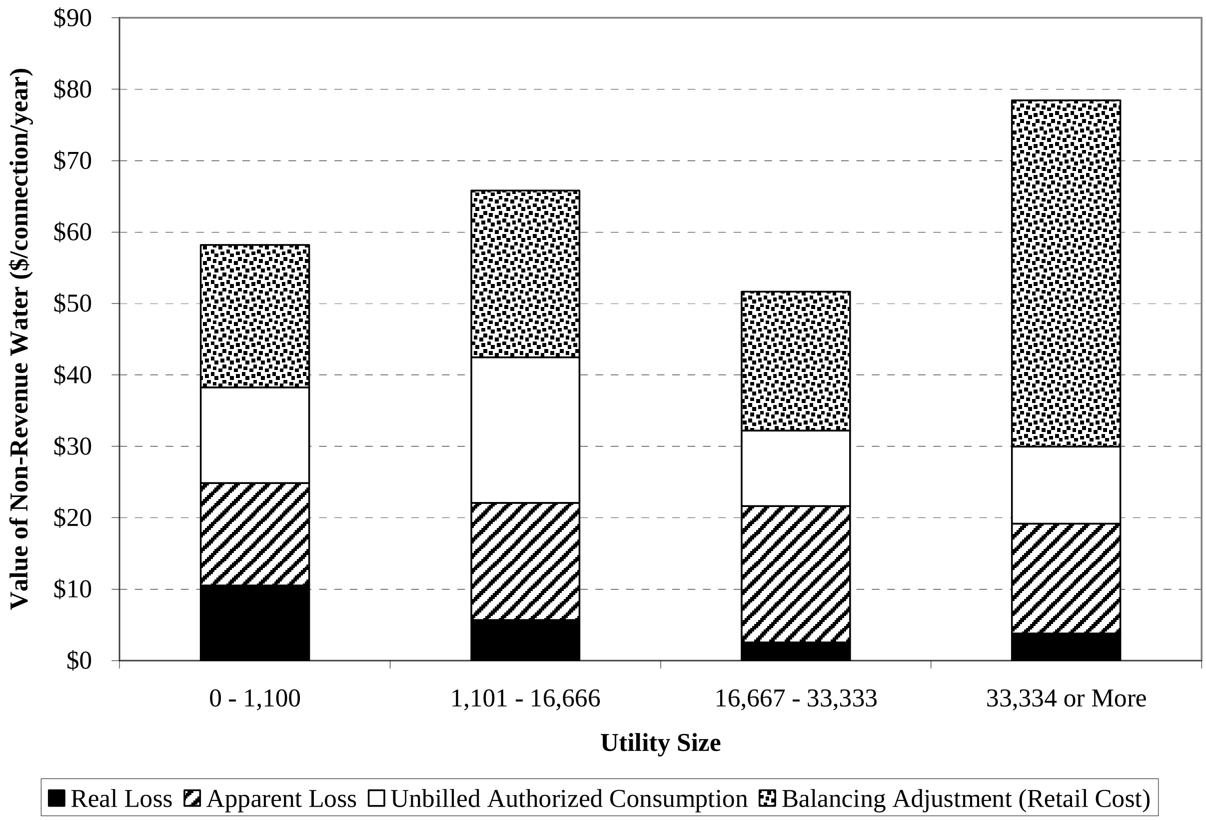


Figure 14-3: Average Annual Value of Non-Revenue Water per Connection by Utility Size



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15 OTHER COMPARATIVE ANALYSIS

In previous chapters, water loss performance has been compared by utility location, type, and size. Water loss performance can be compared by other utility characteristics as well. In this chapter, a comparison of water loss performance by supply source and by connection density is presented. Figures showing the water loss performance indicators are presented in Appendix I.

15.A Comparison by Supply Source

In reporting their water loss data, utilities reported the percentage of water that was supplied from groundwater and the percentage that was supplied from surface water. Utilities that use groundwater typically do not have significant water loss during water treatment and have wells distributed within their service area. Utilities that use surface water may have real losses during transmission of raw water to the treatment plant(s) and may have significant water loss during water treatment.

To assess whether utilities that use groundwater have lower water loss than utilities that use surface water, water loss performance statistics were calculated for utilities that reported using 100 percent groundwater or 100 percent surface water (Figure I-1). Among utilities with fewer than 32 connections per mile of main, the average real loss per mile of main per day does not appear to depend on the supply source. However, among utilities with 32 or more connections per mile of main, it appears likely that utilities that rely on surface water may have a greater average real loss per service connection per day and may have a greater average SLILI in comparison to utilities that use groundwater. It also appears that utilities that use groundwater may have slightly lower average apparent loss per service connection per day and average non-revenue water percentage.

None of these observations is a certainty, however, because of the size of the balancing adjustment. To be sure of these potential trends, utilities must first refine their water audits and reduce the balancing adjustment.

15.B Comparison by Connection Density

To assess whether water loss performance varies with a utility's connection density, water loss performance statistics were calculated for utilities in four categories (Figure I-2):

- 14 or fewer connections per mile of main
- 14-32 connections per mile of main
- 32-62 connections per mile of main
- More than 62 connections per mile of main

These categories roughly correspond to the reported quartiles of connections per mile of main.

Figure I-2 shows two strong trends, even accounting for the balancing adjustment assumption:

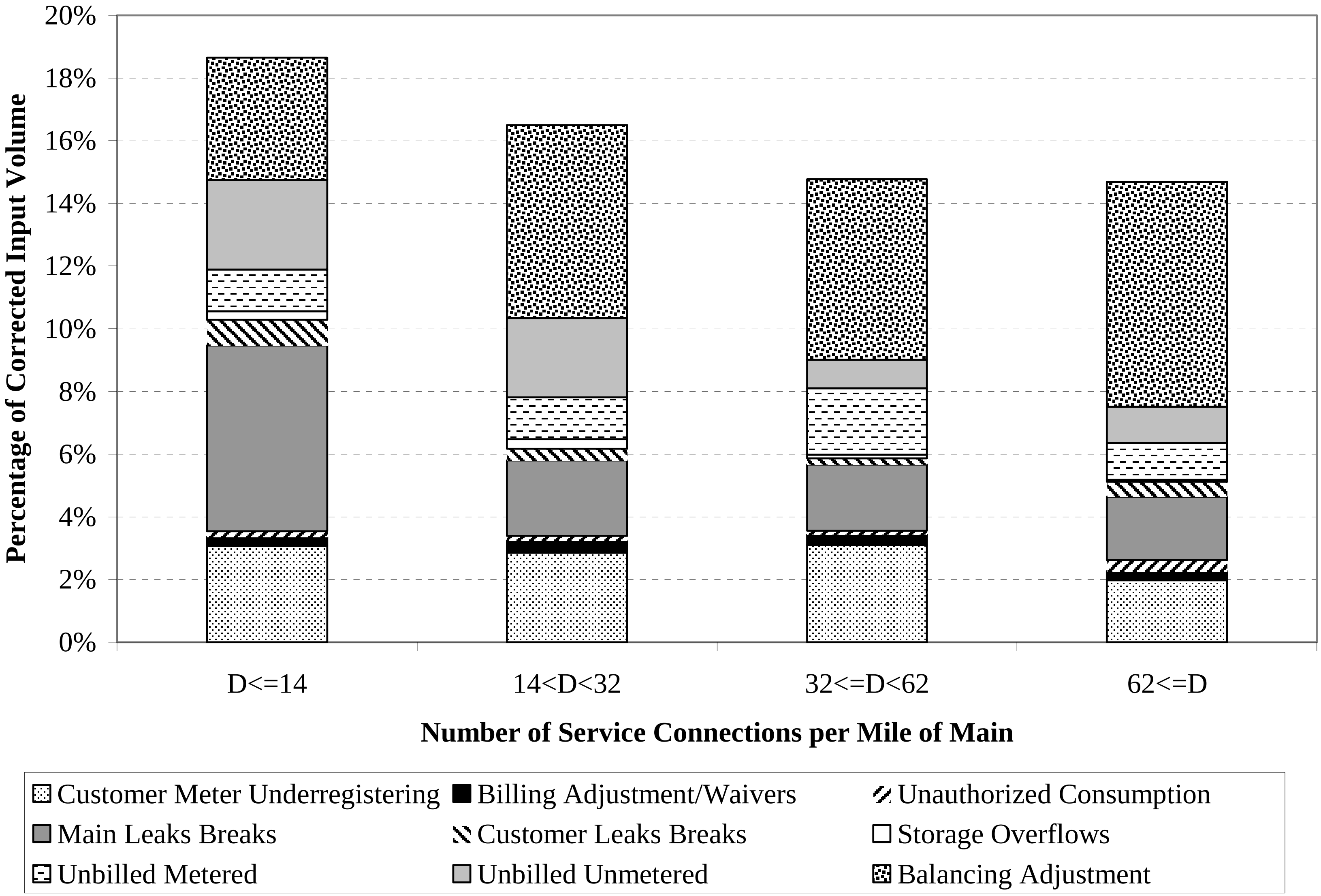
- Average real loss per mile of main per day increases with increasing connection density.
- Average non-revenue water percentage decreases with increasing connection density.

It is not surprising that utilities with greater connection densities would have greater average real loss per mile of main per day, because each additional service connection is another opportunity for real loss. Therefore, utilities with more service connections per mile of main have more opportunities for real loss.

The average non-revenue water percentage for utilities with fewer than 14 connections per mile of main ranges from approximately 15 to 18 percent of corrected input volume. For utilities with more than 62 connections per mile of main, the average non-revenue water percentage ranges from approximately 8 to 15 percent of corrected input volume (Figure 15-1). Utilities with lower connection densities report greater percentages of real loss from main leaks and breaks and apparent loss from unbilled authorized consumption.

Weaker trends of increasing average SLILI and average apparent loss per service connection per day with increasing connection density may be present in the data, but they are obscured by the size of the balancing adjustment. To be sure of these potential trends, utilities must first refine their water audits and reduce the balancing adjustment.

Figure 15-1: Non-Revenue Water Percentage by Connection Density



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16 CONCLUSIONS AND RECOMMENDATIONS

This report, the first broad analysis of water loss and water loss accounting for retail public utilities in Texas, provides information necessary for the TWDB, Regional Water Planning Groups (RWPGs), and retail public utilities to direct planning and funding resources, to recover lost revenue through reduction of non-revenue water, and to achieve water savings through reduction of real loss. However, the size of the balancing adjustment results in significant uncertainty in the water loss performance indicators. Conclusions and recommendations drawn from the analysis of water loss are presented in the following categories: water loss performance, regional water planning, and TWDB actions.

16.A Water Loss Performance

Conclusions and recommendations regarding balancing adjustment, real loss, connection density, non-revenue water, and the value of total water loss are discussed below.

16.A.1 Balancing Adjustment

Whether the comparative analysis of water loss performance is conducted on the basis of utility location, type, size, or water source, the balancing adjustment is too large in relation to other quantities to draw reliable conclusions about water loss trends. From all reported data, balancing adjustment was 6.7 percent of total corrected input volume, while real loss was 2.7 percent, and apparent loss was 2.9 percent. On average, therefore, the balancing adjustment is larger than sum of the real and apparent losses. Given similar statistics, an individual utility would not be able to determine whether its best strategy is to reduce real loss or to reduce apparent loss.

Conclusion #1: In general, the balancing adjustment resulting from water loss data is too large in relation to other quantities to draw reliable conclusions about water loss trends for groups of utilities based on utility location, type, size, or water source.

Recommendation #1: Utilities should refine their water audits until the balancing adjustment is small in comparison to the other quantities of interest (*e.g.*, real and apparent water loss) so that reliable conclusions about water loss trends can be drawn. It may be tempting to change the volumes in some water use categories for the sole purpose of eliminating the balancing adjustment. This is not a legitimate way to reduce balancing adjustment: it only disguises the real issues, making it harder to identify what strategies a utility should pursue in the future. To legitimately reduce balancing adjustment, a utility should refine its estimates for each water use category by implementing more accurate measurement and/or estimation procedures.

Conclusion #2: Currently, utilities are only required to conduct a water audit once every five years.[C] Utilities that only audit water use every five years may experience significant changes in water use and utility personnel between audits. Without gradual refinement of water auditing procedures and water volume estimates, utilities may find, after five years have elapsed, that they have not developed sufficient data to reduce the balancing adjustment and improve the reliability of the water audit. In addition, if the personnel responsible for water auditing have changed, the new personnel may have to overcome a learning curve regarding the water audit methodology. Utilities are likely to obtain more reliable water volume estimates for each water use category if they gradually refine their water auditing procedures and water volume estimates on an annual or biennial basis. Refinement activities could include recalibration of production and consumption water meters, flow monitoring in District Metered Areas, and/or other activities that will reduce uncertainty in the water volume estimates for each water use category in the audit.

Recommendation #2: Although utilities are only required to report their water audits every five years, utilities should implement annual or biennial programs to develop the data necessary to gradually reduce the uncertainty in their water audits and should review their water audits annually or biennially. Programs should target the water audit categories with the most uncertain water volume estimates.

16.A.2 Real Loss

The screening-level infrastructure leakage index (SLILI) is the real loss divided by the theoretical unavoidable annual real loss. In theory, the SLILI should not be less than one, because the real loss should not be less than the unavoidable annual real loss. However, the statewide median SLILI is 0.22 when calculated from reported data. In addition, the statewide median real loss is 3.6 gallons per connection per day, which is only about 23 percent of the lowest identified real loss for a North American system (16 gal/conn/day for Halifax Central, shown in Table 7-1).

Even assuming that the balancing adjustment is unreported real loss, the statewide median SLILI is only 2.04 and the statewide median real loss is 18.8 gal/conn/day. Compared to the AWWA guidelines for ILI goals (Table 7-3) and real loss performance by North American utilities (Table 7-1), these statistics seem to indicate that at least half of reporting utilities have excellent real loss control. However, most utilities in Texas practice real loss control in a reactive way (rather than a proactive way), so it is surprising that half of the reporting utilities have such excellent real loss performance, particularly in comparison to other North American utilities.

<u>Conclusion #3</u>: Because the actual statewide median SLILI value is so low (somewhere between 0.22 and 2.04), it appears that most reporting utilities have underestimated actual real loss. Furthermore, from comparison to AWWA guidelines and real loss performance by other North American utilities, it appears likely that the actual real loss is underestimated even if the balancing adjustment is treated as real loss.

<u>Recommendation #3</u>: Utilities should refine their water audits to better estimate their actual real loss. This may involve confirmation of existing information (*e.g.*, calibration of production and consumption meters), additional analysis of existing information, and collection of new information (*e.g.*, flow monitoring in District Metered Areas).

<u>Conclusion #4</u>: Judging from the AWWA guidelines (Table 7-3), at least 8 to 30 percent of the larger utilities[25] in Texas, particularly in Regions I and K, might benefit from real loss control measures. The actual percentage may be greater, given the real loss estimation problems discussed above.

<u>Recommendation #4</u>: Utilities should determine their economic level of leakage (ELL) and should use the ELL as a goal for real loss. Prior to determining an ELL, utilities should strive for a maximum ILI of 3.0 (Table 7-3). Utilities with an SLILI greater than 3.0 and other utilities with significant real loss in comparison to other North American utilities (Table 7-1) should consider implementing real loss control measures.

16.A.3 Water Loss Performance and Connection Density

Conclusion #5: As discussed above, trends in the water loss data are largely obscured by the balancing adjustment. However, even after accounting for the balancing adjustment, average real loss per mile of main per day increases with increasing connection density,[26] and average non-revenue water percentage decreases with increasing connection density (Figure I-2).

Recommendation #5: Reasons for these trends should be identified. Future analysis of water loss performance should consider connection density as an independent variable, along with utility location, type, and size.

16.A.4 Non-Revenue Water

Conclusion #6: Regions I and J have the highest average non-revenue water percentage (ranging from approximately 19 percent to as much as 27 percent of corrected input volume). These regions also had the highest reported average unbilled authorized water use, at 5.5 percent and 9.4 percent of corrected input volume, respectively, compared to the statewide reported average of 2.6 percent. In addition, non-revenue water may be as high as 18.7 percent in Harris County and may be as high as about 15 percent in Hidalgo, Nueces, Tarrant, and Travis Counties.

Recommendation #6: Utilities should determine their economic target level for non-revenue water and strive to reduce their non-revenue water to the economic target level. In particular, utilities in Regions I and J should consider steps to recover lost revenue from unbilled authorized consumption, and utilities in Harris, Hidalgo, Nueces, Tarrant, and Travis Counties should consider steps to reduce non-revenue water.

16.A.5 Statewide Value of Total Water Loss

Conclusion #7: The estimated total value of total water loss in Texas is between $152 million and $513 million per year.

Recommendation #7: To increase the reliability and narrow the range of this estimate, the production and retail water costs should be reported in consistent units, and utilities must refine their water accounting, thereby reducing the balancing adjustment.

[26] The number of service connections per mile of main.

16.B Regional Water Planning

Conclusion #8: During the previous two regional water planning efforts, limited water audit data were available to the RWPGs, and those data were not uniformly reported, making estimation of potential water savings from system water audits and water loss prevention strategies difficult. The research results provide baseline water audit information for each reporting retail public utility, greatly enhancing the RWPG knowledge of how water is being used in each region and of the potential for water and cost savings.

Recommendation #8: RWPGs should use the research results to estimate potential water savings from system water audits and water loss prevention strategies and should update the regional water plans as appropriate.

Conclusion #9: The regional water planning cycle and the water audit reporting cycle are misaligned. The next regional water plans are due January 1, 2011, and current water loss data may be out-of-date by that time. However, the next water audits are not due until March 31, 2011. As utilities refine their water audits, reducing balancing adjustment and improving real loss estimates, it is expected that water loss data reported from the next round of water audits will be more useful for planning purposes than the current water loss data. For maximum utility in development of the next regional water plans, the RWPGs need to receive new water loss data by at least January 1, 2010. Allowing time for quality control and analysis, this means that new water loss data would have to be reported by March 31, 2009, if not sooner.

Recommendation #9: The TWDB should work to align the regional water planning cycle and the water audit reporting cycle so that up-to-date water loss data is used in developing the regional water plans.

16.C TWDB Actions to Enhance Water Loss Accounting and Prevention

The TWDB should consider the following actions to enhance water loss accounting and prevention in Texas:

Recommendation #10: To provide a more comprehensive picture of water loss in Texas, the TWDB should consider extending water auditing requirements to include wholesale utilities that provide raw or potable water. This may require additional authorization from the Legislature.

Recommendation #11: The TWDB should continue to promote water loss prevention to retail public utilities, focusing on the retail public utilities that have the greatest need for water loss reduction.

Recommendation #12: To make the water loss data more comprehensive, the TWDB should continue to seek water audit data from retail public utilities that have not reported.

Recommendation #13: The TWDB should continue to provide equipment, education, and financial assistance to help retail public utilities achieve improved water loss accounting and water loss performance.

Recommendation #14: To minimize the impact of balancing adjustment on the water loss analysis, the TWDB should consider devoting additional personnel and/or resources to assisting utilities with refinement of their water audits.

Recommendation #15: The TWDB should convey the findings, conclusions, and recommendations of this research effort to stakeholders through workshops or other means of communication.

In addition, the water loss reporting process needs to be revised to help assure data quality and to make the maximum use of reported water loss data. Conclusions and recommendations regarding data quality control and the water loss reporting process are discussed below.

Conclusion #16: The reported population may include the population served by wholesale customers. Therefore, care should be taken when using the reported data to compare per capita water use between water suppliers. Because both the retail water supplier and the wholesale water supplier may report some populations, the total population served by reporting utilities is uncertain. To obtain the total retail population served, a distinction between retail and wholesale populations is necessary.

Recommendation #16: The TWDB should revise its Water Audit Reporting Form and web-based reporting interface to include separate reporting of retail and wholesale populations, with the wholesale population being optional. This will allow calculation of retail per capita water use statistics. Per capita water use statistics are not particularly important to the IWA/AWWA water loss accounting methodology or to the water loss performance indicators, but they are the topic of much discussion among water planners in Texas. Since per capita water use statistics are likely to be extracted from the reported data, it is important that they be based on the correct population.

Conclusion #17: Wholesale water sales are reported as billed metered consumption. Therefore, wholesale water sales are included in the water delivery for both the wholesale water supplier and the wholesale water customer, and the sum of reported water deliveries (and corrected input volumes) for all reporting utilities includes wholesale water sales multiple times.

Recommendation #17: The TWDB should revise its Water Audit Reporting Form and web-based reporting interface to break out wholesale water sales within the billed metered consumption category. This will allow calculation of total water delivery and total corrected input volume for a region, county, *etc.*, without counting wholesale water sales multiple times.

Conclusion #18: The units for the reported production meter accuracy percentage and customer meter accuracy percentage are unclear. Some utilities reported the percentages as whole numbers, and others reported the percentages as decimal numbers.

Recommendation #18: The TWDB should revise its Water Audit Reporting Form and web-based reporting interface to clarify that the production meter accuracy percentage and customer meter accuracy percentage should be entered as decimal numbers. For example, a production meter accuracy of 99.2 percent would be entered as "0.992." The web interface should be programmed to reject a production meter accuracy percentage or customer meter accuracy percentage that is greater than two and to question entries that are less than 0.80 or greater than 1.20.

Conclusion #19: The units for reported production water cost and retail water cost are unclear. Some reported costs appeared to be in units of dollars per gallon, and others appeared to be in units of dollars per thousand gallons.

Recommendation #19: The TWDB should revise its Water Audit Reporting Form and web-based reporting interface to clarify that the production water cost and retail water cost should be entered in units of dollars per thousand gallons for utilities that report their water volumes in gallons and in units of dollars per acre-foot for utilities that report their water volumes in acre-feet. The web interface should be programmed to reject a production water cost or retail water cost that is less than $0.01 per thousand gallons or $10 per acre-foot and to question a production water cost or retail water cost that is greater than $10 per thousand gallons or $3,300 per acre-foot.

Conclusion #20: Some utilities reported a retail water cost that is less than the production water cost. It is very unlikely that a utility would sell water for less than it costs to produce.

Recommendation #20: The TWDB should revise its Water Audit Reporting Form and web-based reporting interface to clarify that the production water cost should be less than the retail water cost. The web interface should be programmed to question a retail water cost that is less than the production water cost.

Conclusion #21: It was not possible to calculate the ILI for a given utility, which the AWWA says is the best indicator for comparison of real losses between systems,[D] because the average length of service connection from curb-stop to meter and the average system water pressure were not reported.

Recommendation #21: The TWDB should revise its Water Audit Reporting Form and web-based reporting interface to request the average length of service connection from curb-stop to meter and the average system water pressure. This will allow calculation of the ILI using utility-specific data rather than screening-level assumptions.

Conclusion #22: It was not possible to calculate the ratio of the value of non-revenue water to the total annual cost of running the water system for a given utility, a financial efficiency performance indicator recommended by the AWWA,[H] because the total annual cost of running the water system was not reported.

Recommendation #22: The TWDB should revise its Water Audit Reporting Form and web-based reporting interface to request the total annual cost of running the water system during the reporting period. This includes all fixed and variable costs associated with purchasing, treating, and distributing water and will allow calculation of the value of non-revenue water as a percentage of the total annual cost of running the water system.

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