Critical Importance of Validation in Water Audits

Texas Water Conservation Advisory Council Meeting

May 9, 2018

SAVE TEXAS WATER
Water Conservation Advisory Council

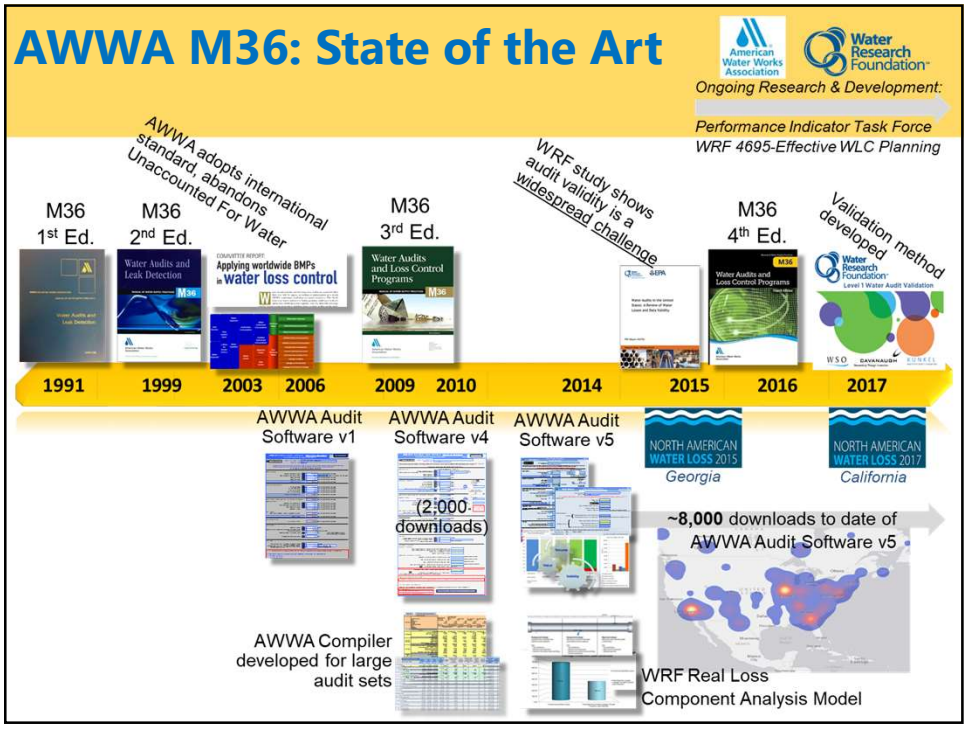
Steve Cavanaugh, P.E.
Chief Innovation Officer
AWWA WLCC, Outreach Chair
steve.cavanaugh@cavanaughsolutions.com

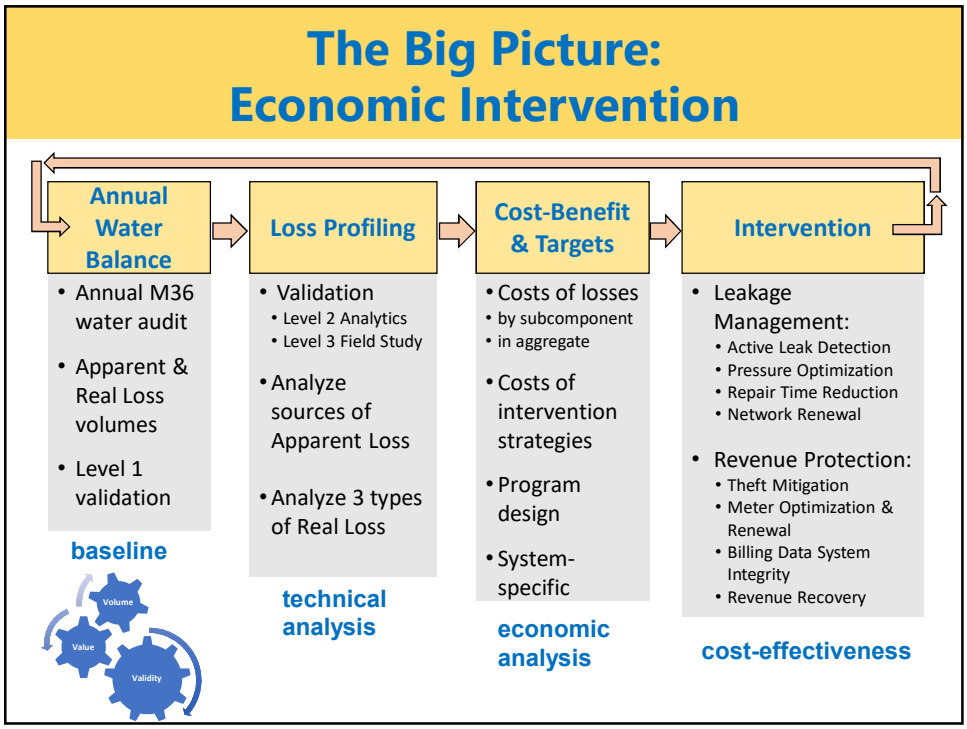
Slide acknowledgement to Cavanaugh & WSO

Presentation Objectives

1. Transfer insights from other states in their efforts to increase reliability of water audits
2. Share perspective on how validity training/projects have changed water loss reports and strategies in other states
3. Share some concrete examples of where audit data led a Utility/State in the wrong direction – wrong tool, wrong problem

I realize that the group's baseline knowledge and interest in Water Loss may vary greatly


AWWA M36: State of the Art
American Water Works Association
Water Research Foundation
Ongoing Research & Development:
Performance Indicator Task Force
WRF 4695-Effective WLC Planning
AWWA adopts international standard, abandons Unaccounted For Water
WRF study shows audit validity is a widespread challenge
Validation method developed
M36 1st Ed.
M36 2nd Ed.
M36 3rd Ed.
M36 4th Ed.
1991
1999
2003
2006
2009
2010
2014
2015
2016
2017
AWWA Audit Software v1
AWWA Audit Software v4
AWWA Audit Software v5
(2,000 downloads)
NORTH AMERICAN WATER LOSS 2015
Georgia
NORTH AMERICAN WATER LOSS 2017
California
~8,000 downloads to date of AWWA Audit Software v5
AWWA Compiler developed for large audit sets
WRF Real Loss Component Analysis Model


The Big Picture:
Economic Intervention
Annual Water Balance
Loss Profiling
Cost-Benefit & Targets
Intervention
• Annual M36 water audit
• Apparent & Real Loss volumes
• Level 1 validation
baseline
• Validation
• Level 2 Analytics
• Level 3 Field Study
• Analyze sources of Apparent Loss
• Analyze 3 types of Real Loss
technical analysis
• Costs of losses
• by subcomponent
• in aggregate
• Costs of intervention strategies
• Program design
• System-specific
economic analysis
• Leakage Management:
• Active Leak Detection
• Pressure Optimization
• Repair Time Reduction
• Network Renewal
• Revenue Protection:
• Theft Mitigation
• Meter Optimization & Renewal
• Billing Data System Integrity
• Revenue Recovery
cost-effectiveness
Volume
Value
Validity

Water Audits 101

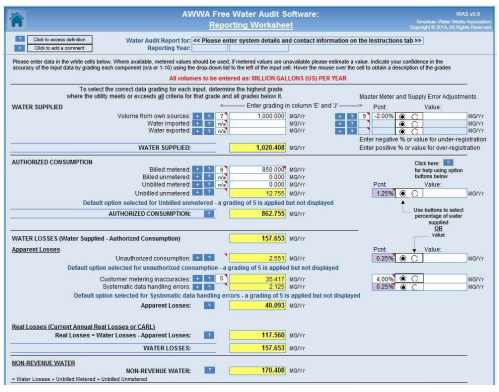
what are our distribution system losses?

<table>
<tr><td rowspan="5">WATER SUPPLIED</td><td rowspan="2">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="2">$ $ $</td></tr>
<tr><td>UNBILLED UNMETERED CONSUMPTION</td></tr>
<tr><td rowspan="3">WATER LOSSES</td><td rowspan="3">$ $ $
APPARENT LOSSES
$ $ $</td><td>CUSTOMER METER INACCURACIES</td><td rowspan="3">NONREVENUE WATER
💧</td></tr>
<tr><td>UNAUTHORIZED CONSUMPTION</td></tr>
<tr><td>DATA HANDLING ERRORS</td></tr>
<tr><td colspan="4">💧 REAL LOSSES 💧</td></tr>
</table>

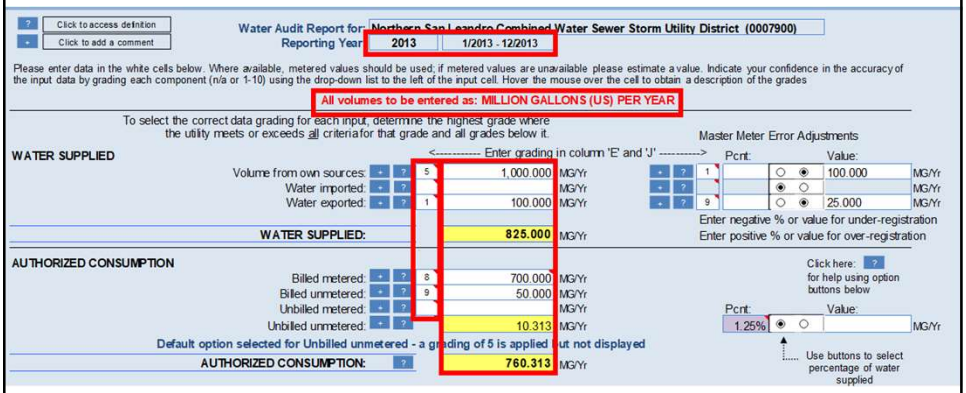
- *Mass balance – process of elimination*
- *Account for all water*
- *Accuracy matters!*

Water Audits 101

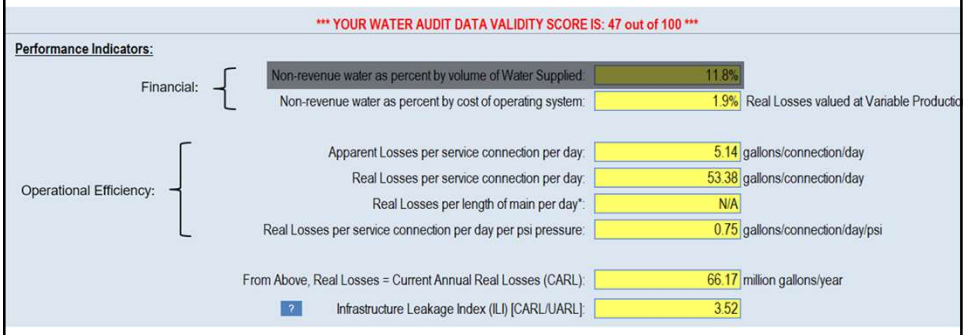
- Goals of Top Down Water Audit: **Assess Volumes of Water Loss**
- *Water Audit Software:*
  - collects water balance volumes, cost data, and system data
  - considers data validity
  - determines total volumes of water losses
    - Apparent Losses
    - Real Losses
    - Non-Revenue Water
  - calculates performance indicators



AWWA Free Water Audit Software

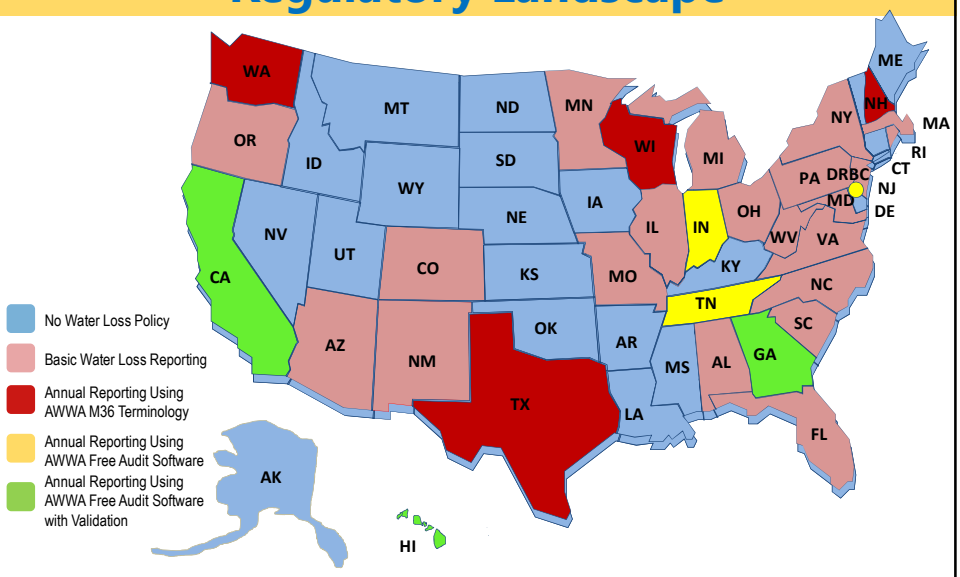


AWWA Free Water Audit Software



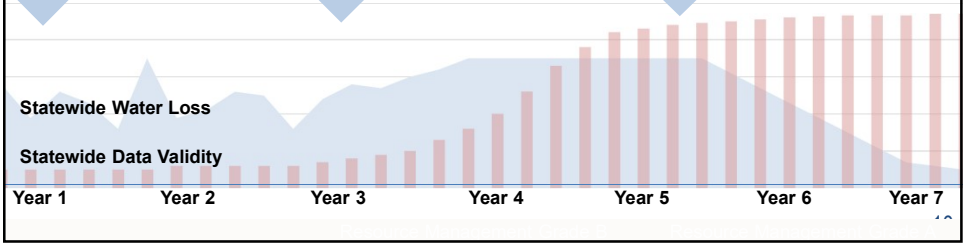
M36: State of the Art

AWWA M36 Regulatory Landscape



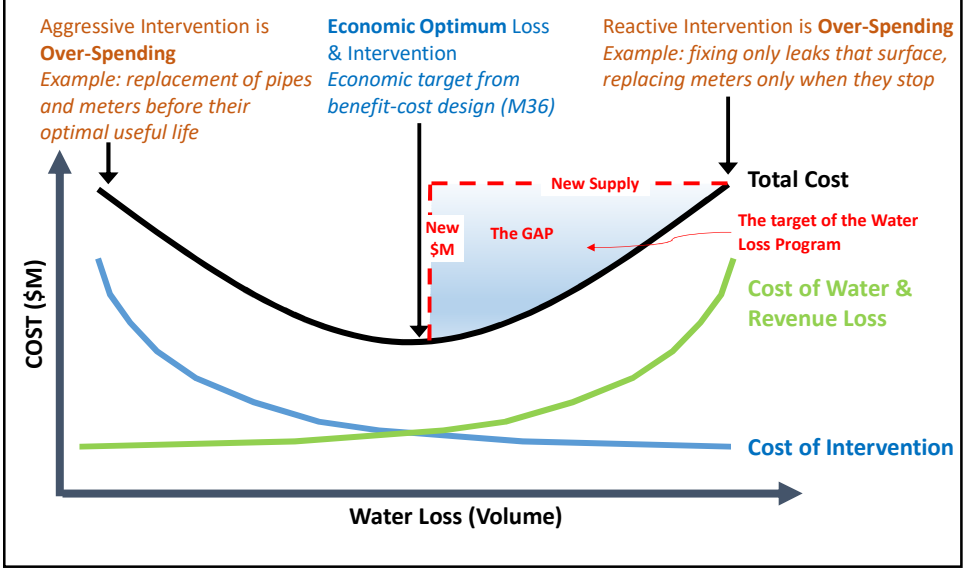
Statewide Water Loss Management Program – Model Implementation

	Phase 1 Establish Annual M36 Water Auditing	Phase 2 Achieve Minimum Standard of Audit Reliability	Phase 3 Manage Water Loss Performance for Long-Term Reduction
	Auditing: Establish annual M36 Water Auditing for all utilities	Data Management: Develop and implement data management system	Benchmarking: Suite of Performance and Process Measures
		Establish posting system and communication protocols	System specific improvement over time in a cost-effective manner
	Outreach: Educate Regulatory Community on M36 Method and appropriate use of performance indicators	Validation: Establish minimum standards of validation for quality assurance	No universal targets
		Determine by Agency or 3rd Party	Excessive thresholds established
	Establish Statewide Water Loss Control Committee	Establish validation program until certification program is in place	Improvement: Annual audit submission threshold exceedances
	Training & Tech Asst: Develop State Manual and Training Framework	Certification: Design and implement a Certified Water Audit program for sustained quality control	System specific progress review at designated regulatory touchpoints
	Provide extended, progressive training to utilities (funded)	Statewide Water Loss Control Committee provides support	



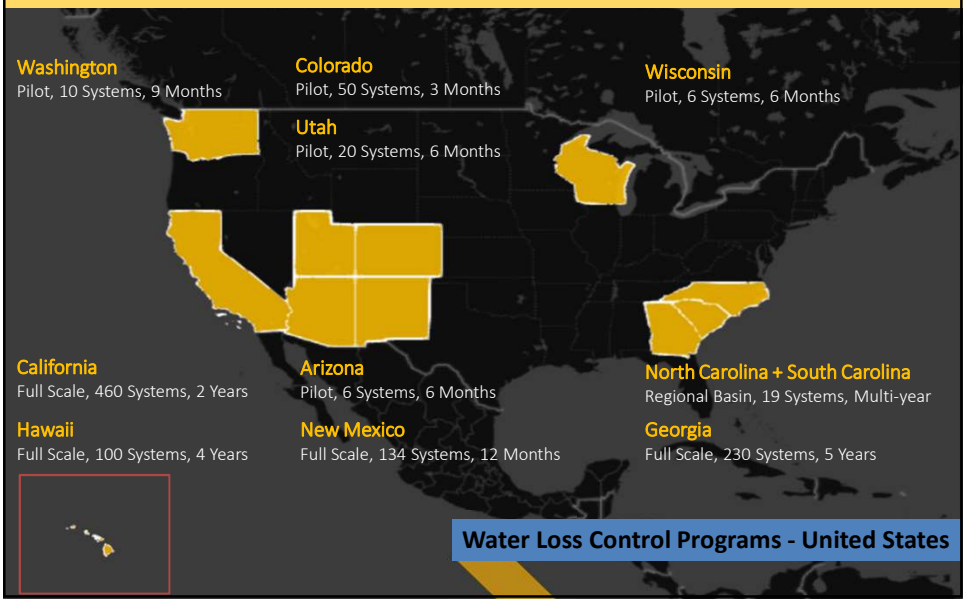
M36: State of the Art

AWWA M36
Economic Optimum



M36: State of the Art

AWWA M36
State Programs



Data Validity Grades

Data validity grades (DVGs) document utility practices of:

- Data collection
- Data review
- Instrument maintenance

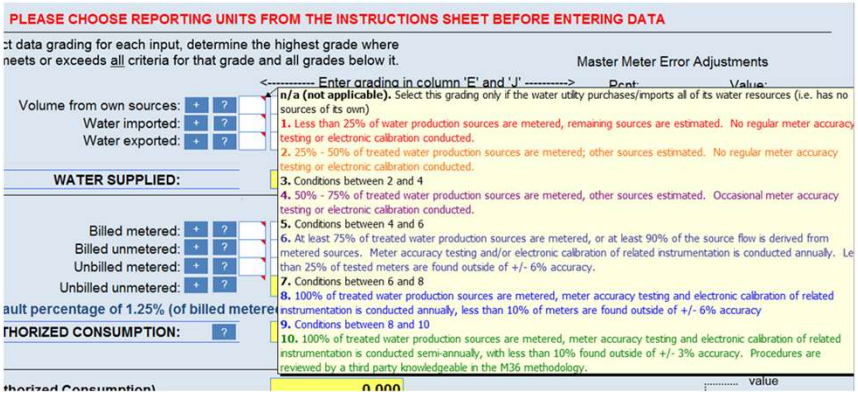
Each audit input is assigned a DVG between 1 and 10 based on criteria

The Data Validity Score is an indicator of:

- **the extent best-practices for measurement and data-management are being applied**
- **If next steps should be focused more on data-improvement or water loss control**

The Data Validity Score is NOT an indicator of audit accuracy

Data Validity Grades



Meet all criteria at a grade for that grade to apply or drop to a lower grade …

"meet/beat….or retreat"

Water Audit Results Across the Country

- *Water Research Foundation 4372B*
- many audits are **unrealistic**
  - *more training (ie GA, TN) produces fewer unrealistic audits*
  - *even level 1 validation doesn't fully eliminate unrealistic audits*

	CA	DRBC	GA	TN	TX
total audits	300	517	452	629	2,646
# of unrealistic audits	100	130	74	122	1,065
% of unrealistic audits	*33%*	*25%*	*16%*	*19%*	*40%*

sources of uncertainty:

- data source quality (primary measurement or secondary data management)
- methodology (use of the software, selection of data)

Levels of Validation

Validation

Water audit validation aims to:

- Identify and correct errors
- Evaluate and communicate uncertainty

Level 1 – interview & summary records

Level 2 – deep data review

Level 3 – new data from the field

Levels of Validation

Different levels of review and investigation to confirm water audit inputs

Self-Reported	Level 1	Level 2	Level 3
• No validation • Accuracy and reliability have not been confirmed	• Examined for inaccuracies evident in summary data and application of methodology • Data validity grades assigned to inputs accurately reflect utility	• Investigations of raw data and archived reports of instrument accuracy corroborate volumes • Best sources of data to inform the water audit have been identified and applied	• Bolstered by field tests of instrument accuracy • The estimate of Real Losses has been confirmed through pilot leak detection, Component Analysis of Real Losses, and/or minimum night flow analysis.

Project 4639

Water Research Foundation

Validation in Action!

California Level 1 Water Audit Program: Water Loss TAP

WAVE 1	WAVE 2	WAVE 3	WAVE 4
in-person work session	teleconference work session	in-person work session	teleconference validation session

Georgia Level 1 Water Audit Program

Georgia Association of Water Professionals

GEORGIA Department of Natural Resources Environmental Protection Division

GEFA

Accuracy in the Water Balance

SYSTEM INPUT VOLUME	AUTHORIZED CONSUMPTION	BILLED AUTHORIZED CONSUMPTION	BILLED METERED CONSUMPTION	REVENUE WATER
			BILLED UNMETERED CONSUMPTION	
		UNBILLED AUTHORIZED CONSUMPTION	UNBILLED METERED CONSUMPTION	NONREVENUE WATER
			UNBILLED UNMETERED CONSUMPTION	
	WATER LOSSES	APPARENT LOSSES	CUSTOMER METER INACCURACIES	
			UNAUTHORIZED CONSUMPTION	
			DATA HANDLING ERRORS	
		REAL LOSSES		

Where does error sneak in!?

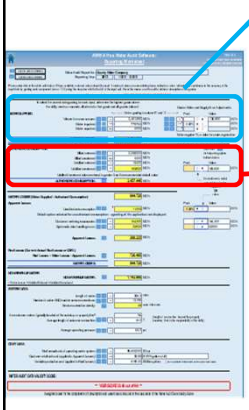
- Primary instrumentation
- Secondary data management, archival, and summary
- Interaction with data and methodology; estimation

inaccuracy & uncertainty in inputs → inaccuracy & uncertainty in results*

* especially for systems with low levels of loss

Accuracy in the Water Balance

the accuracy of our two most important volumes in the water balance makes a big difference!



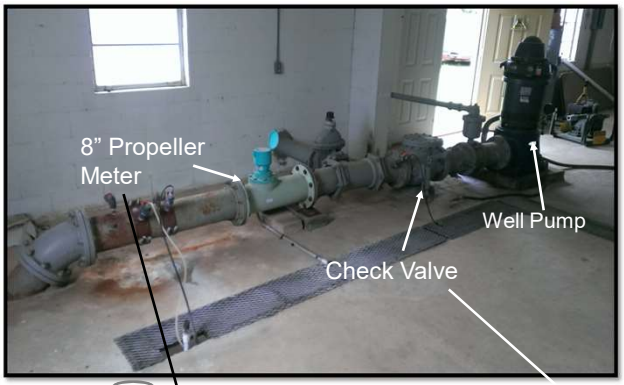
SYSTEM INPUT VOLUME	AUTHORIZED CONSUMPTION	BILLED AUTHORIZED CONSUMPTION	BILLED METERED CONSUMPTION	REVENUE WATER
			BILLED UNMETERED CONSUMPTION	
		UNBILLED AUTHORIZED CONSUMPTION	UNBILLED METERED CONSUMPTION	NONREVENUE WATER
			UNBILLED UNMETERED CONSUMPTION	
	WATER LOSSES	APPARENT LOSSES	CUSTOMER METER INACCURACIES	
			UNAUTHORIZED CONSUMPTION	
			DATA HANDLING ERRORS	
		REAL LOSSES		

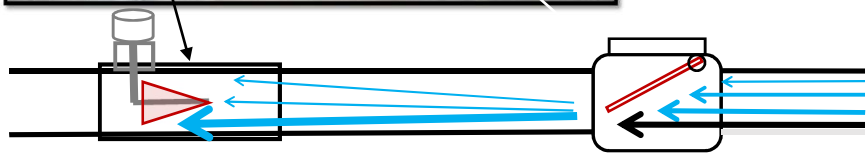
System Input Review

SYSTEM INPUT VOLUME	AUTHORIZED CONSUMPTION	BILLED AUTHORIZED CONSUMPTION	BILLED METERED CONSUMPTION	REVENUE WATER
			BILLED UNMETERED CONSUMPTION	
		UNBILLED AUTHORIZED CONSUMPTION	UNBILLED METERED CONSUMPTION	NONREVENUE WATER
			UNBILLED UNMETERED CONSUMPTION	
	WATER LOSSES	APPARENT LOSSES	CUSTOMER METER INACCURACIES	
			UNAUTHORIZED CONSUMPTION	
			DATA HANDLING ERRORS	
		REAL LOSSES		

- #1 – Meter wear
- #2 – Meter location
- #3 – Meter selection
- #4 – Meter programming
- #5 – Flow data archiving

System Input Review





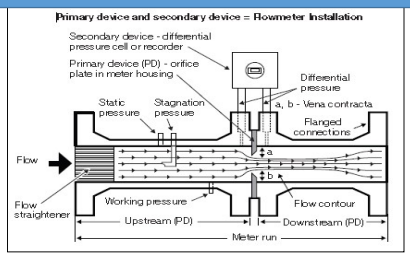
Accuracy results from MFR test bench: 99.5%

Accuracy results from in-situ test: 142.2%

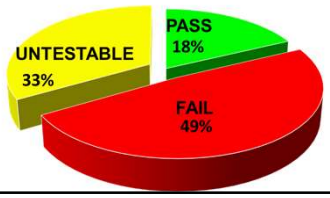
Courtesy MESCO

System Input Review

- Flow (Accuracy) Testing confirms the accuracy of the primary device – the element that measures the flow of water
- Signal Calibration confirms the functions of the secondary device – which is a data transfer device, typically a differential pressure cell, chart recorder, or similar device
- Many water utilities regularly calibrate their secondary devices, but do not regularly verify the primary device by regular flow accuracy testing. Thus, inaccuracies can be carried through to reports



Orifice Plate Flowmeter components
(Source: AWWA M36 Publication, 4th Ed.)



System Input Review

Flow Data Archiving

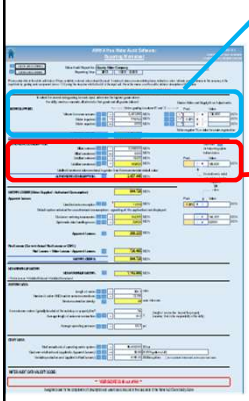
- Production flow data should be reviewed every business day for data gaps
- Gaps occur due to:
  - Unplanned interruption: lightning strike, power failure
  - Planned interruption: instrumentation calibration
- Gaps in water flow data should be quantified and added back to the daily total

(Source: AWWA M36 Publication, 4th Ed.)

Example of Water Pumping Data Gaps an		
8/15/2012, hrs	High Service Pumping Rate, mgd actual flow	High Service Pumping Rate, mgd raw recorded data
0:00	8.69	8.69
1:00	8.65	8.65
2:00	8.32	8.32
3:00	8.11	8.11
4:00	7.94	0
5:00	8.02	0
6:00	8.44	0
7:00	8.98	0
8:00	9.34	0
9:00	9.25	0
10:00	9.17	0
11:00	9.12	9.12
12:00	9.27	9.27
13:00	9.22	9.22
14:00	9.08	9.08
15:00	8.99	8.99
16:00	9.14	9.14
17:00	9.18	9.18
18:00	9.25	9.25
19:00	9.22	9.22
20:00	8.82	8.82
21:00	8.78	8.78
22:00	8.75	8.75
23:00	8.71	8.71
0:00	8.68	8.68
Total	**212.43**	**151.29**
Average	**8.85**	**6.30**
Difference		**2.55**

Accuracy in the Water Balance

the accuracy of our two most important volumes in the water balance makes a big difference!



SYSTEM INPUT VOLUME	AUTHORIZED CONSUMPTION	BILLED AUTHORIZED CONSUMPTION	BILLED METERED CONSUMPTION	REVENUE WATER
			BILLED UNMETERED CONSUMPTION	
		UNBILLED AUTHORIZED CONSUMPTION	UNBILLED METERED CONSUMPTION	NONREVENUE WATER
			UNBILLED UNMETERED CONSUMPTION	
	WATER LOSSES	APPARENT LOSSES	CUSTOMER METER INACCURACIES	
			UNAUTHORIZED CONSUMPTION	
			DATA HANDLING ERRORS	
		REAL LOSSES		

Authorized Consumption Review

SYSTEM INPUT VOLUME	AUTHORIZED CONSUMPTION	BILLED AUTHORIZED CONSUMPTION	BILLED METERED CONSUMPTION	REVENUE WATER
			BILLED UNMETERED CONSUMPTION	
		UNBILLED AUTHORIZED CONSUMPTION	UNBILLED METERED CONSUMPTION	NONREVENUE WATER
			UNBILLED UNMETERED CONSUMPTION	
	WATER LOSSES	APPARENT LOSSES	CUSTOMER METER INACCURACIES	
			UNAUTHORIZED CONSUMPTION	
			DATA HANDLING ERRORS	
		REAL LOSSES		

- #1 – Redundant volumes
- #3 – Non-potable volumes
- #2 – Omitted volumes
- #4 – Mis-aligned timeframes

Accuracy in the Water Balance

Locatio	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
26478	413	369	430	387	27437		1375	536	513	441	381	455

3” meter

Locatio	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
130558	4	5	4	10	419	13	31	34	25	5	14	7

1” meter

Location	1	2	3	4	5	6	7	8	9	10	11	12	Grand Total
36534	1	44	309										354
110936	430	17			0	0	0	0	0	1	1	1	450
31014	4	4	3	6	1	0	9	7	7	8	2	409	460
139728	345	0	0	0	0	1	6	22	12	0	0		386
43636	0	0	1	0	1	1	0	0	0	0	0	282	285
1464	7	244	3			0	2	5	3	4	4	5	277
124422	2	262	2	1	2	17	22	16	10	11	2	3	350
43992	6	7	3	5	0	2	0	0	0	0	0	255	278
16600	0	149	15	0									164
115394	11	0	5	3	6	10	58	100	183	120	52		548
130224	7	4	1	0	0	28	1	0	42	211	0	3	297
2906	19	25	12	7	6	8	6	13	10	8	8	214	336

5/8” meters

Location II	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
88964	2	3	2	3	169	915	939	657		700	7	2

2” meter

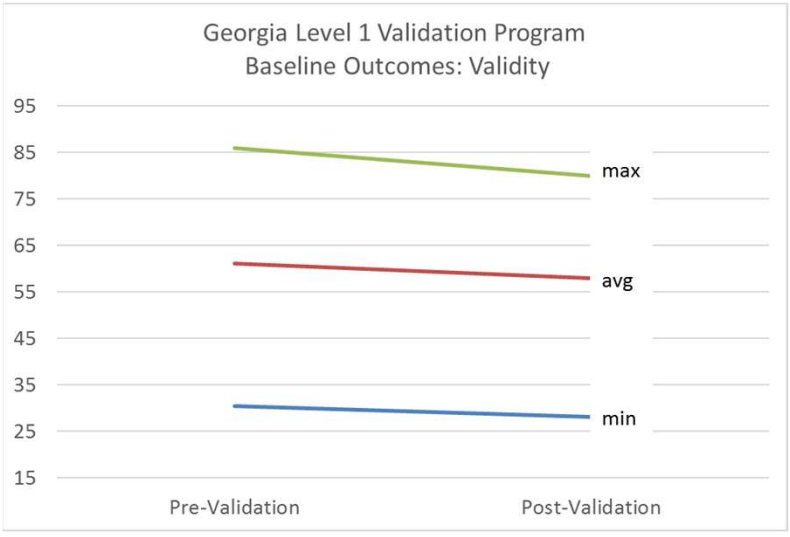
93972	574	438	512	513	439		1374	1048	1092	1245	842	1217

2” meter

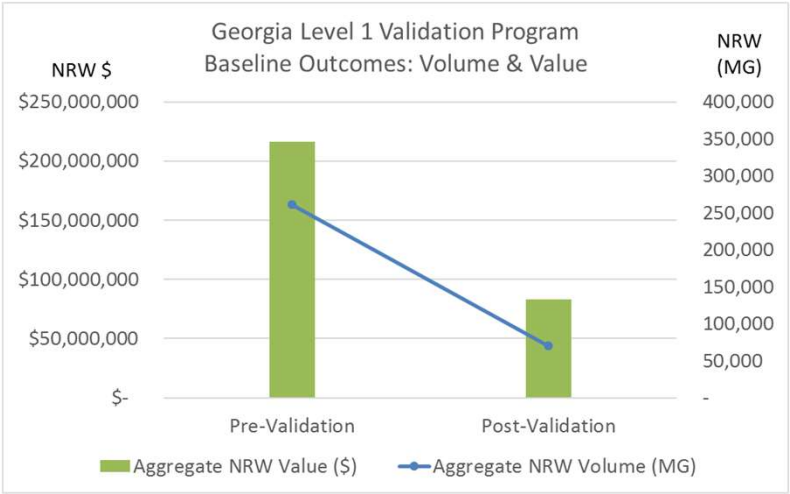
88954	75	80	59	65	267	877	924	630		826	66	56

3” meter

Validation Outcomes



Validation Outcomes

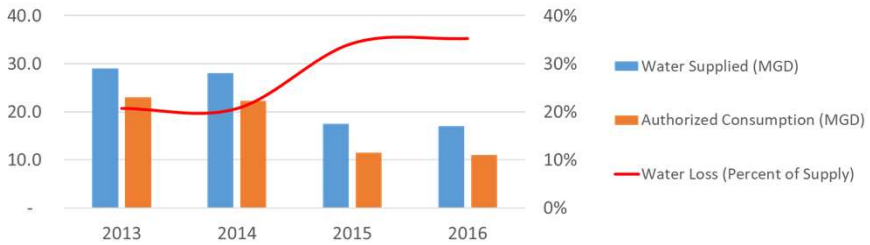


Real World Example

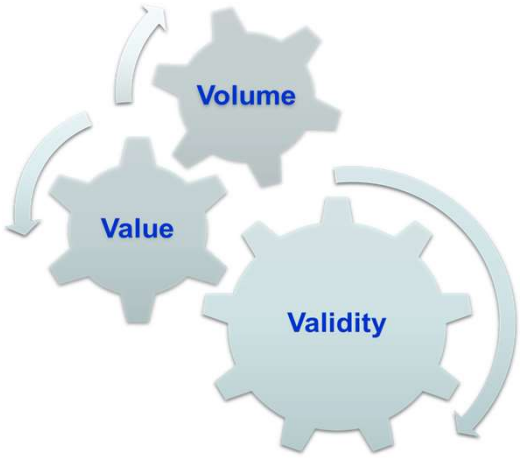
% Based Performance Indicator

Large Industry left → % ↑ →

"Water Loss Problem"



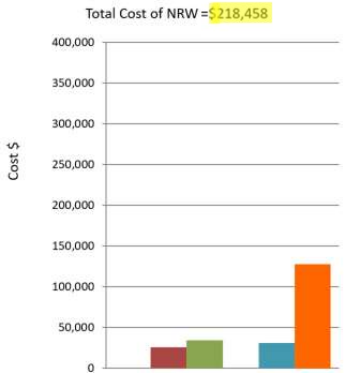
Validation Outcomes



***Pre*-Level 1 Validation**

Data Validity Score = 84

NRW Component Values

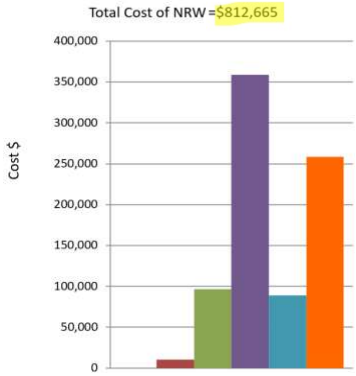


Leakage Index = 2.1

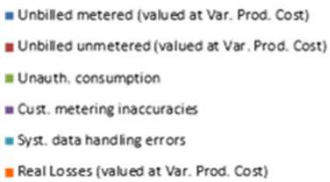
***Post*-Level 1 Validation**

Data Validity Score = 51

NRW Component Values



Leakage Index = 2.1



Validation Examples

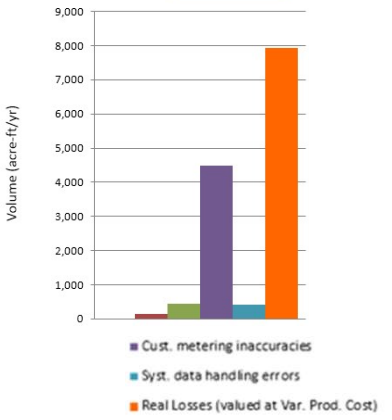
***Pre*-Level 1 Validation**

Data Validity Score = 72

NRW Component Volumes

Leakage Index = 1.2

Total Volume of NRW = 13,421 acre-ft/yr

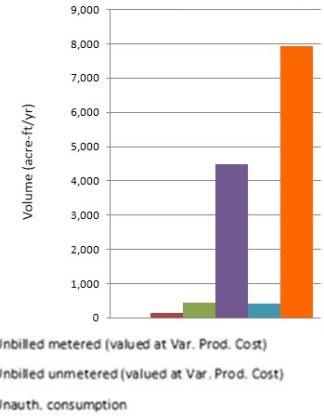


***Post* - Level 1 Validation**

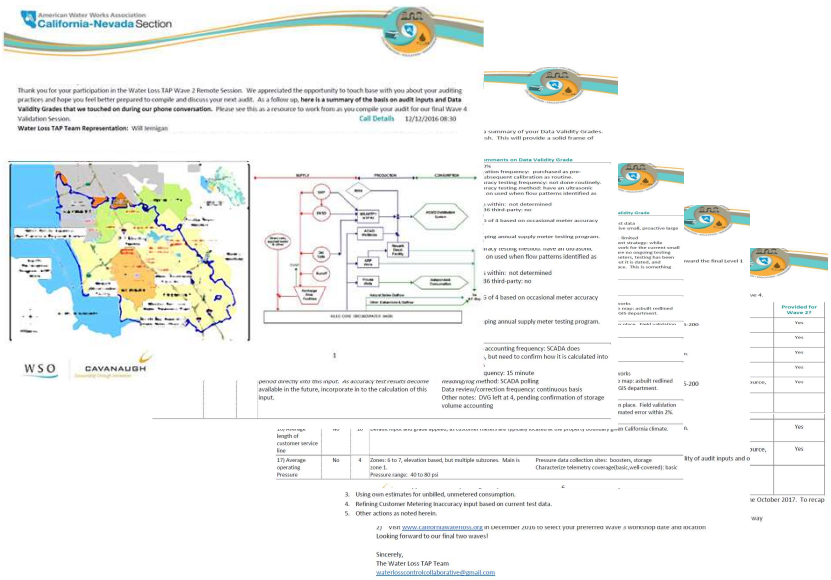
Data Validity Score = 55

NRW Component Volumes

Total Volume of NRW = 13,421 acre-ft/yr



Validation Examples



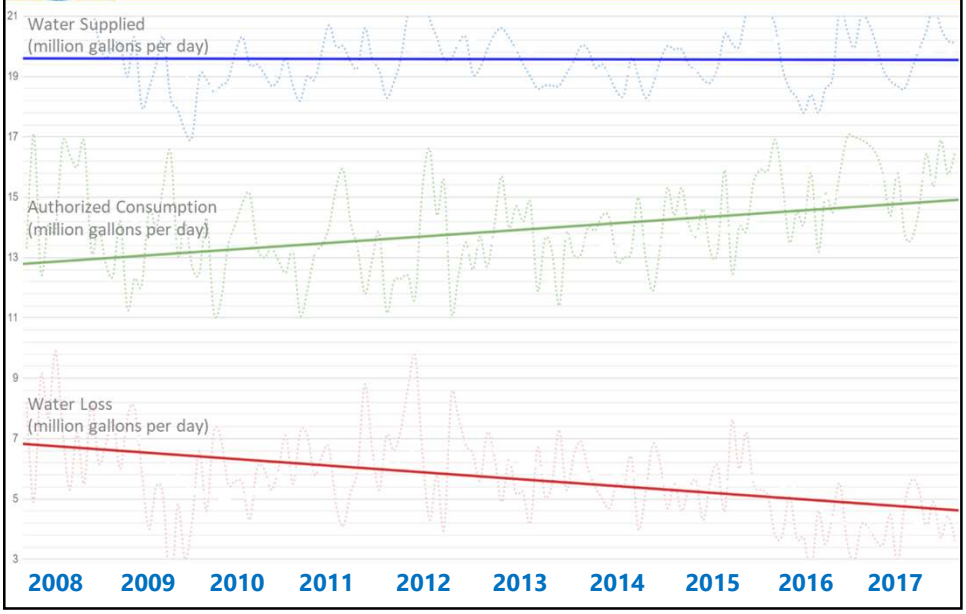
Value of Validation

1 **Discussions** about data sources & best practices can unveil a lot!

2 **Water Audits** benefit from scrutiny (internal & third party!)

3 **Accuracy** Paves the Way for **Action**!

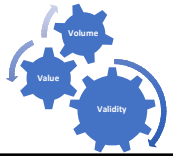
The Big Picture: Sustainability



The Big Picture: Economic Intervention

Annual Water Balance
- Annual M36 water audit
- Apparent & Real Loss volumes
- Level 1 validation

baseline



Loss Profiling
- Validation
  - Level 2 Analytics
  - Level 3 Field Study
- Analyze sources of Apparent Loss
- Analyze 3 types of Real Loss

technical analysis

Cost-Benefit & Targets
- Costs of losses
  - by subcomponent
  - in aggregate
- Costs of intervention strategies
- Program design
- System-specific

economic analysis

Intervention
- Leakage Management:
  - Active Leak Detection
  - Pressure Optimization
  - Repair Time Reduction
  - Network Renewal
- Revenue Protection:
  - Theft Mitigation
  - Meter Optimization & Renewal
  - Billing Data System Integrity
  - Revenue Recovery

cost-effectiveness

Critical Importance of Validation in Water Audits

Texas Water Conservation Advisory Council Meeting

May 9, 2018

Steve Cavanaugh, P.E.
Chief Innovation Officer
AWWA WLCC, Outreach Chair
steve.cavanaugh@cavanaughsolutions.com

SAVE TEXAS WATER
Water Conservation Advisory Council

Slide acknowledgement to Cavanaugh & WSO