



# Water Loss Symposium

## August 22, 2013



# Water Loss

**Dr. Robert E. Mace**  
**Texas Water Development Board**







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OUR CITIES: LONDON

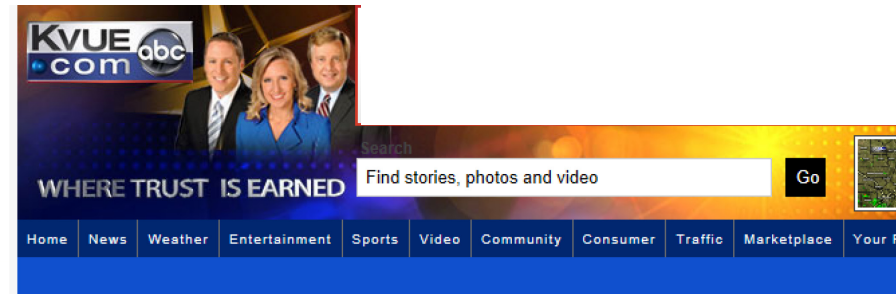
## Austin is Losing Three Billion Gallons of Water a Year



(alamosbasement/Flickr)

KVUE reports that thanks to broken and leaky pipework, Austin is losing three billion gallons of water a year, a particularly striking number given the area's formidable drought conditions. Ironical, too, given how vigilant the city is about enforcing water restrictions—Austin Water is known to send out crews in the middle of the night to photograph proof of improper watering.

"When we're in a drought, and we're asking people to conserve water and do their part, it sends a really bad



Home

## 3 billion gallons of water lost



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by ANDY PIERROTTI / KVUE News and  
photojournalist DEREK RASOR  
[Bio](#) | [Email](#) | Follow: [@AndyP\\_KVUE](#)

[kvue.com](#)  
Posted on August 19, 2013 at 10:38 PM  
Updated yesterday at 7:28 AM

AUSTIN -- A KVUE Defenders investigation uncovers the city of Austin loses more than three billion gallons of water a year due to leaky or broken pipes. It's happening during one of the worst droughts in Texas' history too.

# Water loss

## audits for 2010

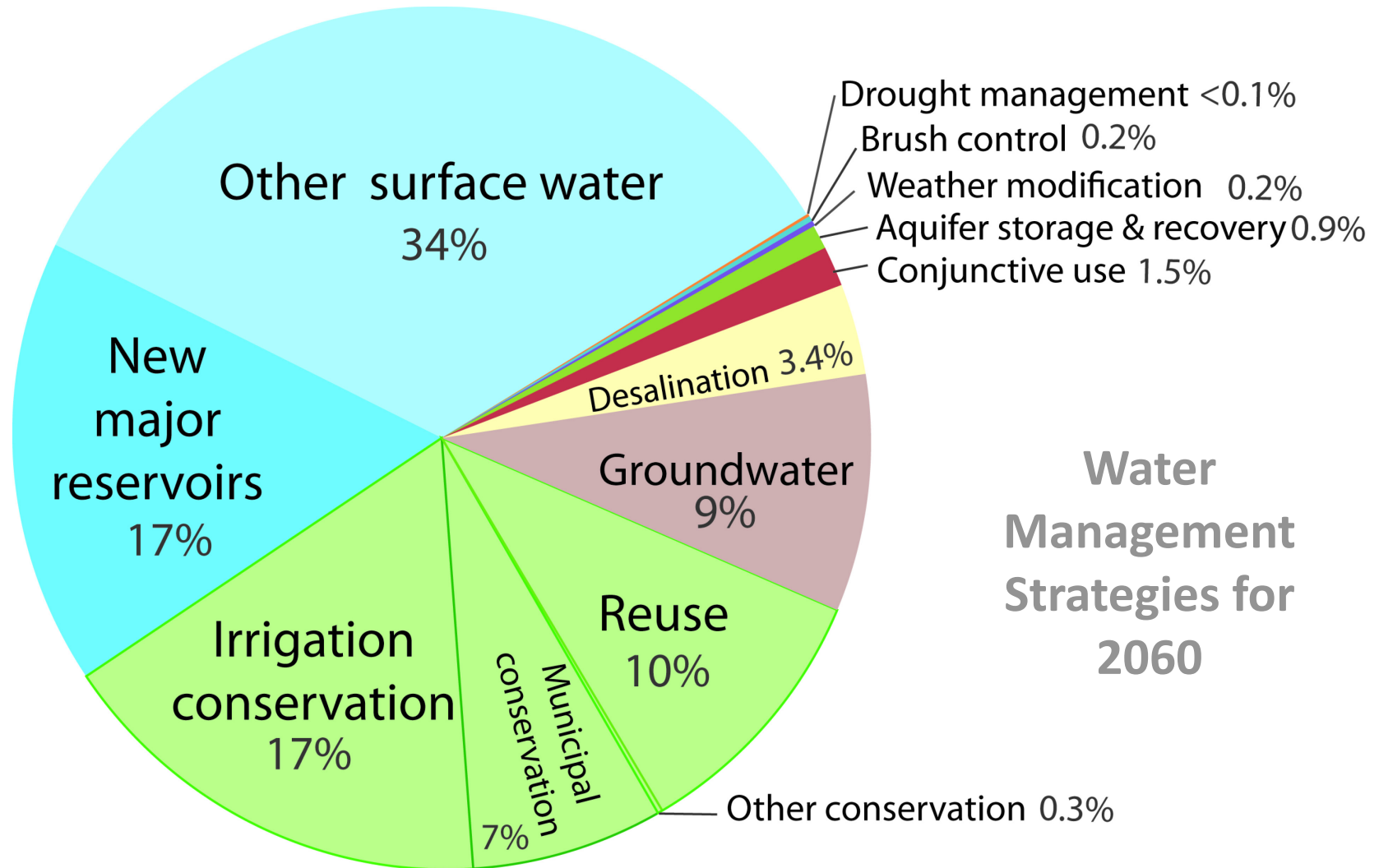
- 16.8 percent loss
  - 3.1 apparent
  - 13.7 real





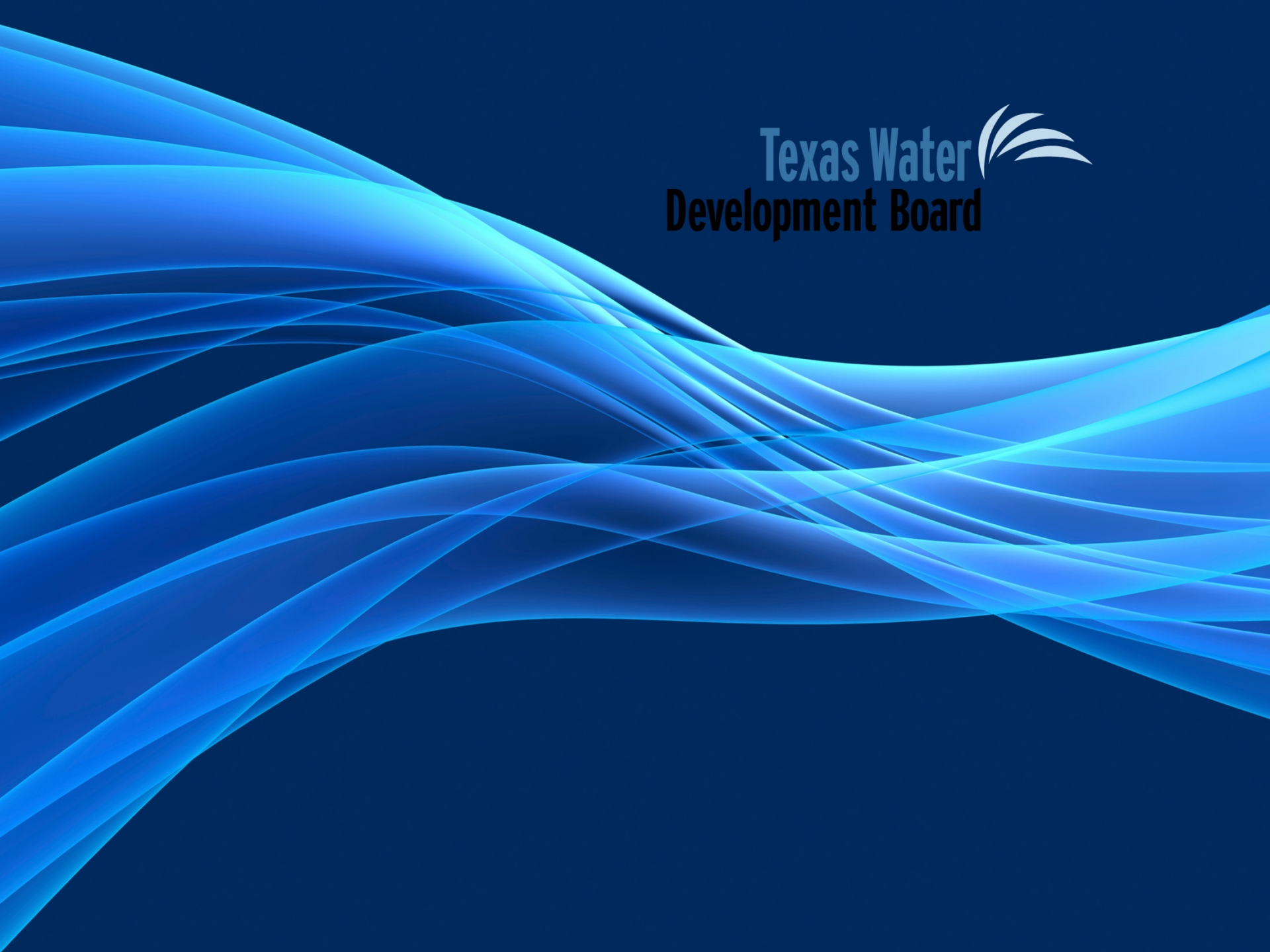


# What can we do for more H<sub>2</sub>O?







The background of the entire image is composed of numerous overlapping, translucent blue wavy lines that flow from the left side towards the right. These lines vary in opacity and color intensity, ranging from a deep navy blue to a bright, glowing cyan, creating a sense of movement and depth.

**Texas Water**  
**Development Board**



# **WATER BALANCE 101: PROCESS & BENEFITS OF A WATER AUDIT**

**Water Loss Symposium**

**August 22, 2013**

***TEXAS WATER DEVELOPMENT BOARD***

**KATE GASNER — PROJECT MANAGER**

**WATER SYSTEMS OPTIMIZATION, INC.**

08/21/2013

**W S O**





# Water Systems Optimization, Inc.

## **About WSO:**



- Highly specialized in water loss assessment and management
- Acknowledged as one of the leading water loss control companies in North America
- Carried out many successful water loss control contracts for water utilities across North America and South East Asia
- Offices in Nashville, TN and in San Francisco, CA
- Implemented numerous Water Loss Control programs and trainings throughout the United States:
  - ▣ Philadelphia Water Department
  - ▣ Los Angeles Department of Water and Power
  - ▣ Metro Water Department (Nashville, TN)
  - ▣ Eastern Municipal Water District
  - ▣ City of Folsom
  - ▣ San Francisco Public Utilities Commission
  - ▣ California Urban Water Conservation Council
  - ▣ Phoenix Water Department

# Non-Revenue Water



REAL LOSSES

APPARENT LOSSES





# Benefits of NRW Management

Save Water

Reduce Costs

Culture of  
Accountability

- ❑ Comprehensive understanding of your system
- ❑ Financial Benefits – Reduction in O&M & CIP costs
- ❑ Better Asset Management
- ❑ Optimized Meter Replacement/Management
- ❑ Water Conservation (Supply Side & Demand Side)
- ❑ Sustainability (Water/Energy Nexus)
- ❑ Be Ahead of Regulatory Arena
- ❑ Less Liability
- ❑ Build Credibility with Stakeholders and Regulators

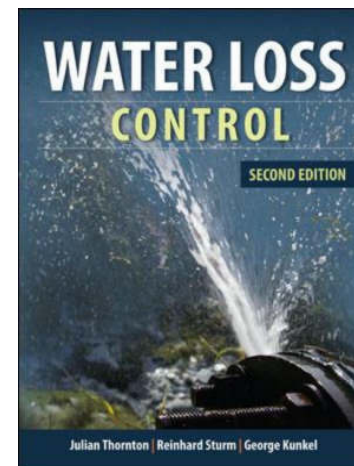
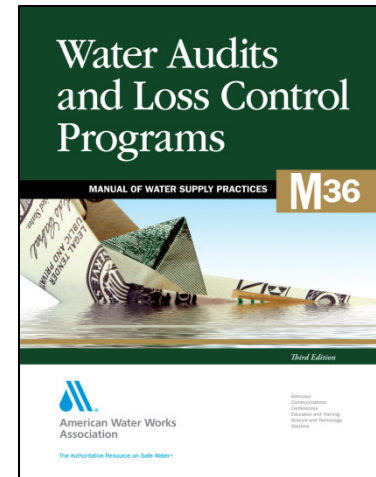
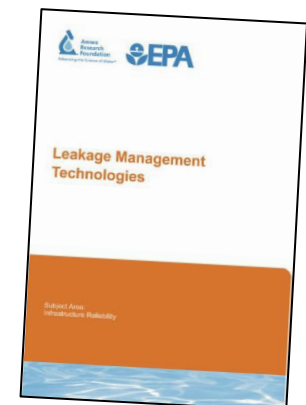
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# Best Practice Tools for Water Loss Control

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- ❑ AWWA Water Loss Control Committee's Free Water Audit Software©
  - ❑ Current version is 4.2 in English and French languages
  - ❑ Includes data grading capability
  - ❑ Companion "Compiler" Software
- ❑ Water Research Foundation Reports
  - ❑ Project 4372: Leakage Component Analysis is underway
- ❑ Textbooks
- ❑ **www.awwa.com** - type "water loss control" in search box; select first item in list

# AWWA Water Audit

SYSTEM  
INPUT  
VOLUME

# Water Audit Tasks – Critical Data Validation

- Challenge Accuracy of System Input Meters

Volumetric Meter Test



Comparative Meter Test





# AWWA Water Audit

**Authorized  
Consumption**

**SYSTEM  
INPUT  
VOLUME**

# AWWA Water Audit

SYSTEM INPUT VOLUME	Authorized Consumption	Billed Authorized Consumption	Billed Metered Authorized Consumption
			Billed Unmetered Authorized Consumption

# Water Audit Tasks – Critical Data Validation

## □ Validate Billing Data Accuracy

- Second most significant volume that flows into AWWA water balance
- Two components:
  - Billed metered consumption
  - Billed unmetered consumption

- Validation is crucial



# Water Audit Tasks – Critical Data Validation

## ■ Billing Data Export:

### ■ Typical billing data fields to be included:

- Customer identification fields
- Meter identification fields
- Service type identification fields
- Meter read and consumption fields – units
- Trouble codes or flags

## □ Validation Efforts

- Confirm relevant consumption volumes
- Confirm integrity of consumption → look for duplicates and irregularities



# AWWA Water Audit

SYSTEM INPUT VOLUME	Authorized Consumption	Billed Authorized Consumption	Billed Metered Authorized Consumption
		Unbilled Authorized Consumption	Billed Unmetered Authorized Consumption
			Unbilled Metered Authorized Consumption
			Unbilled Unmetered Authorized Consumption

# Validation of Consumption Volumes

- Additionally all components of unbilled metered and un-metered consumption need to be assessed
  - ▣ Street cleaning
  - ▣ Mains flushing
  - ▣ Fire fighting
  - ▣ etc.
- Generally small portion of the “water supplied” volume
- If data is not available, do not spend lots of time on quantifying this value
- Instead, use the default value for “Unbilled Unmetered Consumption”
- Improve data validity over time



# AWWA Water Audit

SYSTEM INPUT VOLUME	Authorized Consumption	Billed Authorized Consumption	Billed Metered Authorized Consumption
			Billed Unmetered Authorized Consumption
		Unbilled Authorized Consumption	Unbilled Metered Authorized Consumption
			Unbilled Unmetered Authorized Consumption
	Water Losses		

# AWWA Water Audit

SYSTEM INPUT VOLUME	Authorized Consumption	Billed Authorized Consumption	Billed Metered Authorized Consumption
			Billed Unmetered Authorized Consumption
		Unbilled Authorized Consumption	Unbilled Metered Authorized Consumption
			Unbilled Unmetered Authorized Consumption
	Water Losses	Apparent Losses	Consumption metering errors
			Unauthorized consumption
			Systematic Data Handling Errors



# Apparent Losses from Small Meters

Meter Size	Meter Population	Test Sample Size	Volume-Weighted Average Accuracy	95% Confidence Limit of Accuracy
5/8"	13,548	66	92.0%	4.0%
3/4"	1,392	10	100.0%	0.4%
1"	2,145	20	96.9%	4.2%
1-1/2"	311	5	94.0%	3.8%
2"	391	13	97.6%	1.7%



# Water Audit Tasks – Critical Data Validation

## □ Task: Assess Customer Meter Accuracy

<b>Meter size</b>	<b>Total volume supplied through meters during audit period (MG)</b>	<b>Average accuracy based on meter test results</b>	<b>Apparent Losses during audit period (MG)</b>
5/8"	691.532	92.0%	59.725
3/4"	94.104	100.0%	-
1"	314.740	96.9%	10.136
1-1/2"	133.960	94.0%	8.535
2"	295.894	97.6%	7.214
<b>Total</b>	<b>1,530.230</b>		<b>85.610</b>



# AWWA Water Audit

SYSTEM INPUT VOLUME	Authorized Consumption	Billed Authorized Consumption	Billed Metered Authorized Consumption
			Billed Unmetered Authorized Consumption
		Unbilled Authorized Consumption	Unbilled Metered Authorized Consumption
			Unbilled Unmetered Authorized Consumption
	Water Losses	Apparent Losses	Consumption metering errors
			Unauthorized consumption
			Systematic Data Handling Errors
		Real Losses	Leakage/overflow at service reservoirs
			Leakage from trunk mains
			Leakage from distribution mains
			Leakage from service connections

# Water Balance Result

AWWA WLCC Free Water Audit Software: <u>Water Balance</u>				Water Audit Report For:		Report Yr:
Copyright © 2010, American Water Works Association. All Rights Reserved.				Philadelphia Water Department		2012
Own Sources  (Adjusted for known errors)  86,050.400	Water Exported 5,483.700			Billed Water Exported		
	Water Supplied  80,566.700	Authorized Consumption  50,184.800	Billed Authorized Consumption  48,987.000	Billed Metered Consumption (inc. water exported)  48,987.000	Revenue Water	
				Billed Unmetered Consumption  0.000	48,987.000	
		Water Losses  30,381.900	Unbilled Authorized Consumption  1,197.800	Unbilled Metered Consumption  0.000	Non-Revenue Water (NRW)	
				Unbilled Unmetered Consumption  1,197.800	31,579.700	
				Unauthorized Consumption  2,712.200		
	Water Imported  0.000	Real Losses  22,563.600	Customer Metering Inaccuracies  1,360.000			
			Systematic Data Handling Errors  3,746.100			
			Leakage on Transmission and/or Distribution Mains  Not broken down			
			Leakage and Overflows at Utility's Storage Tanks  Not broken down			
			Leakage on Service Connections  Not broken down			



# Performance Indicators

- AWWA Recommended Performance Indicators
  - ▣ Real Losses/service conn/day
  - ▣ Apparent Losses/service conn/day
  - ▣ Infrastructure Leakage Index (ILI)

$$ILI = CARL/UARL$$

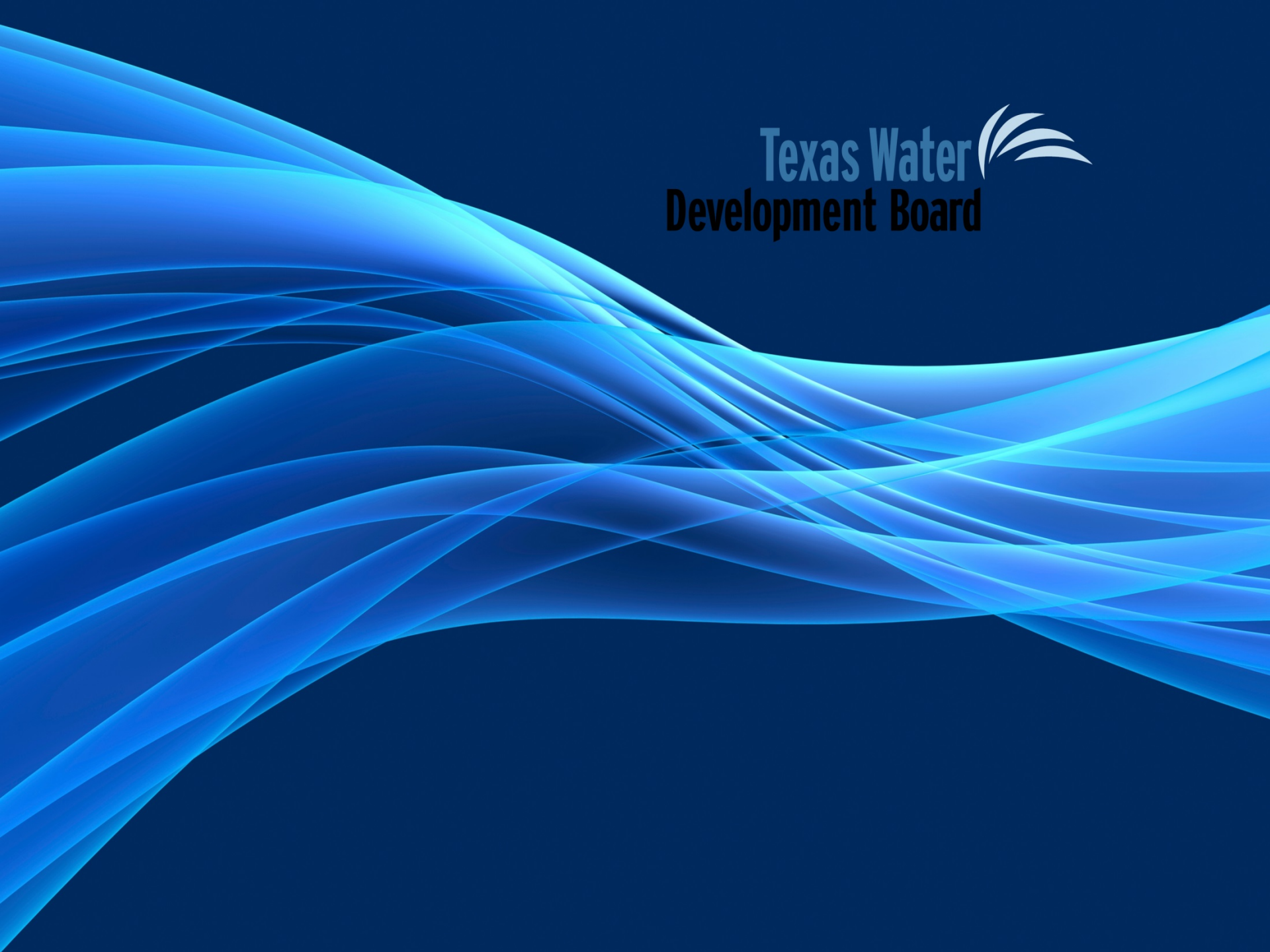




# Thank You!

Kate Gasner

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415.533.0419

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**Texas Water**  
**Development Board**



# **THE ECONOMICS OF WATER LOSS CONTROL**

**Water Loss Symposium**  
**August 22, 2013**  
***TEXAS WATER DEVELOPMENT BOARD***

**REINHARD STURM, VICE PRESIDENT**  
**WATER SYSTEMS OPTIMIZATION, INC**

08/21/2013

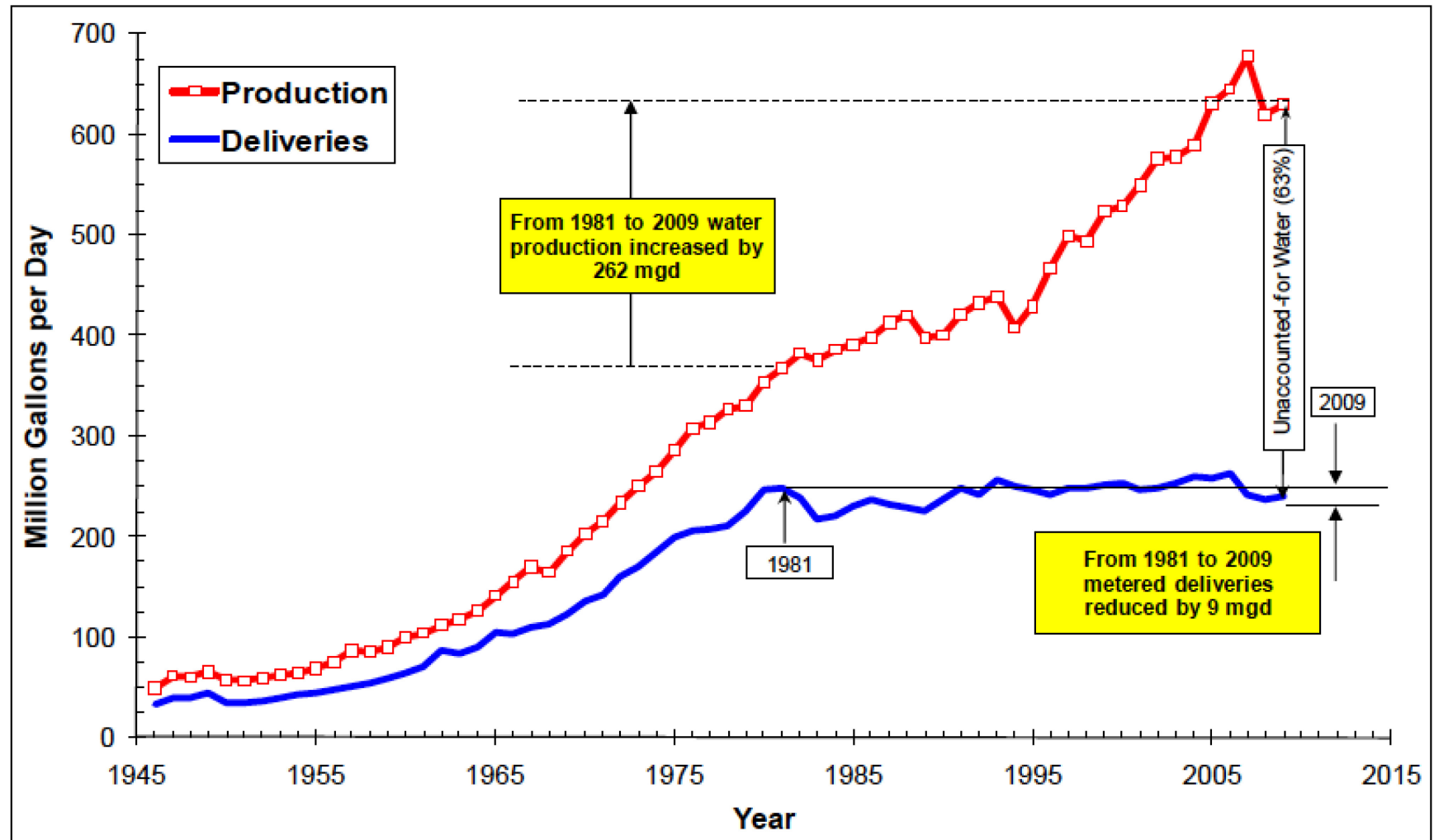
W S O



# What Is Non-Revenue Water (NRW) ???



# What Can Happen ???



Source: PRASA.

# What is the Right Strategy??????





# What Is Non-Revenue Water (NRW)

□ Non Revenue Water consists of:

▣ Real Losses



▣ Apparent Losses



# Apparent Losses





# Apparent Losses

Reducing Apparent Losses  
increases revenue but  
creates no *new* water

- Apparent Losses are often referred to as “paper losses”
- This type of loss is where the most money can be recaptured
- Revenue Generation needs to be OPTIMIZED

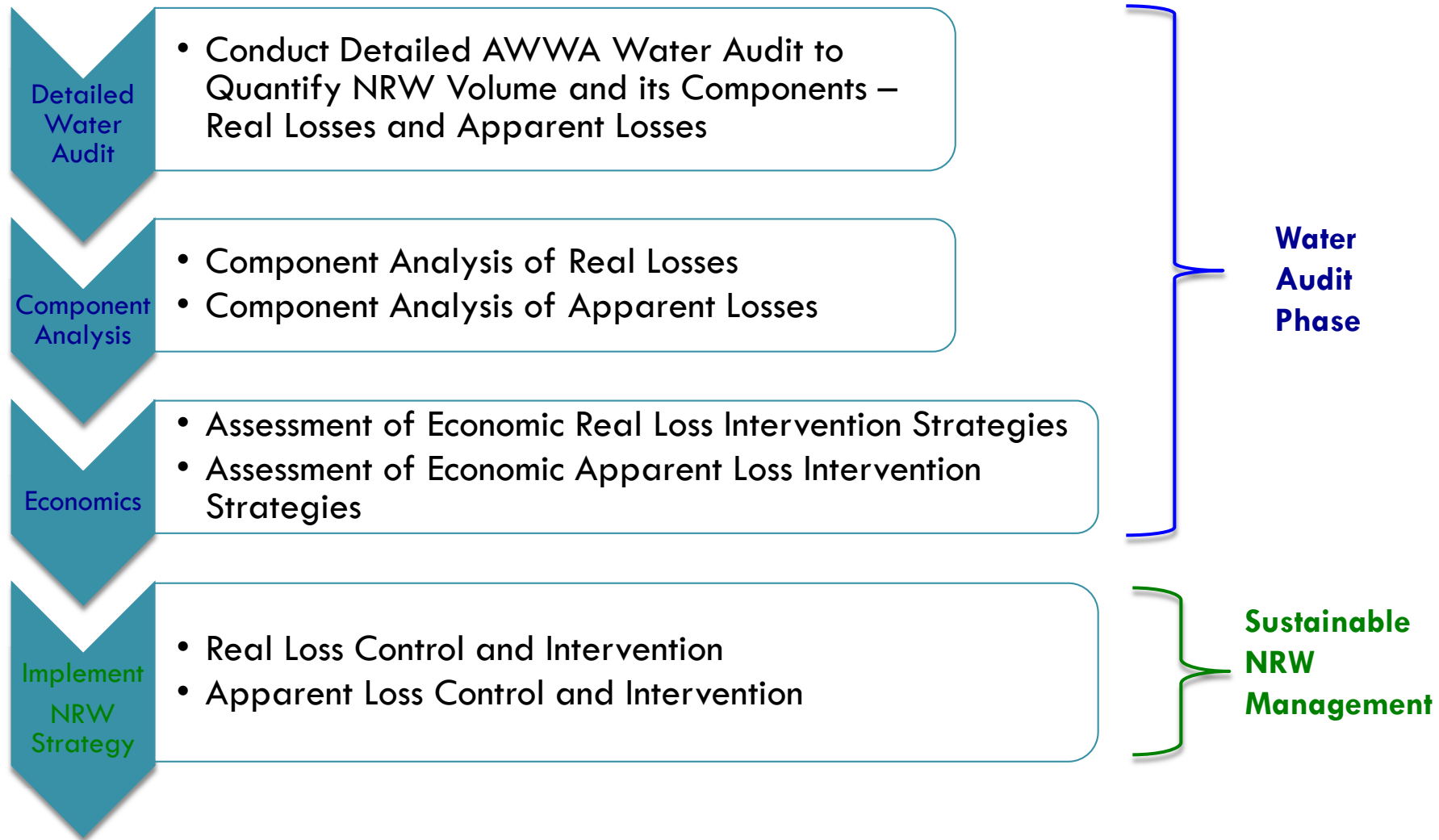
# Real Losses



# Real Losses

Reducing Real Losses creates an additional resource which reduces operating costs and can be used to defer capital expenditure

# How Can We Strategically Manage NRW??



# Non-Revenue Water Management Success Stories

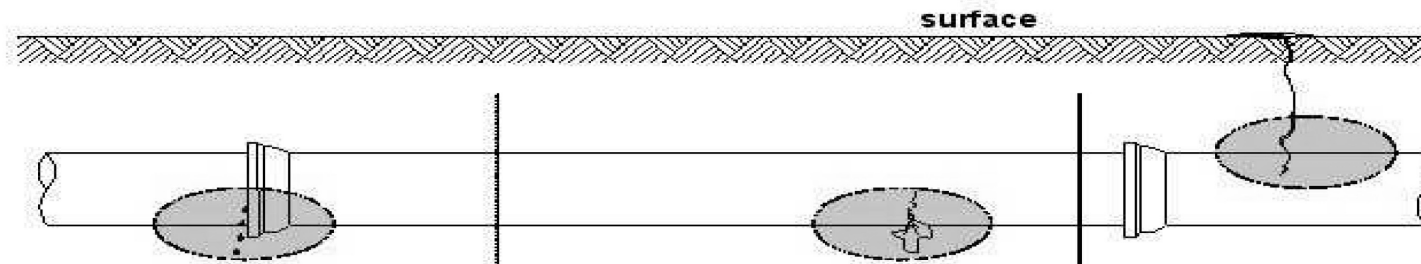
- Philadelphia Water Department
  - ▣ Real Loss Reduction in 11 Years
    - 15,000 MG = \$1.6M Savings
  - ▣ Apparent Loss Reduction in 11 Years
    - \$15M
  
- City of Phoenix – Apparent Loss Reduction
  - ▣ One Meter Make – 745MG/Year
  - ▣ Savings \$2.4M



# Non-Revenue Water Management Success Stories

- City of Folsom – 2year Water Loss Control Program
  - ▣ Real Loss Savings  $\sim 4\text{MGD} = \$700\text{K}/\text{year}$
  - ▣ Permanent Water Loss Monitoring Implemented
  
- City of Panama City
  - ▣ Reduction of customer meter inaccuracy
  - ▣ Increased Revenue  $\$615\text{K}/\text{year}$

# Understanding The Components of Real Losses



## Background leakage

Un-reported and un-detectable using traditional acoustic equipment.

### Tools

- Pressure reduction
- Main and service replacement
- Reduction in the number of joints and fittings

## Un-reported leakage

Often does not surface but is detectable using traditional acoustic equipment.

### Tools

- Pressure reduction
- Main and service replacement
- Reduction in the number of joints and fittings
- Proactive leak detection

## Reported leakage

Often surfaces and is reported by the public or utility workers

### Tools

- Pressure reduction
- Main and service replacement
- Optimized repair time



# WaterRF Research Project 4372 Model

- Extension of AWWA Free Water Audit Software (data easily transferable)
- Allows for basic Economic Assessment of Real Loss Control Options



WaterRF 4372  
Effective Organization and Component Analysis of Water Utility Leakage Data  
Water Audit: City of Austin, TX, USA, 2011  
MAIN MENU

Macros must be enabled to properly use the WaterRF 4372 Component Analysis Modeling Software

Start Page	Enter the audit period and select reporting units
Summary	Summary of the water audit performance indicators and the results of the Real Losses Component Analysis
AWWA Water Balance	Enter the required data from the AWWA WLCC Free Water Audit Software: Reporting Sheet to populate the Water Audit
Performance Indicators	Select your desired water loss performance indicator to be displayed in comparison to a North American water utility data set
Real Loss Components	Carry out a Real Losses Component Analysis using this sheet
RL Components Chart	A chart summarizing the results in the Real Loss Component Analysis
Break Frequency	Comparison of your utility's mains and service line break frequencies against industry averages and targets
A-L-R Times	Use this sheet to evaluate if a reduction in location and repair times for reported and unreported leaks would provide an opportunity to reduce real losses
Economic Intervention	Use this sheet to establish a preliminary schedule for proactive leak detection surveys
Pressure Management	Use this sheet to evaluate if pressure management and a reduction in average system pressure provides an opportunity to reduce real losses cost effectively
Glossary	Glossary of all terms used in the WaterRF 4372 Component Analysis Model
License	License

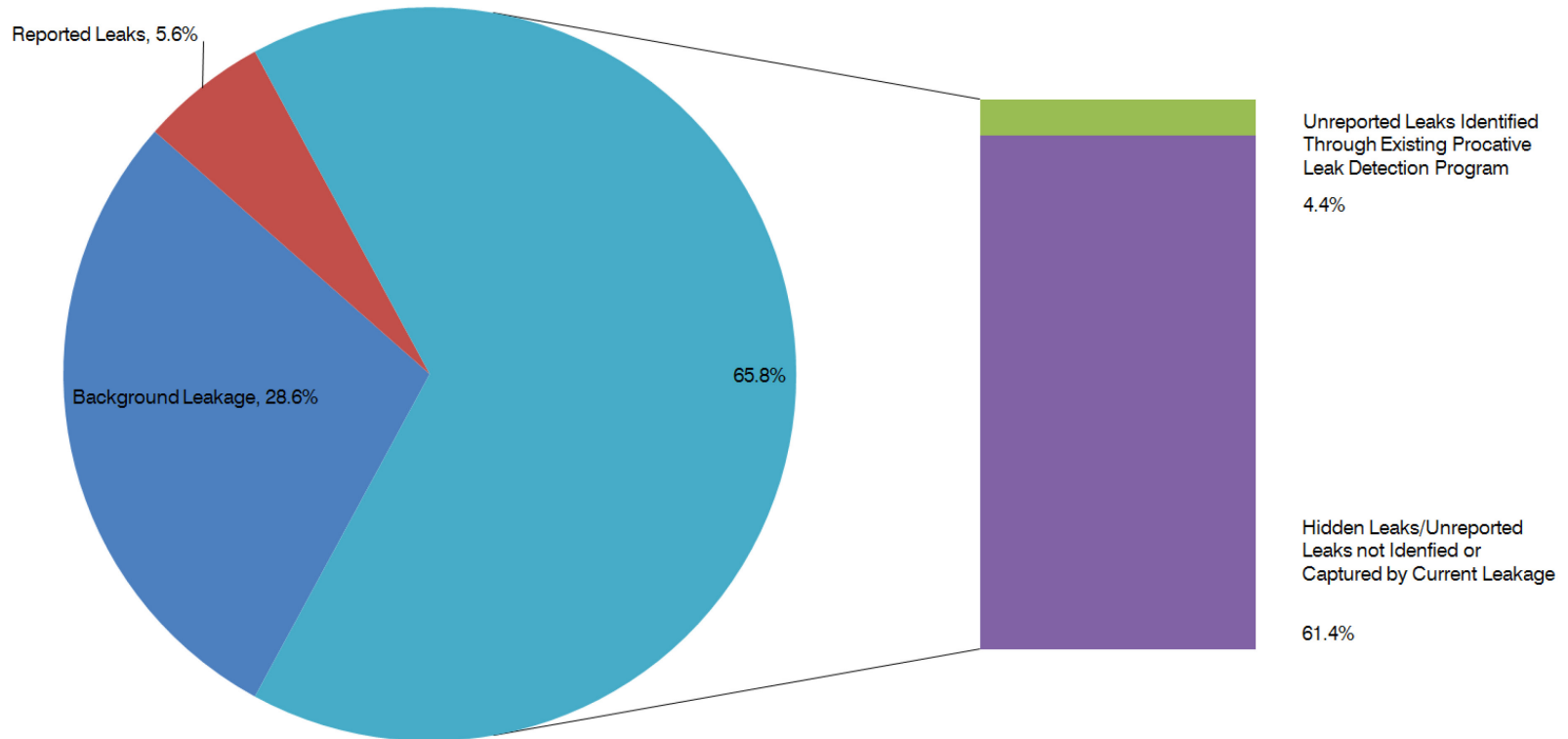
# Understanding The Components of Real Losses

WaterRF 4372: Effective Organization and Component Analysis of Water Utility Leakage Data

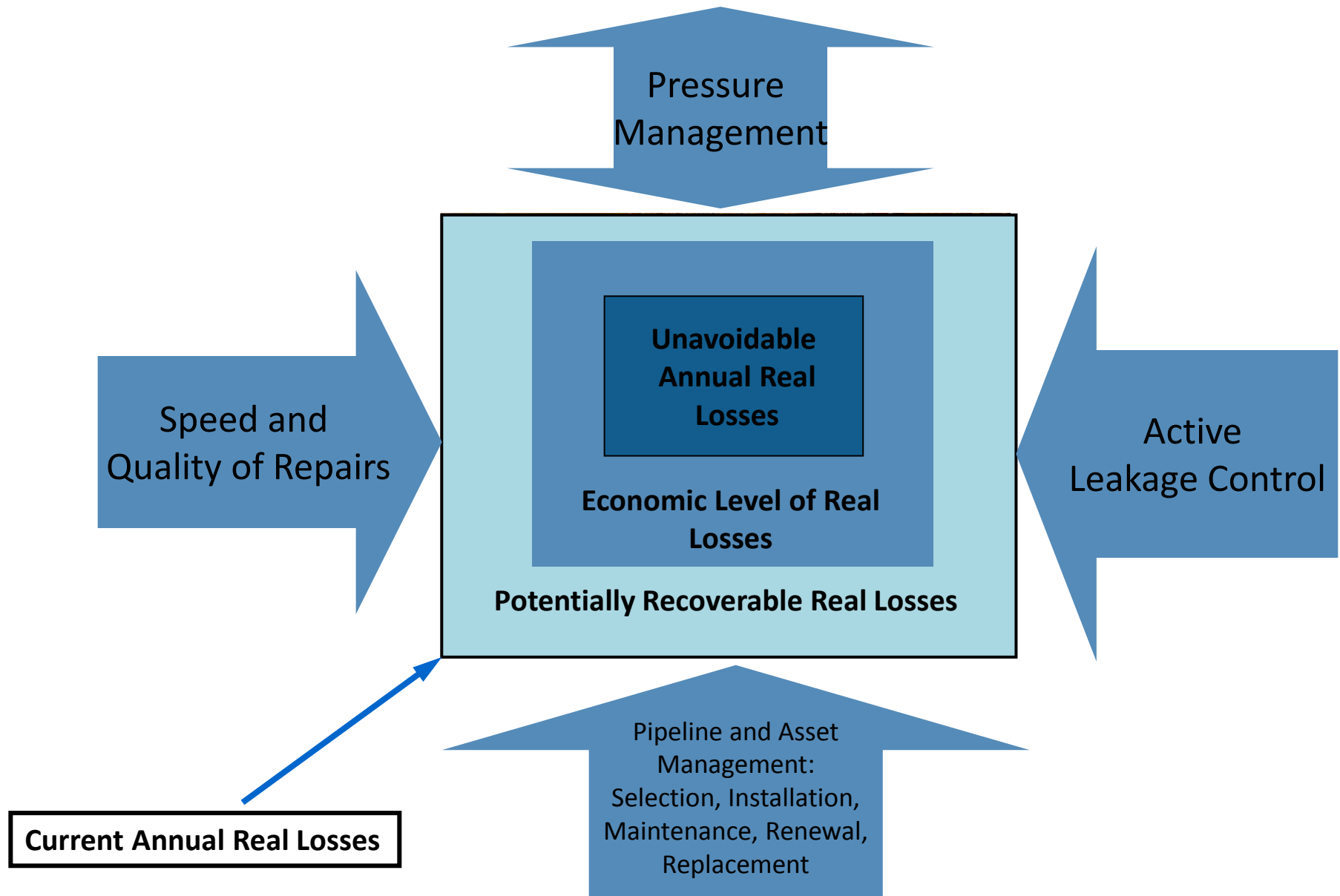
Water Audit: FY11

REAL LOSSES COMPONENTS GRAPH

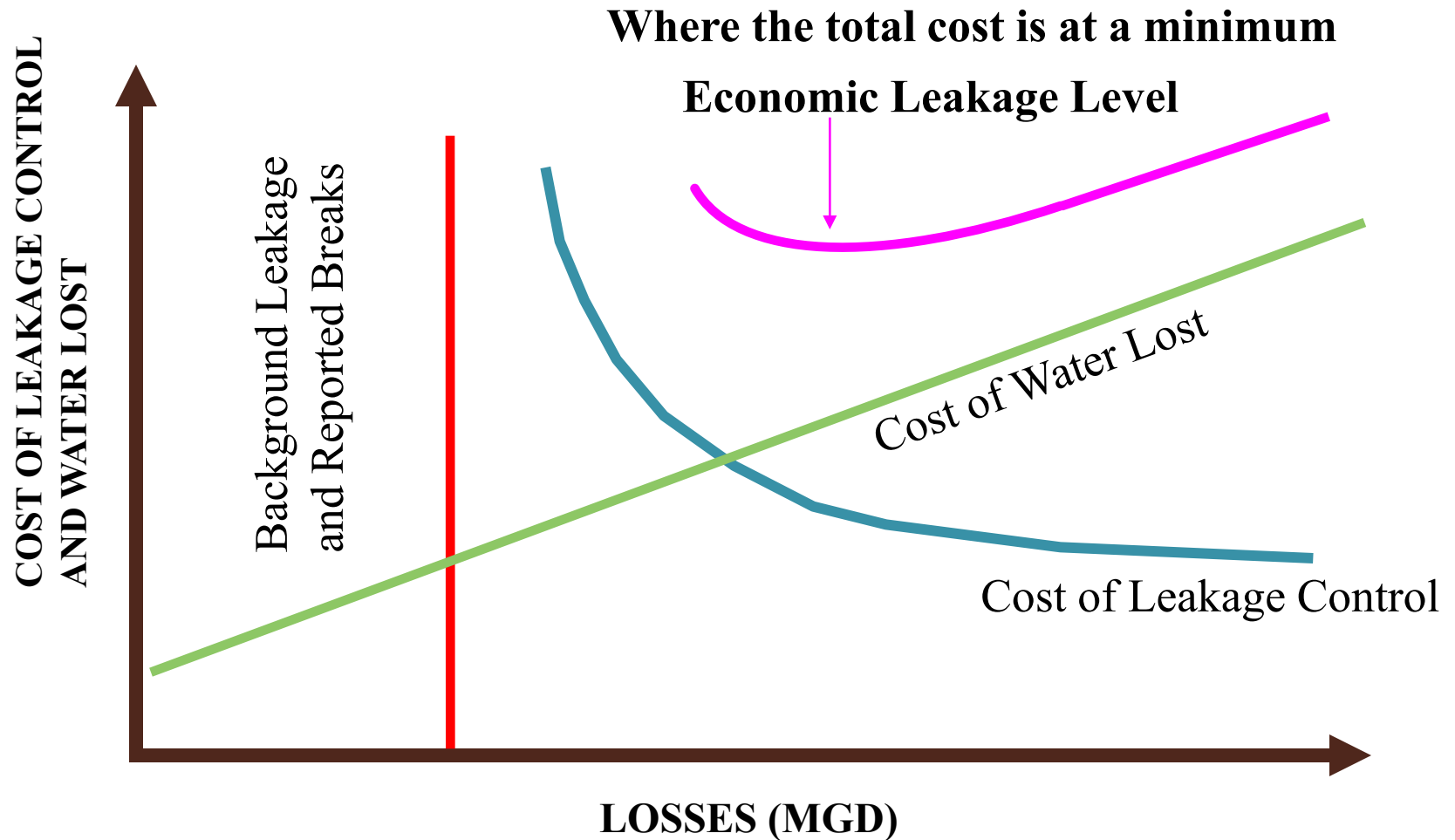
Real Loss Components



# Management Tools for Real Loss Reduction



# What Volume of Real Losses is Economic ??





# PWD System Wide Economic Level of Leakage for Proactive Leak Detection

	<b>Marginal Cost Valuation of Real Losses</b>
<b>Economic Intervention Frequency</b>	36.3 month
<b>% of System to be Surveyed Annually</b>	33%
<b>Annual Budget for Intervention</b>	\$285,686
<b>Economic Unreported Real Losses</b>	1,245 MG/Year
<b>Potential Recoverable Leakage</b>	2,595 MG/Year



# Economic Level of Leakage

- Real losses have real value – they are a hidden cost for the utility
- Leakage control is primarily an operational cost
- The economic optimum is achieved when the **combined** cost of real losses plus the cost of leakage control is at a minimum



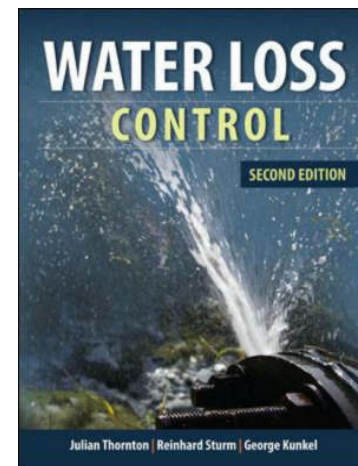
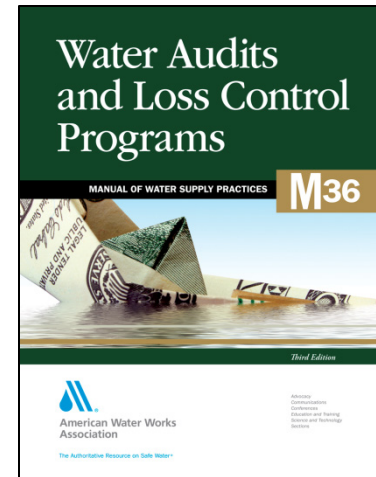
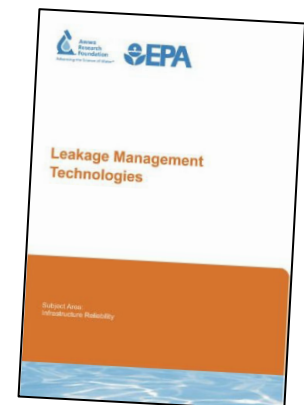
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# Best Practice Tools for Water Loss Control

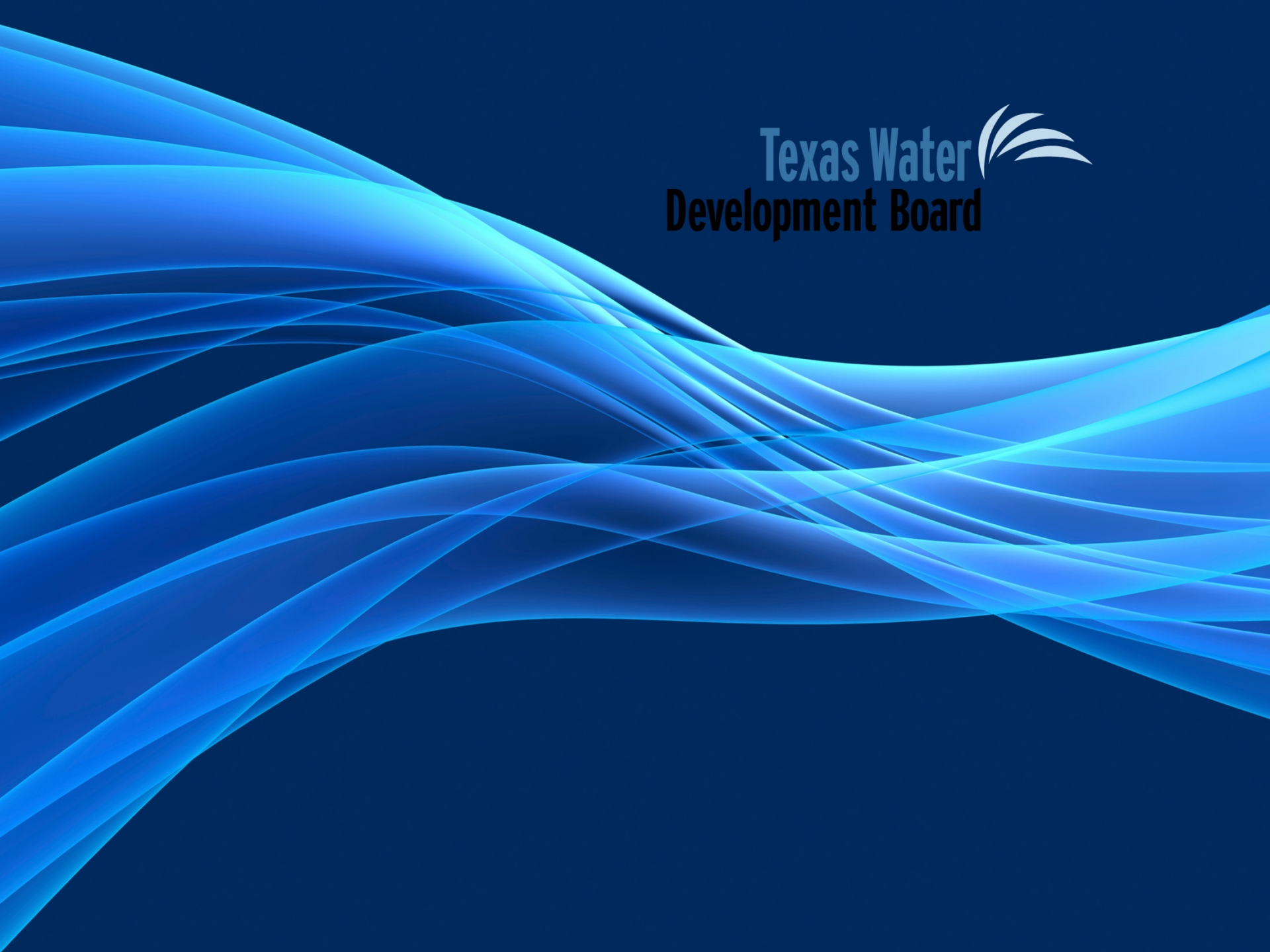
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**Texas Water**  
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# TEXAS WATER AUDIT DATA

**Water Loss Symposium**  
**August 22, 2013**  
***TEXAS WATER DEVELOPMENT BOARD***



**STATE OF THE STATE** BY: ANDREW CHASTAIN-HOWLEY



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Building a world of difference.®

# STATE UPDATES

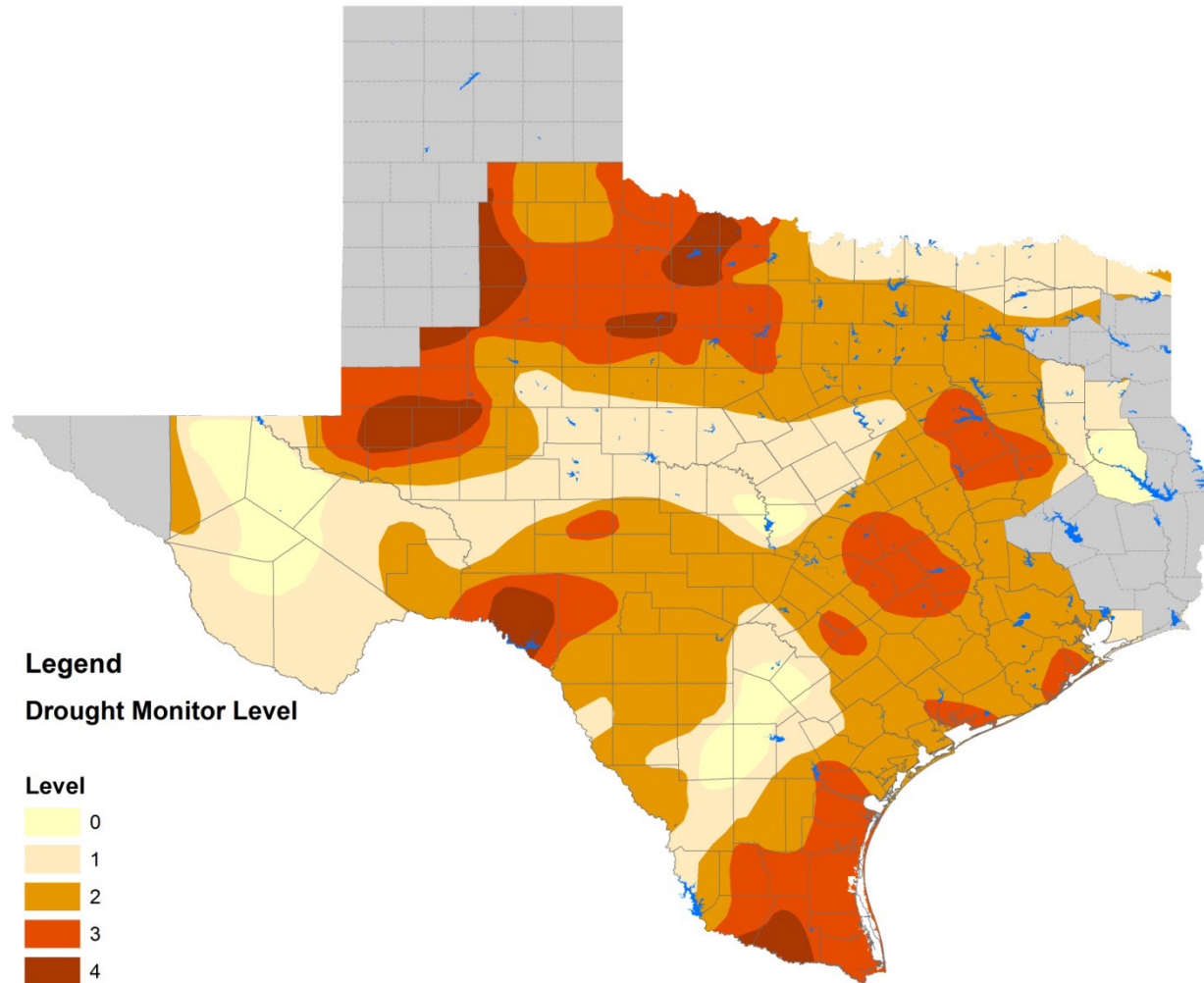
- **2011 Drought**

- Led to significant re-evaluation of water resources and water use in Texas

- **State Legislation**

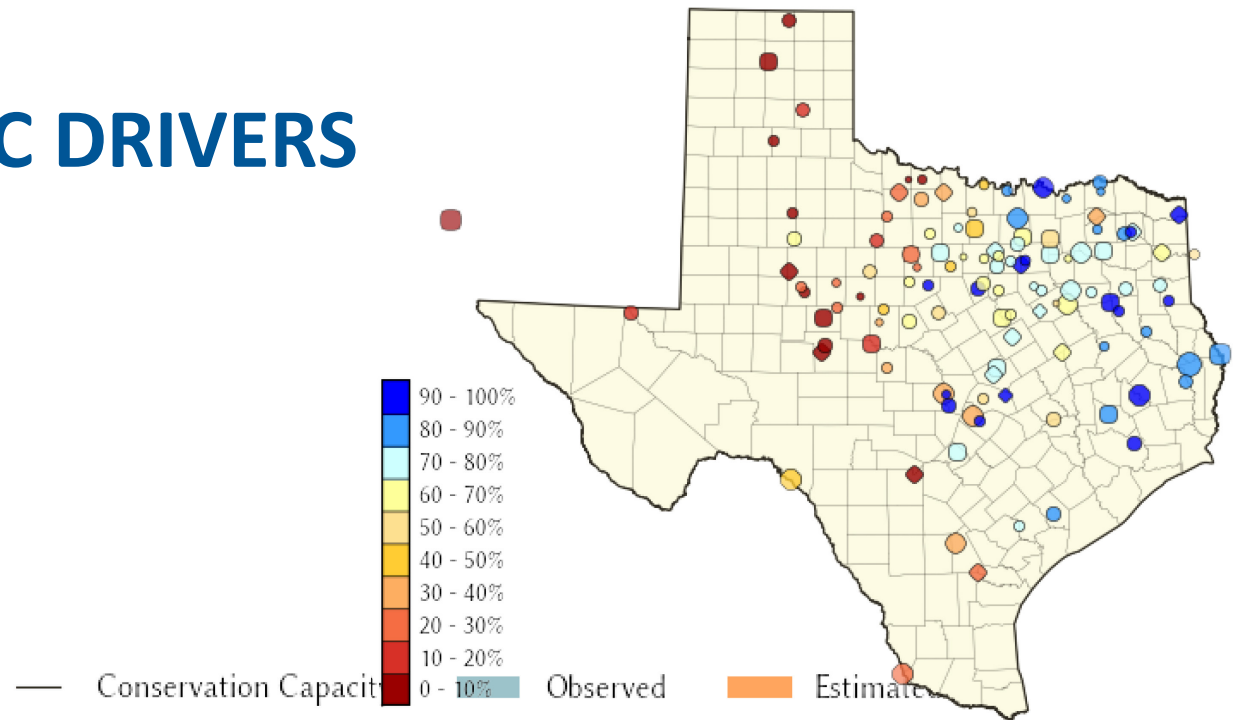
- Significant additions to water audit regulations
  - All utilities supplying more than 3,300 customers need to develop a water audit annually
- \$2 Billion Rainy Day Fund to be used (if voters approve in November) for loans to improve water resource situation.
  - Includes at least 20% for conservation which could include water loss reduction programs

# CLIMATIC DRIVERS



**Drought Monitor July 2013**

# CLIMATIC DRIVERS



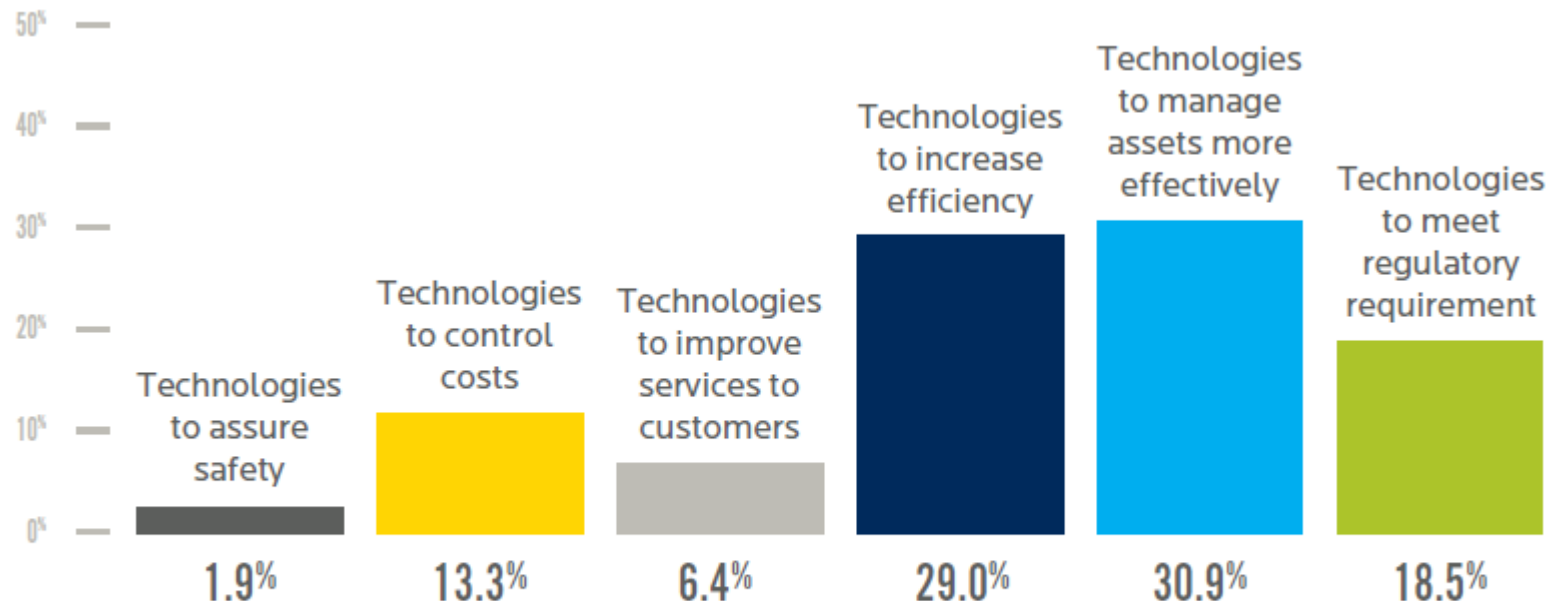
**Lower Colorado Reservoir Resources August 21, 2013**



# WATER UTILITY INFRASTRUCTURE CONCERNS

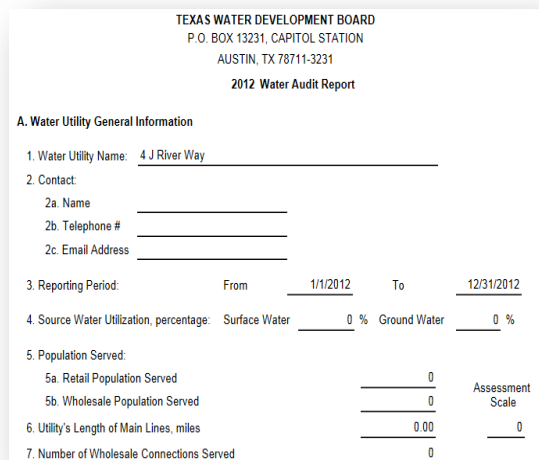
## 2012 Water Industry Survey:

Nearly 60% of responders said technology to increase efficiency and to manage assets more effectively will be the areas given the most emphasis in the future

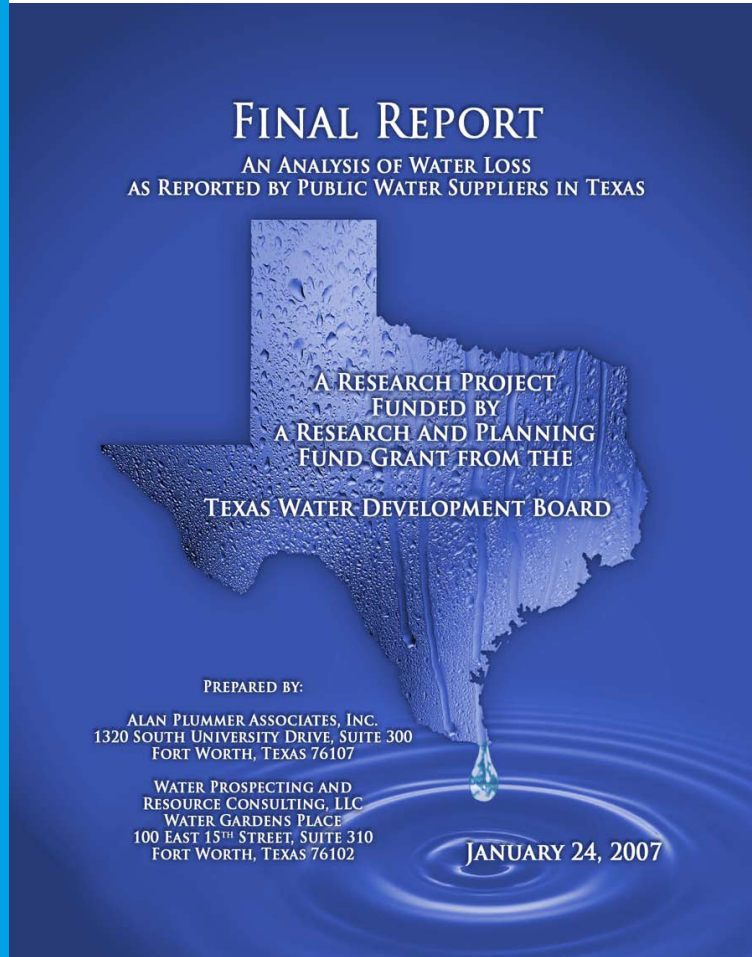


Source: Black & Veatch

- **Water Audit web-portal**
- **Water Audit Manual**
- **Review of 2006 Water Audit Data**
- **Water Audit Section at TWDB**
- **Water Audit Data Analyses**



# THE FIRST SET OF DATA IN 2005



- Approximately half of retail public utilities in Texas reported their water loss data.
- Reporting utilities served as much as 84 percent of the state's population.
- 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.

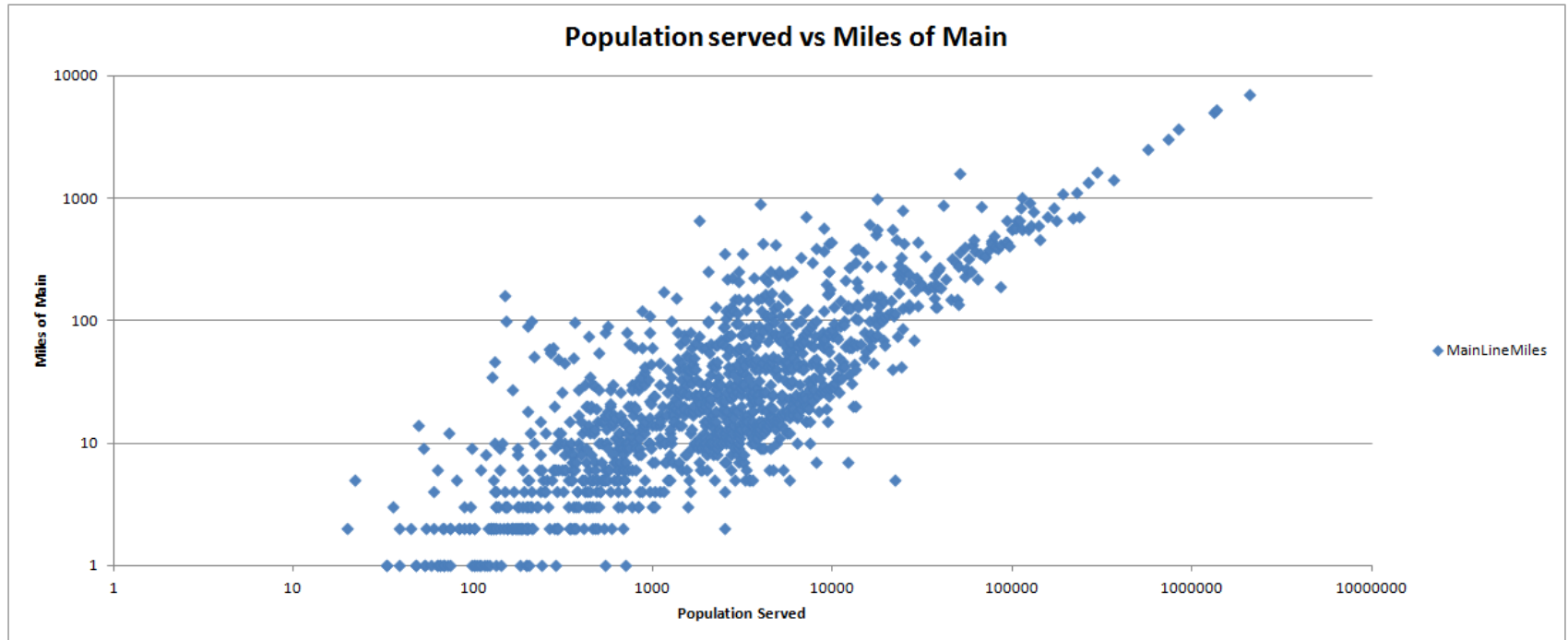
# DATA EVALUATIONS FROM 2005.

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

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

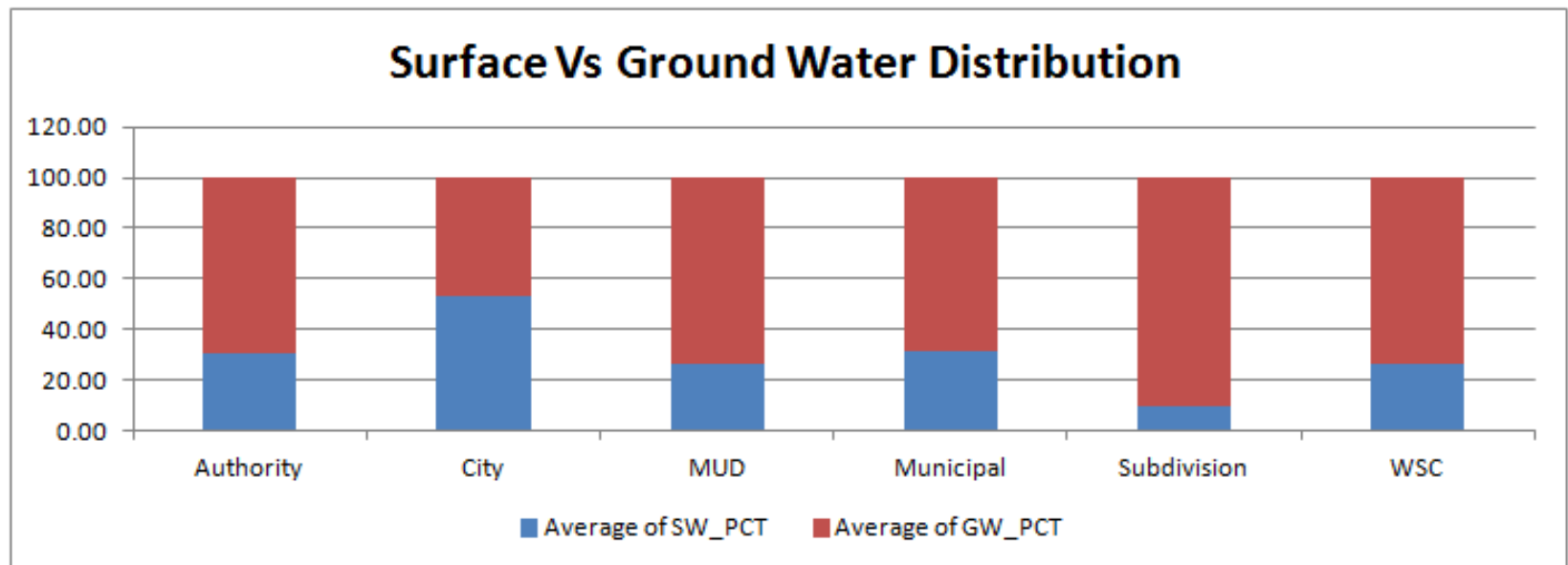
\* Over approximately one year. Most utilities reported data for calendar or fiscal year 2005

# DATA EVALUATIONS FROM 2010, 2011 AND 2012.

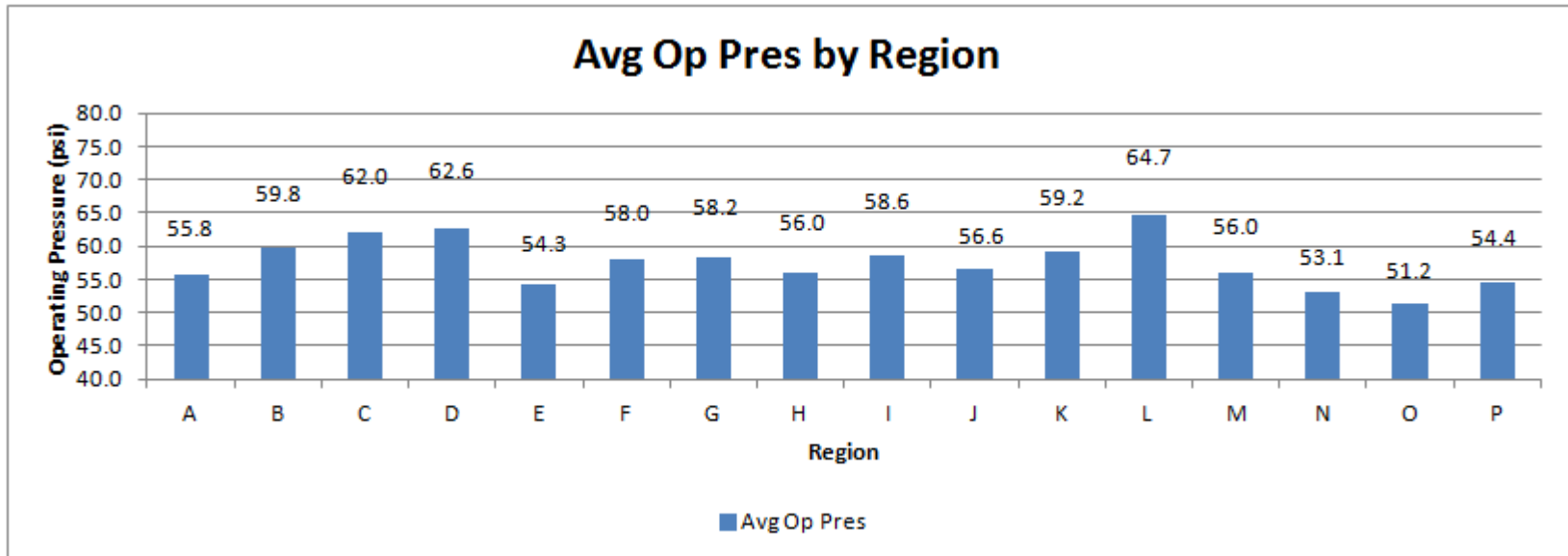




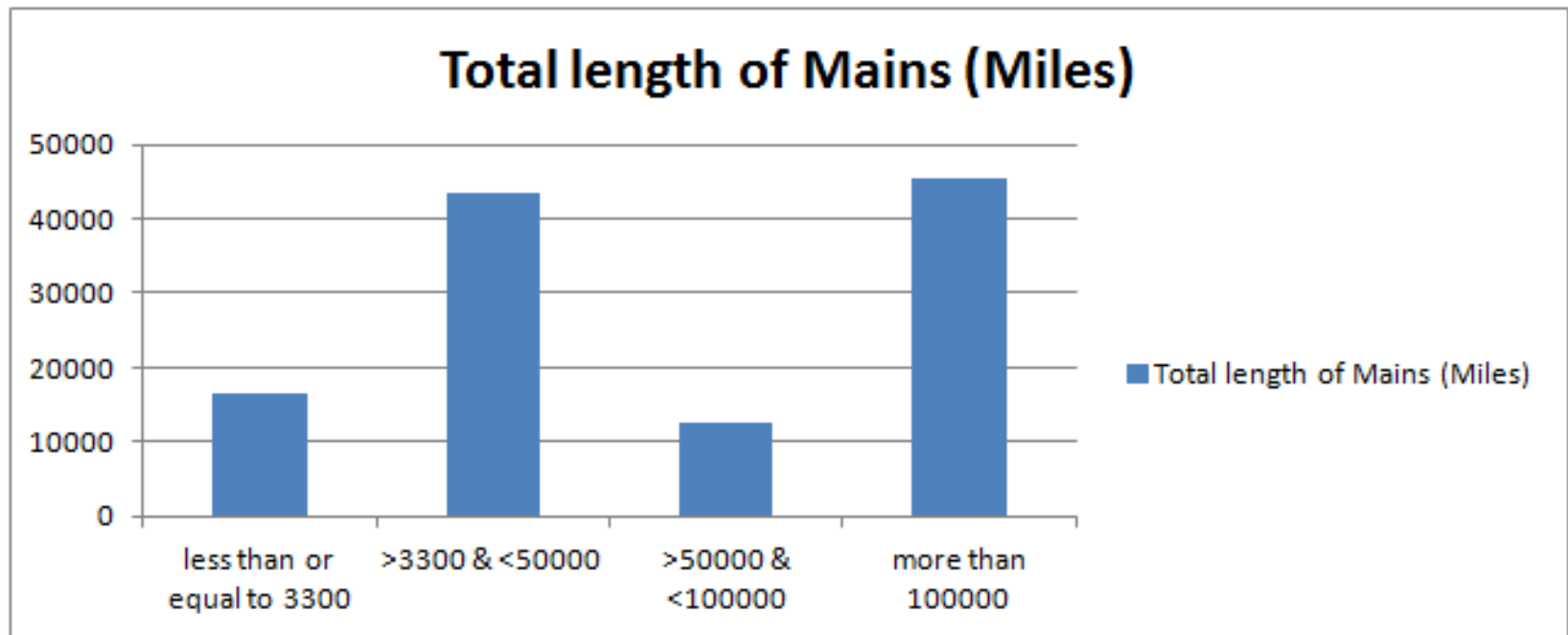
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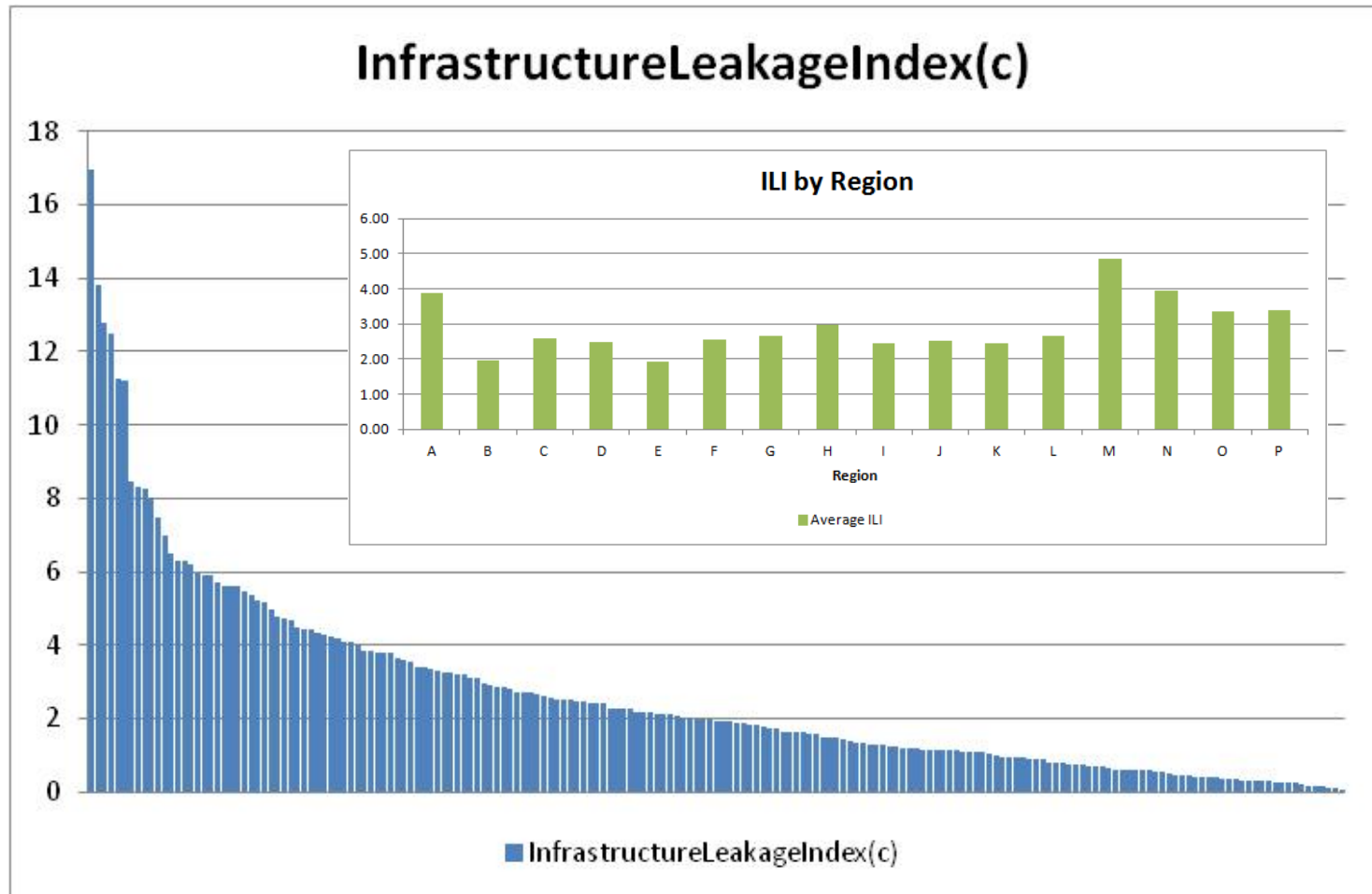
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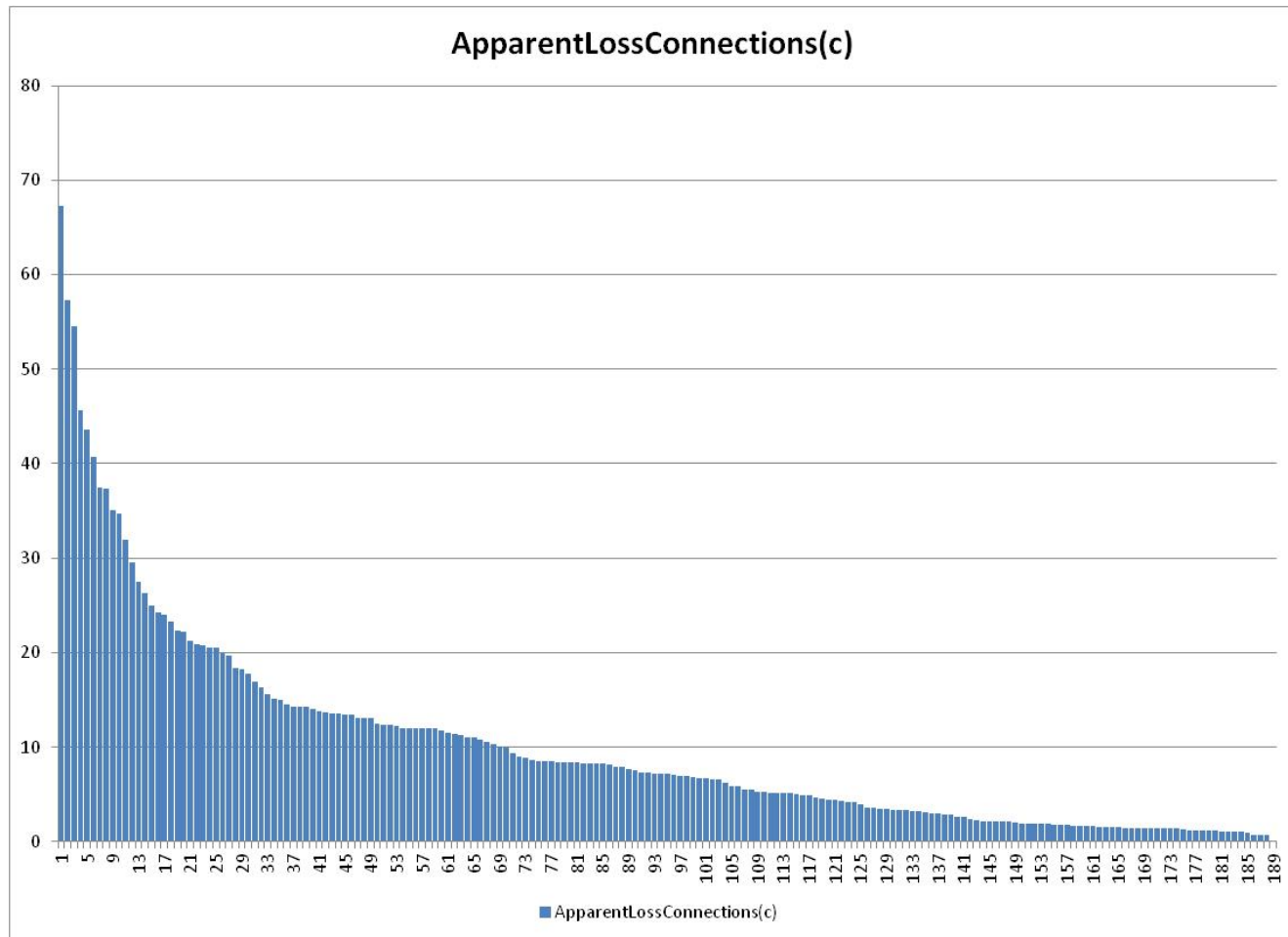
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# INFRASTRUCTURE LEAKAGE INDEX

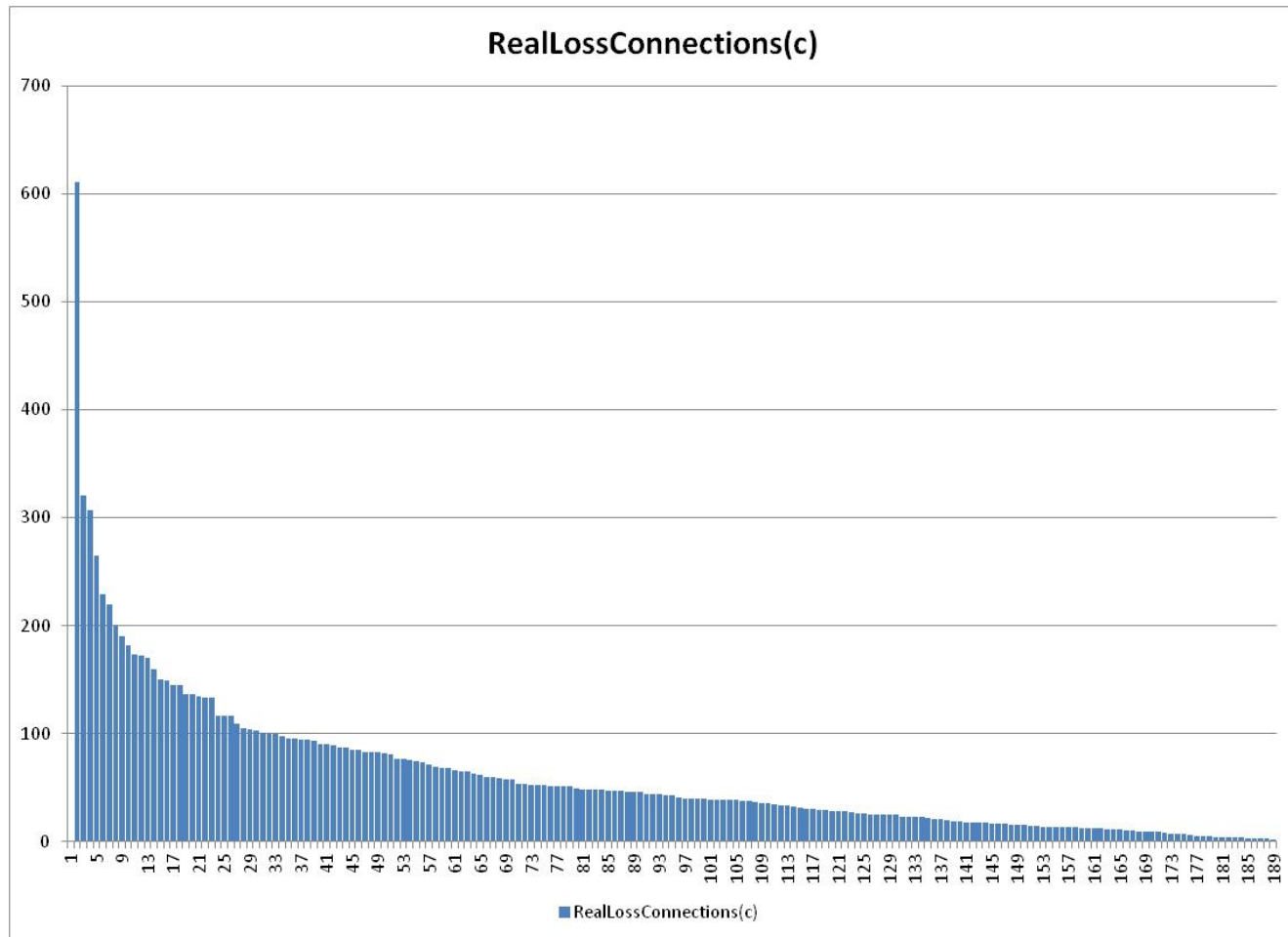


# APPARENT LOSS





# REAL LOSS



# FUTURE WATER LOSS REDUCTION RESOURCES

## Water Loss Reduction Implementation Manual

### Report<sup>1</sup>

by

Andrew Chastain-Howley, M.Phil., P.G.  
Malcolm Brandt B.Eng (Hons), C.Eng., FICE, FCIWEM, MIWater  
Rupa Jha  
Michelle Cumbrell B.Eng (Hons), C.Eng., MCIWEM, C.WEM, MAPM, MIWater  
John Sutton  
Juan Moran-Lopez<sup>2</sup>

### Texas Water Development Board

P.O. Box 13231, Capitol Station  
Austin, Texas 78711-3231  
8014



- Water Loss Reduction Implementation Manual (2014)
- AWWA Resources
- WRF Projects
- Water Conservation Division help
- Rainy Day Fund Loans?



# WATER LOSS REDUCTION IMPLEMENTATION MANUAL

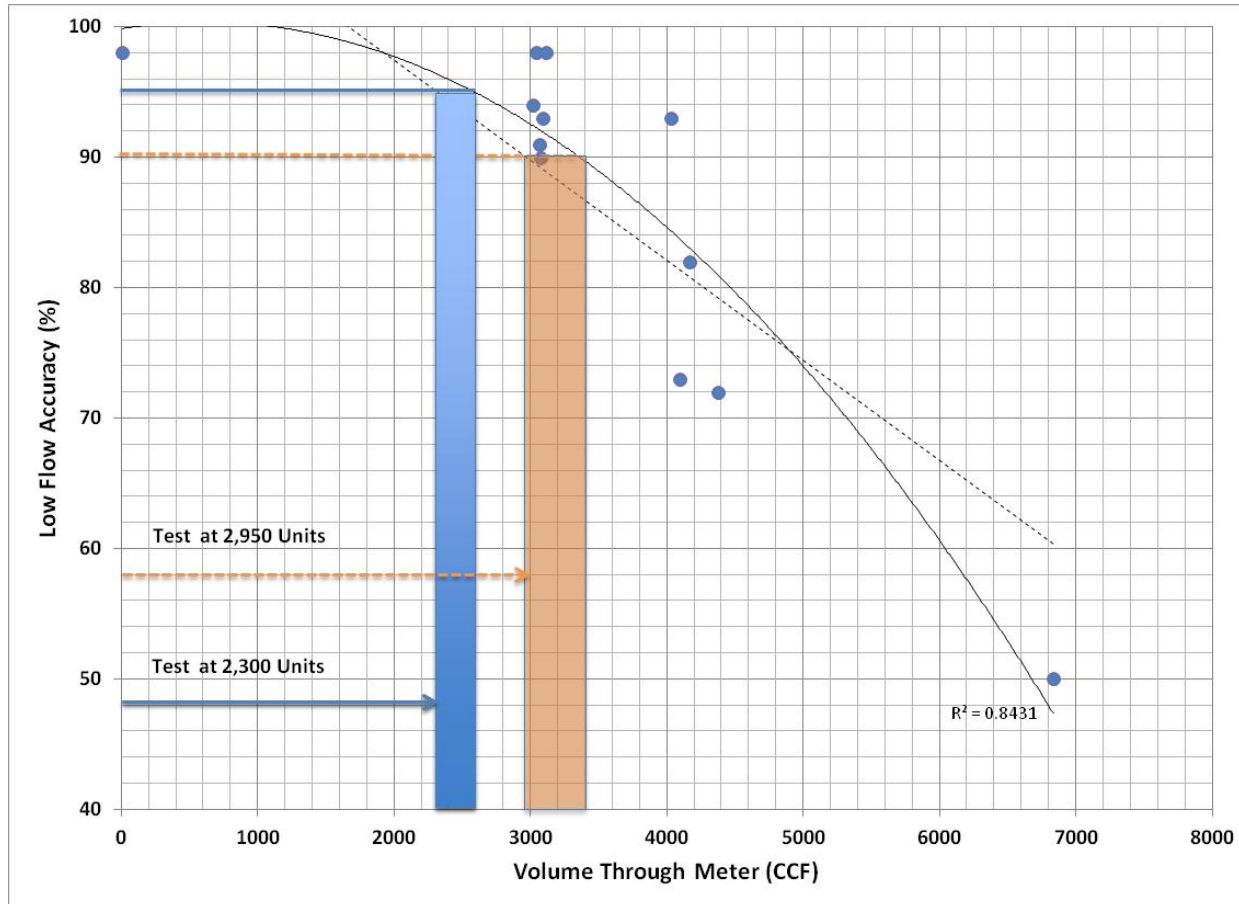
- Due to be completed early 2014
- Will provide information to all sizes of systems for implementing water loss reduction programs
- Details for apparent loss and real loss programs
- Discussion of benchmarks and data ranges

Performance Indicator	Number of records	Average
Apparent loss (gal/conn/day)	310	11.2
Real Loss (gal/conn/day)	248	56.5
Real Loss (gal/mile/day)	62	1,932

# LEAK DETECTION EVALUATION METHODS



# METER ACCURACY EVALUATION METHODS



# NATIONAL WATER AUDIT DATA INITIATIVES

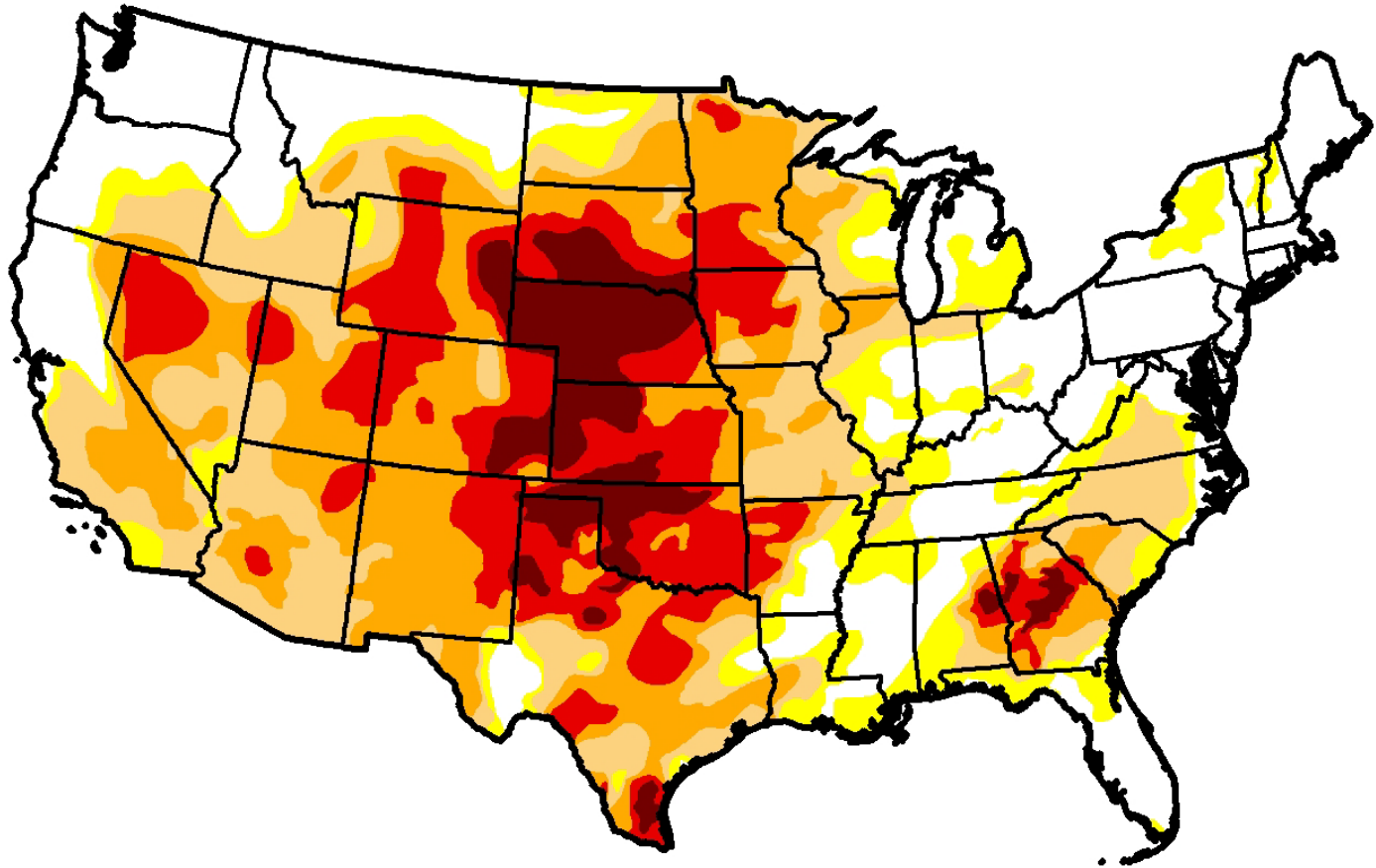
WHAT ELSE IS GOING ON



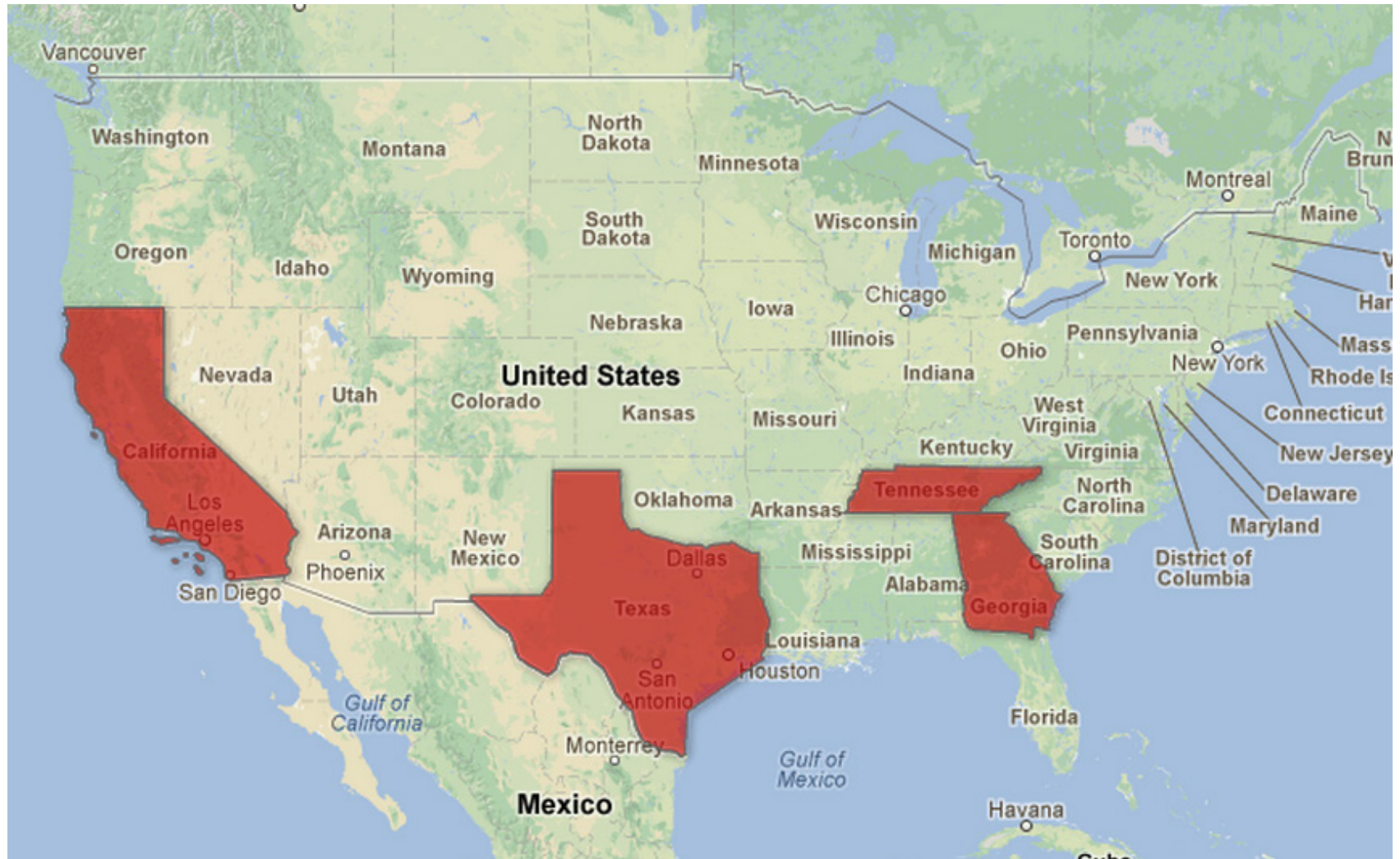
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# ENVIRONMENTAL DRIVERS



# REGULATORY DRIVERS



# STATE OF GEORGIA

- Decades long struggle for use of water from Lake Lanier; 2009 court ruling went against the City of Atlanta's continued level of withdrawals for water supply
- Landmark *Water Stewardship Bill* passed March 18, 2010: requires IWA/AWWA water audit by all water utilities by 2013
- Metropolitan North Georgia Water Planning District: part of Atlanta Regional Commission; oversees +60 water utilities in multi-county Atlanta area
  - Requires water utilities to submit water audits via AWWA Free Water Audit Software©
  - Developed training program around the software



[www.legis.ga.gov/legis/2009\\_2010/pdf/sb370.pdf](http://www.legis.ga.gov/legis/2009_2010/pdf/sb370.pdf)

[www.northgeorgiawater.com/files/WSWC\\_SECTION8.PDF](http://www.northgeorgiawater.com/files/WSWC_SECTION8.PDF)

# **DELAWARE RIVER BASIN COMMISSION PENNSYLVANIA PUBLIC UTILITY COMMISSION**

◆ DRBC revised its Water Code in March 2009 to incorporate the IWA/AWWA Water Audit Method and AWWA Free Water Audit Software©

Collecting water audits – initially on a volunteer basis - mandatory by 2012

◆ PA PUC launched pilot water audit program in 2010 with five companies employing AWWA Free Water Audit Software©:

Pennsylvania-American Water

Aqua Pennsylvania

United Water

York Water Company

Superior Water Company

◆ The two agencies are sharing resources in launching the water audit programs



**Delaware River Basin Commission**

DELAWARE • NEW JERSEY  
PENNSYLVANIA • NEW YORK  
UNITED STATES OF AMERICA



# CALIFORNIA – CUWCC BMP1.2

## BACKGROUND:

- **BMP1.2 – Water Loss Control Program (10years)**
  - **First four years focus on data validation and water loss accounting**
  - **Second phase to establish benchmarks and improvements to water loss performance**
- **Six two-day workshops provided between 2010 and 2012 plus a webinar**
- **WSO received the first data set of water audits for data validation**



# CALIFORNIA – CUWCC BMP1.2

## 2010 and 2011 Water Data Analysis and Validation:

- Simple steps of data validation were applied

	Count	Percent of Full Data Set
Number of Utilities Reporting Water Audit Result	130	100%
Number of Utilities Reporting Negative Water Losses	5	4%
Number of Utilities Reporting ILI<1	36	28%
Number of Utilities Reporting ILI>20	3	2%
Number of Utilities Reporting Erroneous Infrastructure Data	1	1%
Final Data Set After Removal of Erroneous Water Audit Reports	85	65%

- Results highlight the problems utilities are facing when completing an audit for the first time!



# CALIFORNIA – CUWCC BMP1.2

## 2010 Water Data Analysis and Validation:

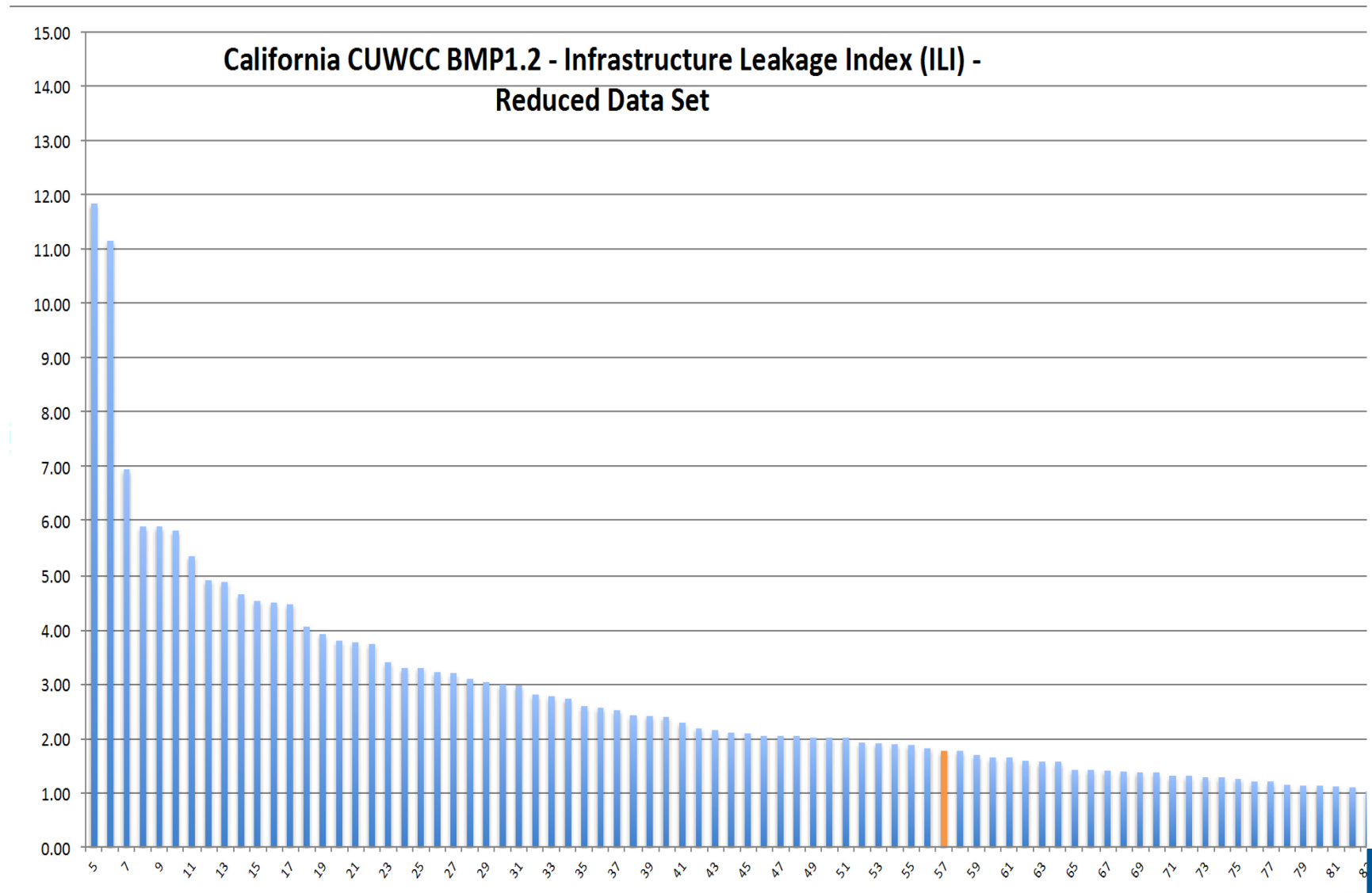
- 35% report implausible results
- Data Validity is an issue – more training and outreach needed

### However:

- Average data validity score 75.6 (Level IV = 71-90)
- Average data validity score of utilities reporting negative water losses 77.0
- 51% of utilities report length for service pipe curb stop to meter
- Financial data reported often questionable
- Especially system input volume and consumption volumes need to be validated

**Note: Texas Water Audit Data showed similar data quality issues – 52% of water audits are technically impossible!!!!**

# CALIFORNIA – CUWCC BMP1.2



# **AWWA NATIONAL WATER AUDIT DATA INITIATIVE**



# VALIDATION METHODOLOGY

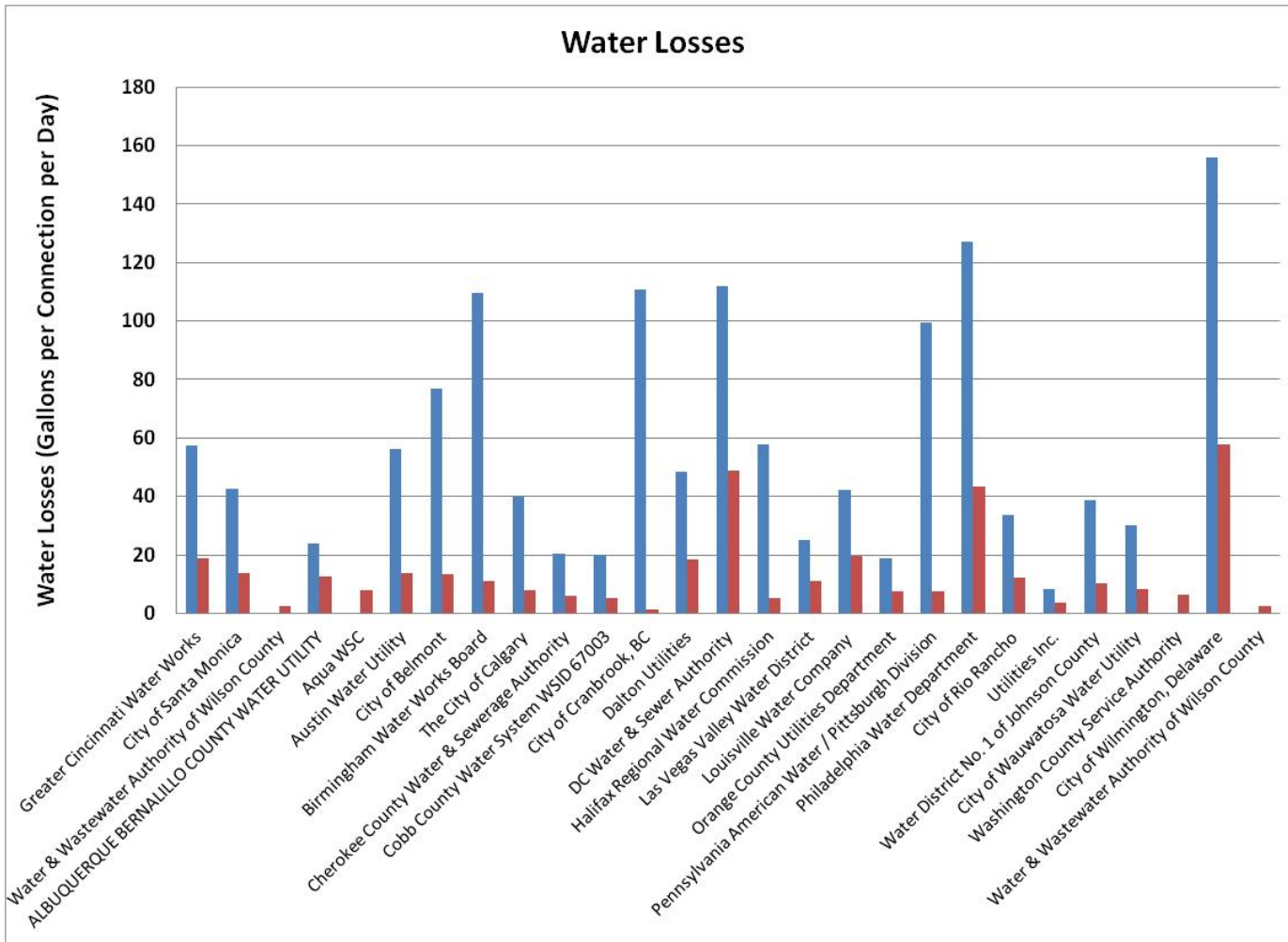
- **Primary Focus : “Validation” over “Outputs”**
  - Assuring valid data, rather than finding the system with the “lowest” losses
- **Validation process – standardized by the WLCC:**
  - A validation checklist of questions was developed to guide the validation telephone interviews
  - Conference call interviews conducted with utility representatives
  - Water audit inputs and gradings modified where deemed appropriate
  - Utilization of AWWA “Compiler” software developed for the management of water audit data from multiple utilities

# USE FOR TEXAS UTILITIES

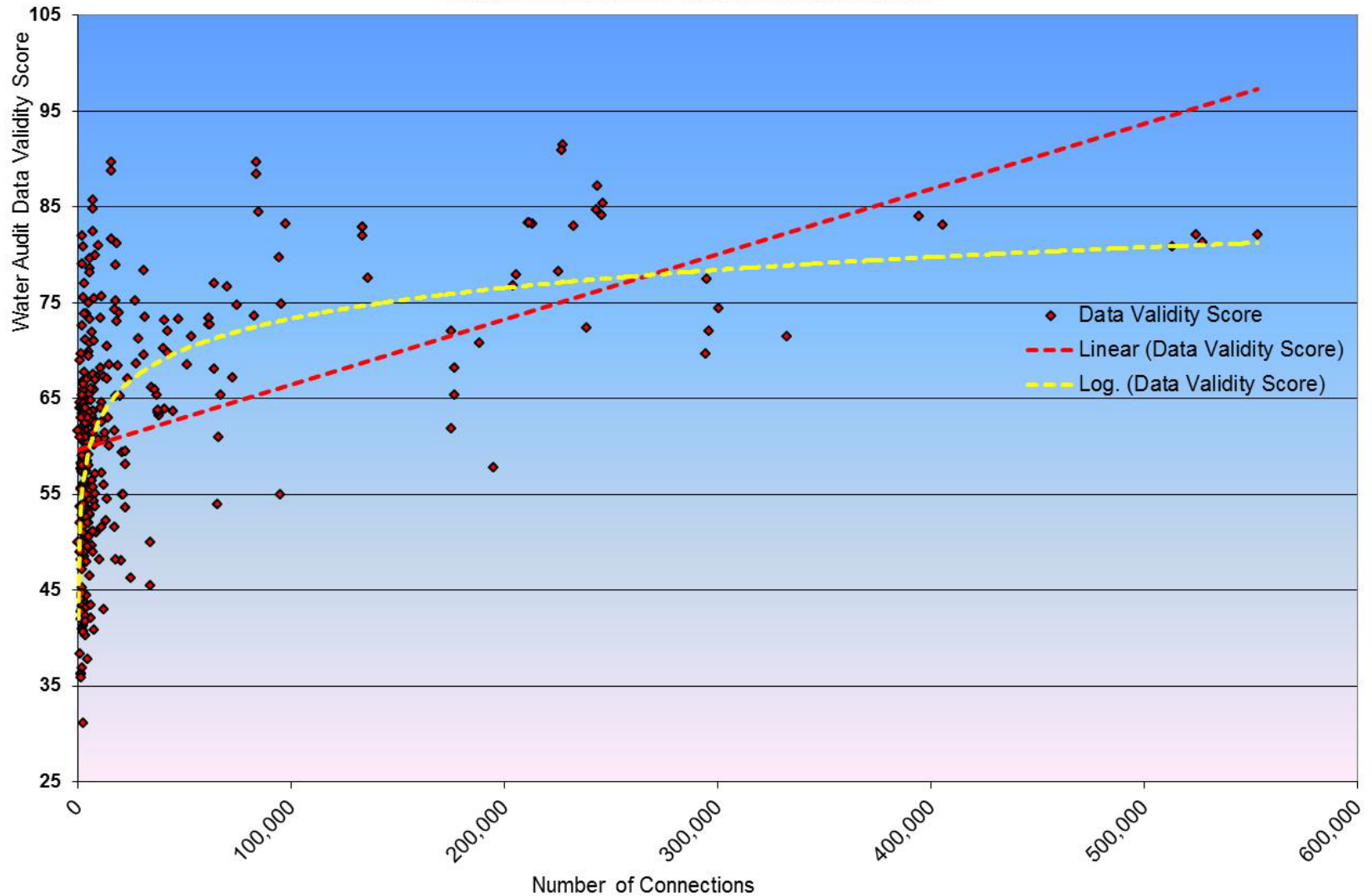
- **National Data from Recognized Utilities**
  - First set of data that puts a name to a dataset
  - Useful in benchmarking against similar utilities (size, location, losses...)
  - Useful in helping determine a value for difficult to determine inputs and to make sure data is within a reasonable range
- **Standard Process and Documentation**
  - Aids with auditing for the Texas Audit as the procedures and data inputs required are very similar



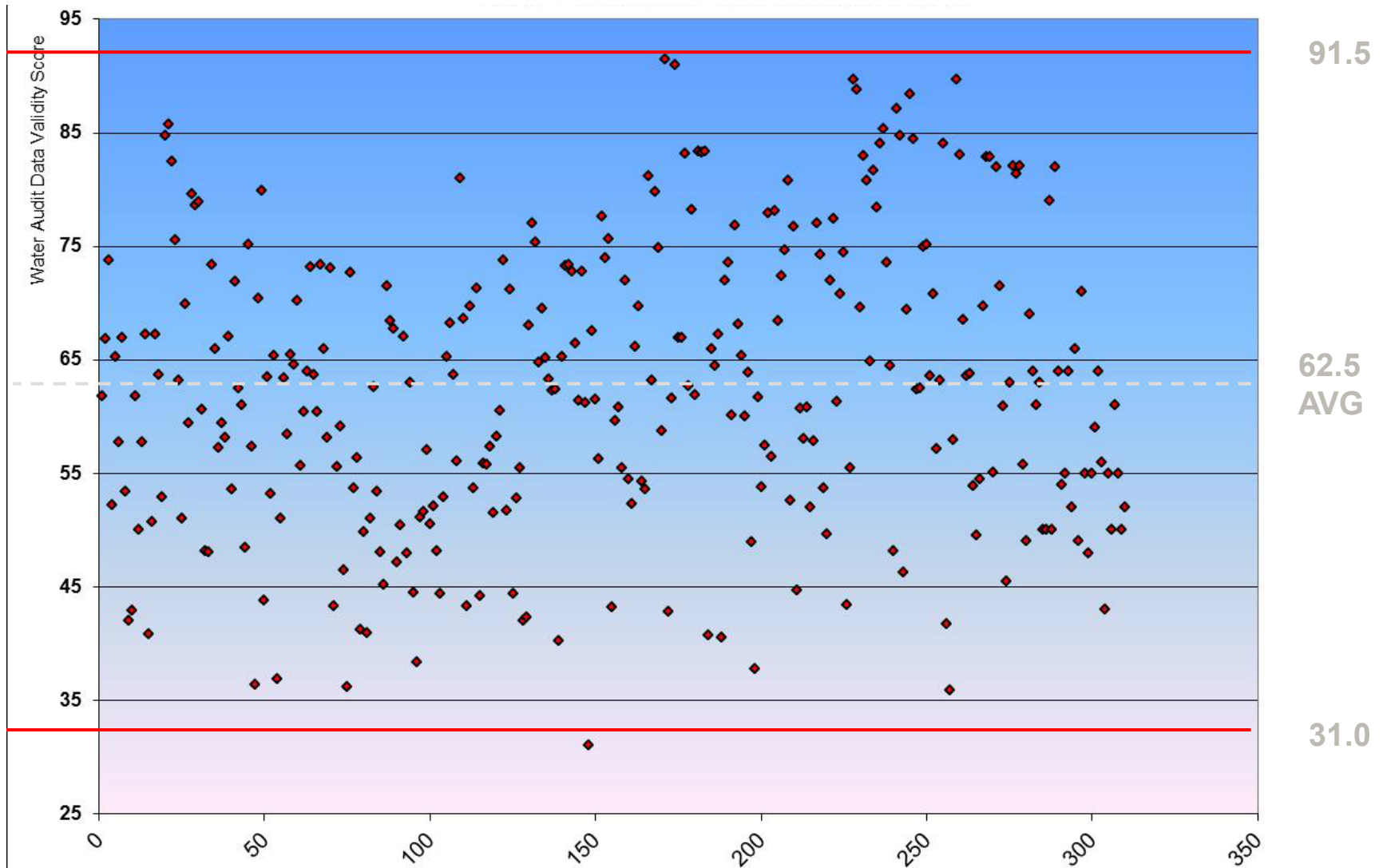
# OVERALL WATER LOSSES



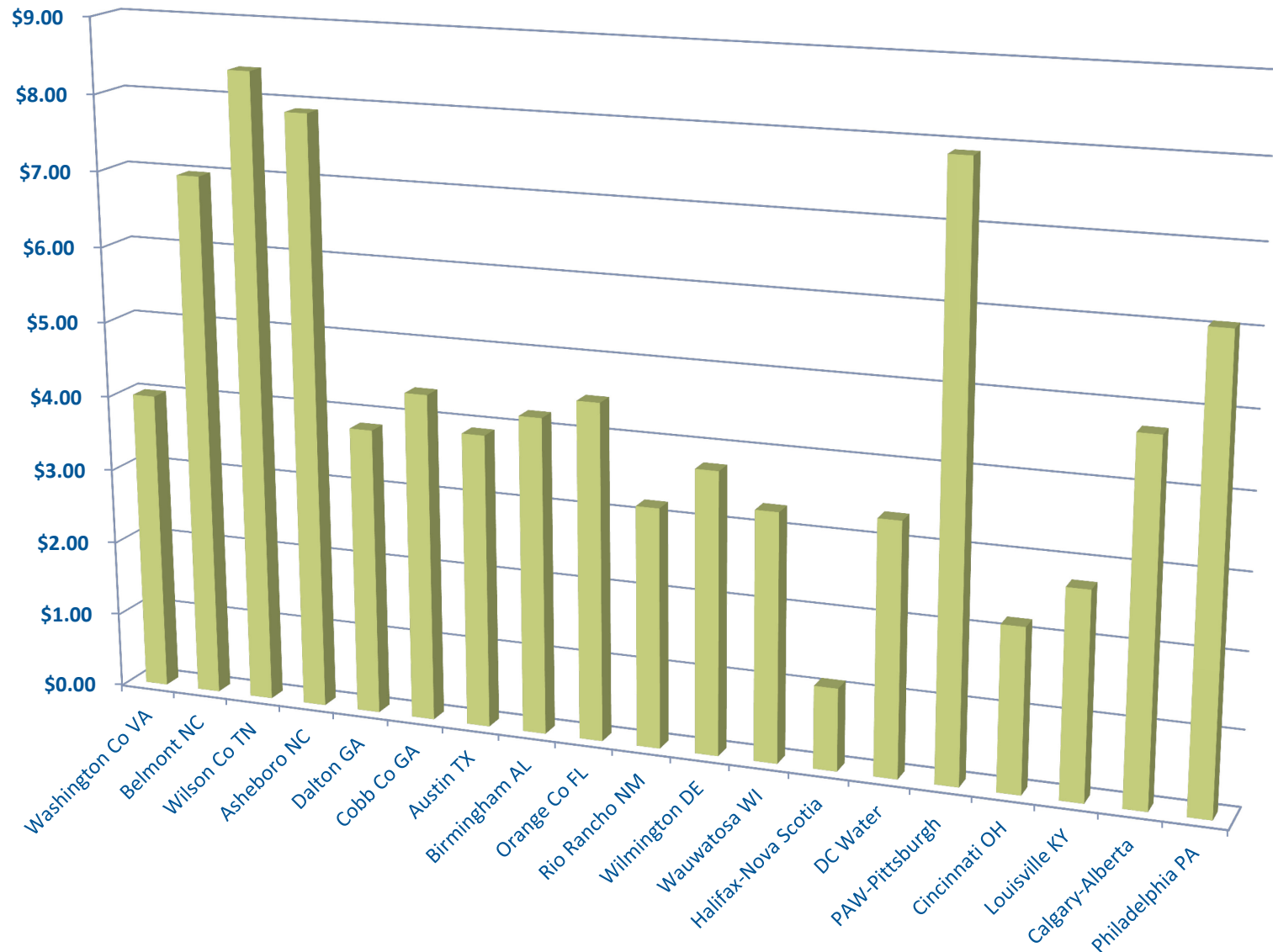
# DATA VALIDITY VS SYSTEM SIZE



# DATA VALIDITY

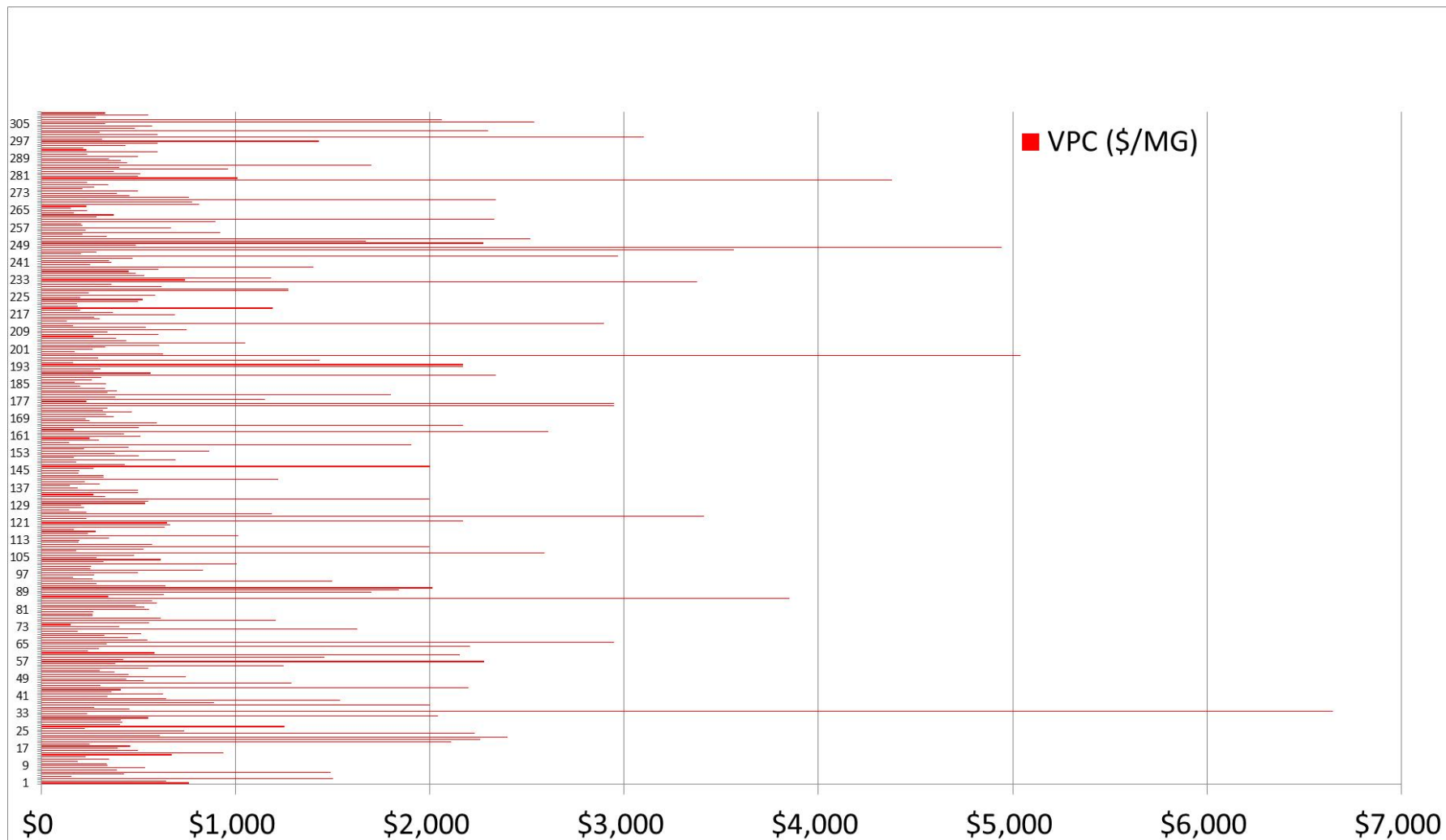


## Customer retail unit cost (applied to Apparent Losses)



## Water Loss Benchmarks

# VARIABLE PRODUCTION COST



**Own Sources - Average \$485/MG**  
**Total - Average \$813/MG**

# DATA SUMMARY (JUNE 2013)

Key Performance Indicator	n	AVG
Data Validity Score	310	62.5
Non-Revenue Water as % by Volume	310	23.1%
Non-Revenue Water as % by Cost	310	9.1%
Apparent Loss (gal/connection/day)	310	11.2
Real Loss (gal/connection/day)	248	56.5
Real Loss (gal/mile of main/day)	62	1,932
Infrastructure Leakage Index	283	3.0



# NATIONAL DATA INITIATIVE

## ACKNOWLEDGEMENTS

### **Water Audit Software Subcommittee (WASS) Members:**

**WLCC Chair: John Van Arsdel, M.E. Simpson Company, Inc.**

**WASS Chair: Andrew Chastain-Howley, Black & Veatch**

**George Kunkel, Philadelphia Water Department**

**Will Jernigan, Cavanaugh & Associates, P.A.**

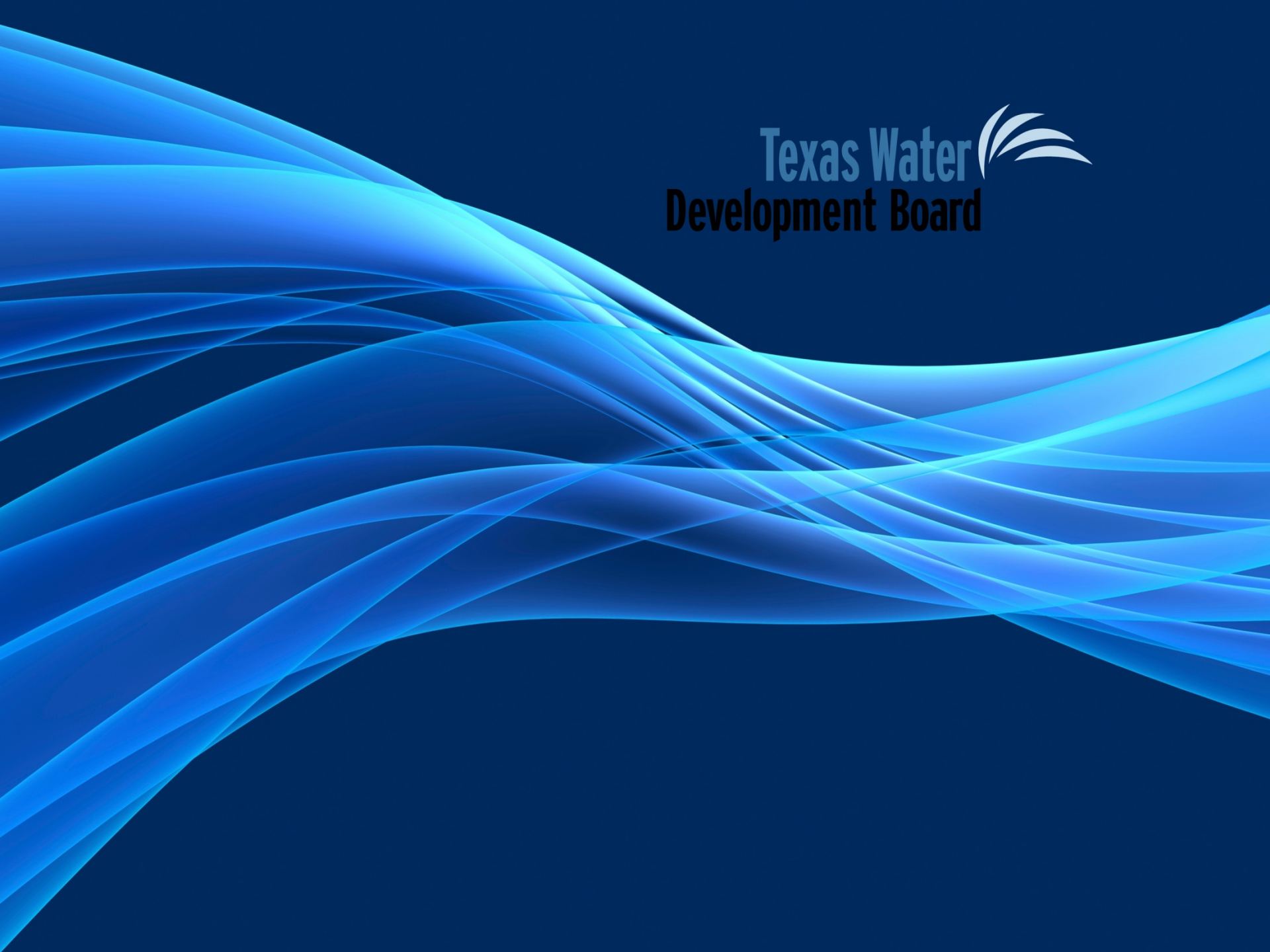
**Alain Lalonde, Veritec Consulting Inc.**

**Ralph McCord, Louisville Water Company**

**David Sayers, Delaware River Basin Commission**

**Brian Skeens, CH2M HILL**

**Isabel Szendry, Puerto Rico ASA**

The background of the entire image is composed of numerous overlapping, translucent blue wavy lines that flow from the left side towards the right. These lines vary in thickness and opacity, creating a sense of movement and depth. The colors range from a deep navy blue to a bright, glowing cyan.

**Texas Water**  
**Development Board**

