FROM AUDIT TO ACTION:

CATALYZING A REGIONAL MOVEMENT FOR NON-REVENUE WATER CONTROL

NOVEMBER 6, 2025

Steve Cavanaugh| President/CEO | steve.cavanaugh@cavanaughsolutions.com

CAVANAUGH

IMPORTANCE OF WATER LOSS CONTROL

CAVANAUGH

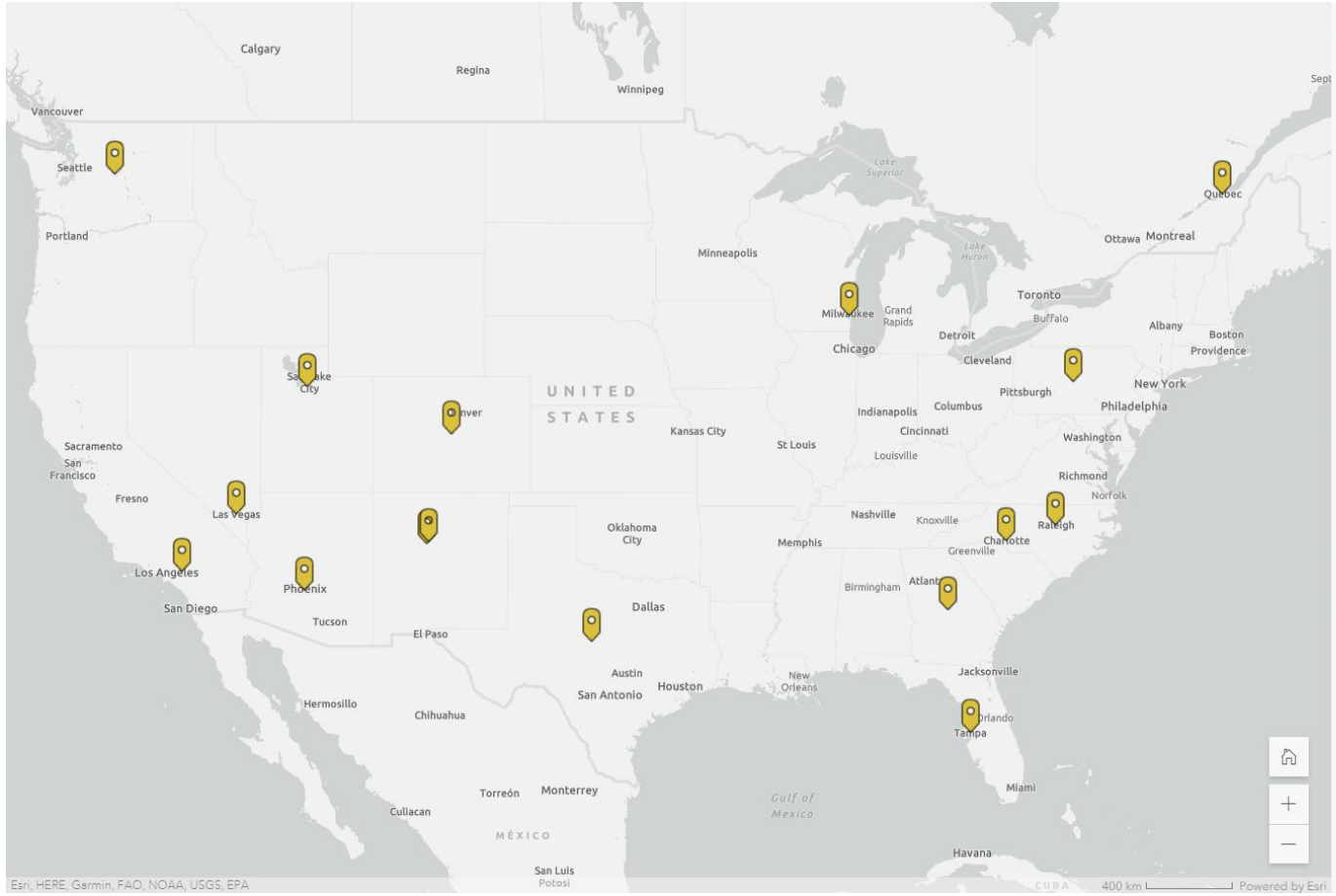
Every water system experiences water loss.

Establishing a baseline of validated water audit data is the anchor of a successful water loss strategy.

The IWA/AWWA methodology provides a path to building and progressing your water loss program.

NATIONAL LANDSCAPE

PILOT STUDIES | STATEWIDE PROGRAMS | CERTIFICATION PROGRAMS




Georgia Water Loss Program


Wisconsin M36 Water Loss Auditing


New Mexico Water Loss Control Training Program

California Water Loss Technical Assistance…


Utah Water System Efficiency and Water Loss…

Washington Water Loss Pilot Program

Florida Water Loss Pilot Technical Assistance…

North Carolina Water Loss Program


The Catawba-Wateree Water Loss Program

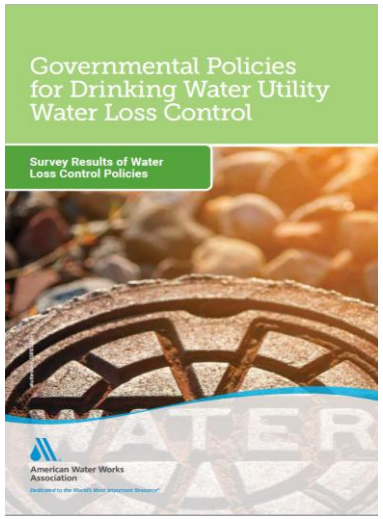

Arizona Water Loss Pilot Program

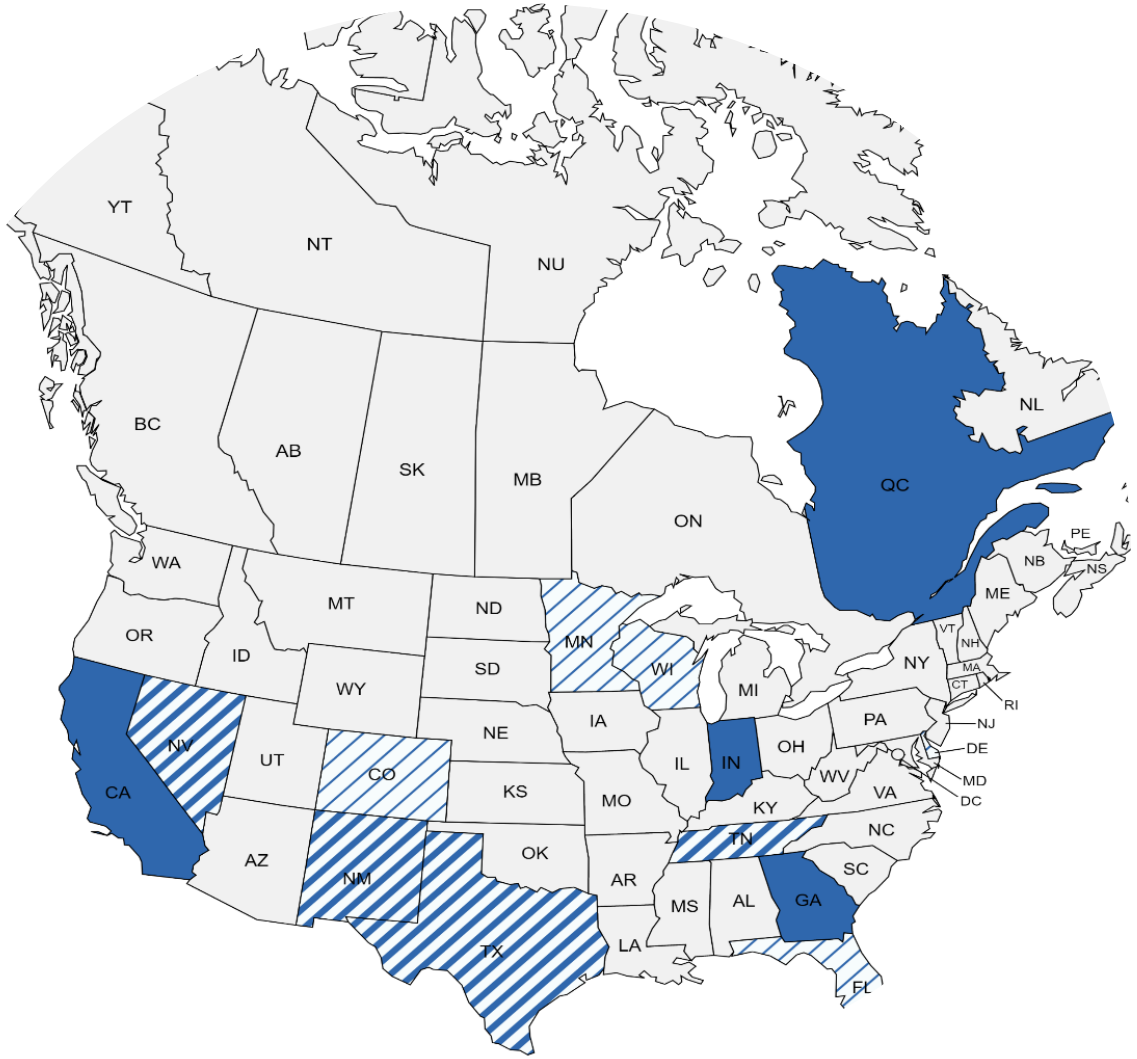

Colorado Water Loss Initiative


Quebec's Water Efficiency Strategy

https://arcg.is/1nrHTv0

NORTH AMERICAN REGULATORY STATUS (2021)

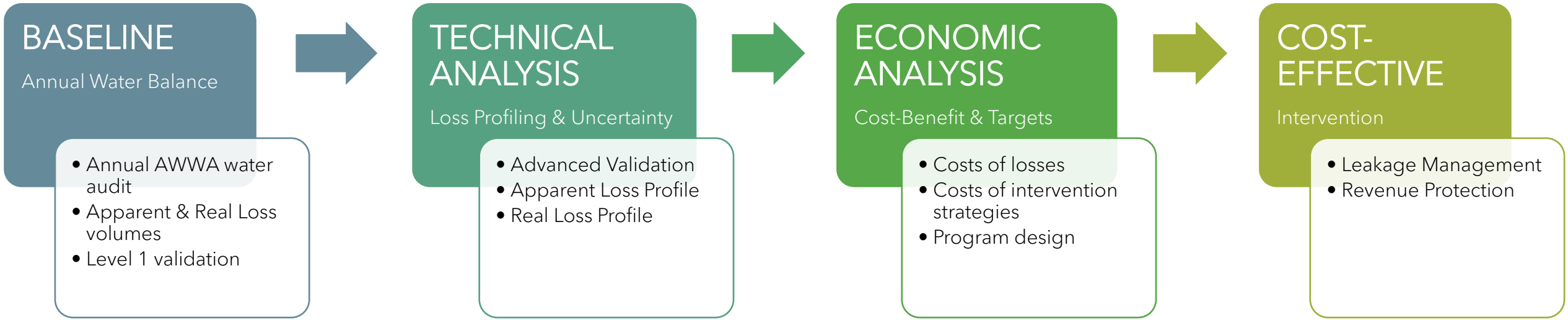


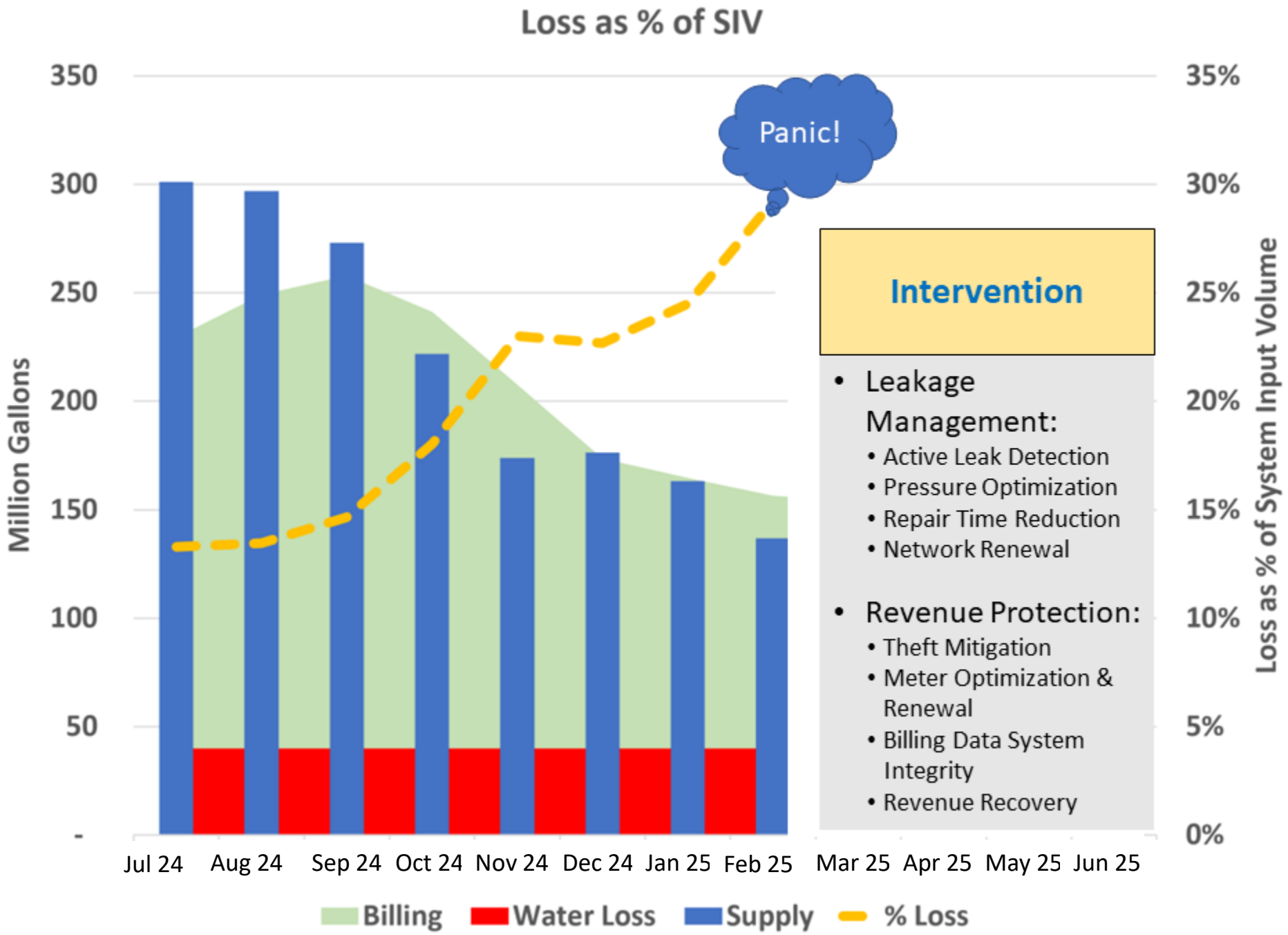


- Minimum Standards:
  - AWWA M36 Water Balance
  - Data Validity Assessment
  - Level 1 Validation
- Minimum Standards:
  - AWWA M36 Water Balance
  - Data Validity Assessment
  - No Level 1 Validation (Self-Reported)
- Minimum Standards:
  - AWWA M36 Water Balance
  - No Data Validity Assessment
  - No Level 1 Validation (Self-Reported)

THE BIG PICTURE

- ***Every*** water system experiences water loss.
- Establishing a baseline of validated water audit data is the anchor of a ***successful*** water loss strategy.
- The IWA/AWWA methodology provides a path to building and progressing your ***water loss program***.

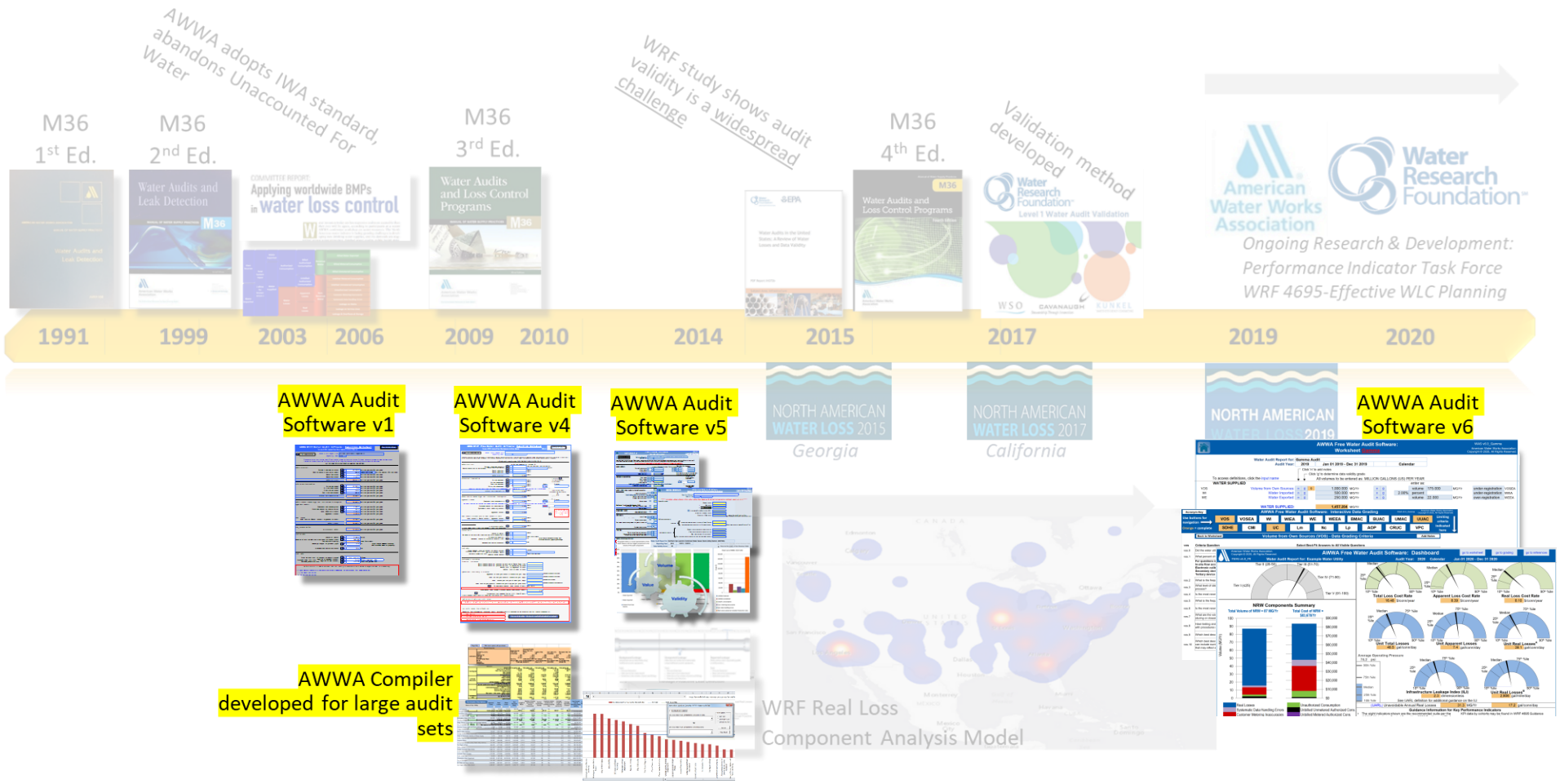



Loss as % of SIV
350
300
250
200
150
100
50
-
Million Gallons
35%
30%
25%
20%
15%
10%
5%
0%
Loss as % of System Input Volume
Panic!
Intervention
• Leakage Management:
• Active Leak Detection
• Pressure Optimization
• Repair Time Reduction
• Network Renewal
• Revenue Protection:
• Theft Mitigation
• Meter Optimization & Renewal
• Billing Data System Integrity
• Revenue Recovery
Jul 24
Aug 24
Sep 24
Oct 24
Nov 24
Dec 24
Jan 25
Feb 25
Mar 25
Apr 25
May 25
Jun 25
Billing
Water Loss
Supply
% Loss

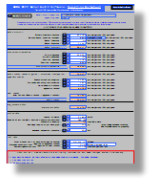
UTILIZATION OF AWWA M36 PRESCRIPTIVE METHODOLOGY

CAVANAUGH

AWWA M36 METHODOLOGY – EVOLUTION OF THE WATER AUDIT SOFTWARE

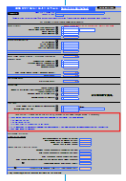


FWAS v1
(200)



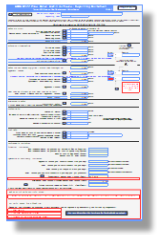
MG volumes only
Data grading:
either ‘measured’
or ‘estimated’

FWAS v2 – v3



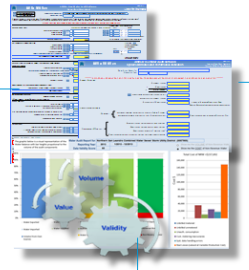
Megaliters added
Two financial performance indicators added (cost of real and apparent losses)
Acre-ft added
Example audits included
Two default values
Data checks / instant feedback added

FWAS v4
(2,000)



Data grading matrix (1-10)
Service connection diagram
French language version available

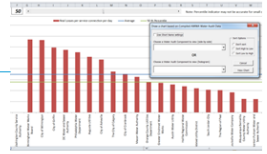
FWAS v5
(13,000)

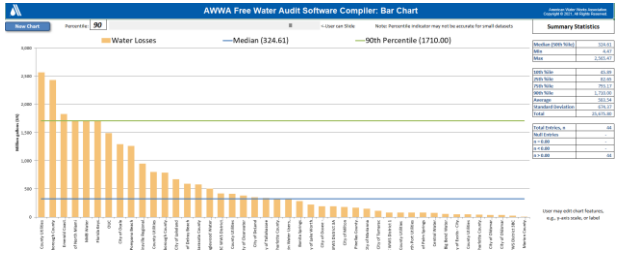


Separate data input/output tabs
Dashboard
Volume weighted data grading
Comments page
Meter error adjustment for all water supplied components

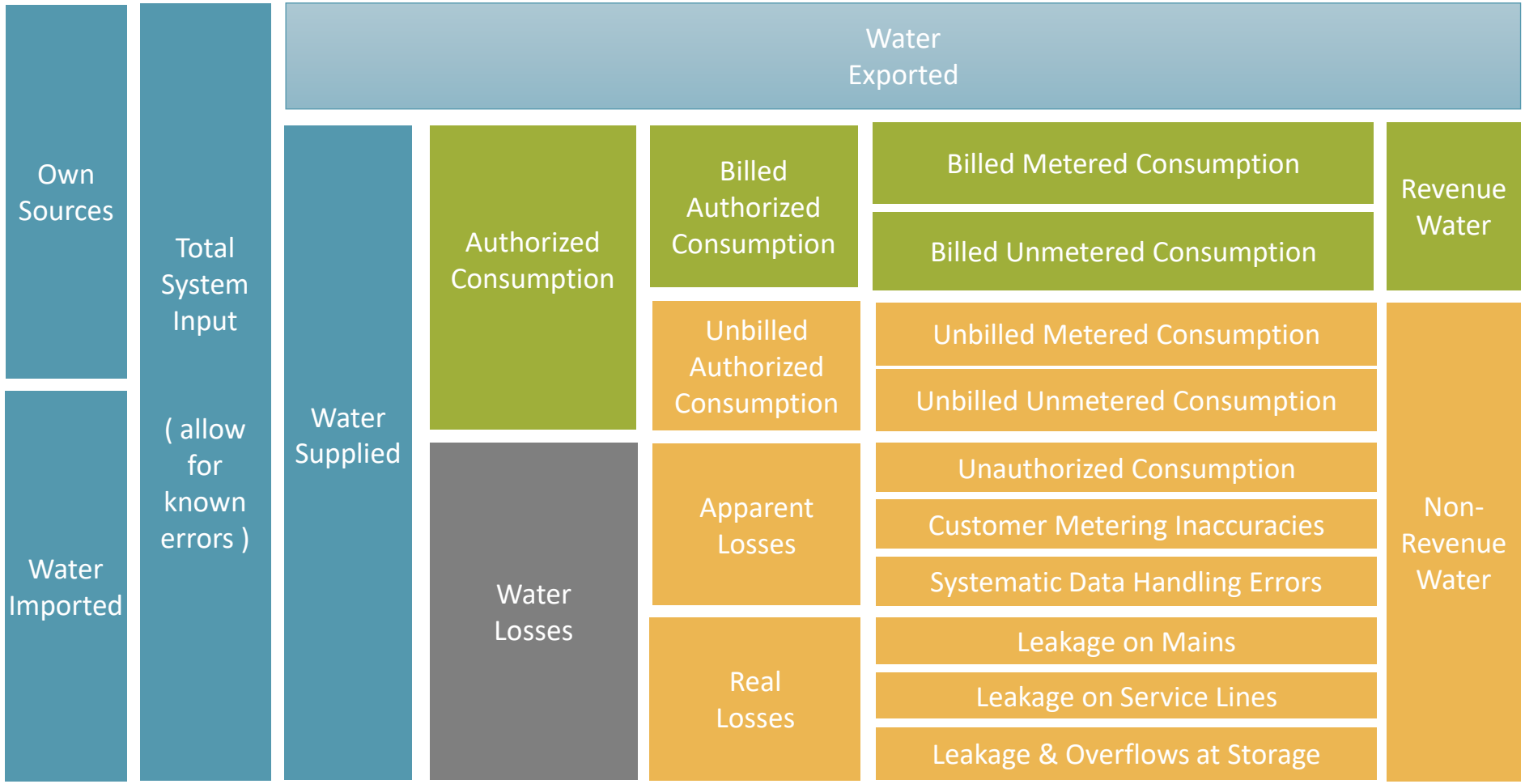
FWAS v6

AWWA Compiler developed for large audit sets

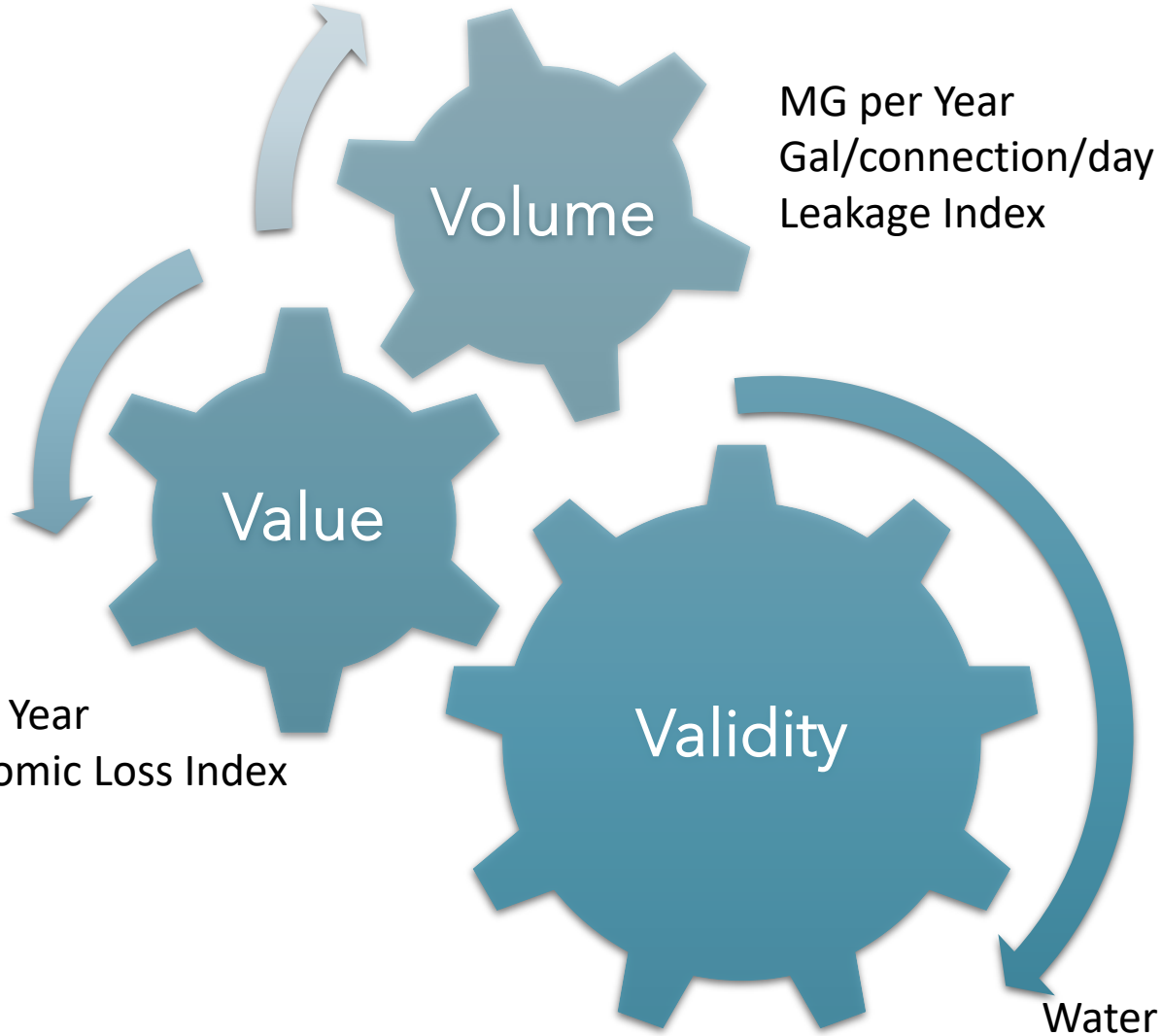




THE IWA/AWWA WATER BALANCE



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

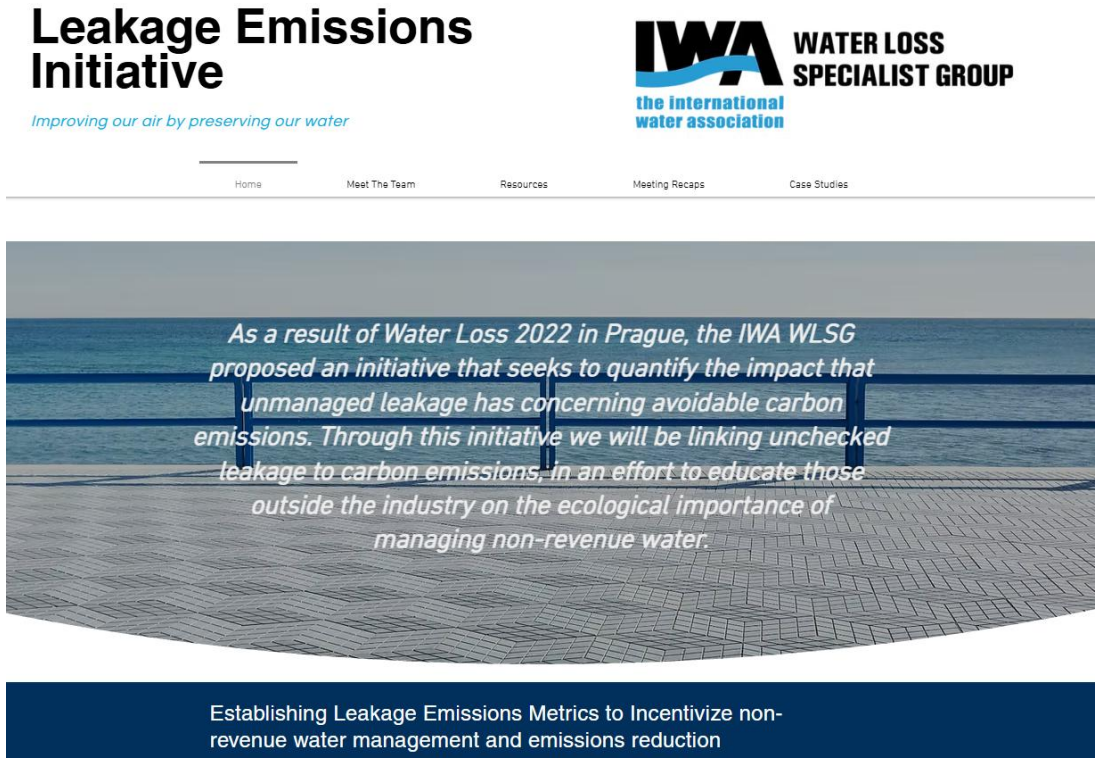


MG per Year
Gal/connection/day
Leakage Index

$ per Year
Economic Loss Index

Water Audit Data Validity Score
95% Confidence Limits
Key Data Input Grades

WHO INVITED CARBON TO THE PARTY?



www.leigroup.org

CARBON DATING VERSION 6.1

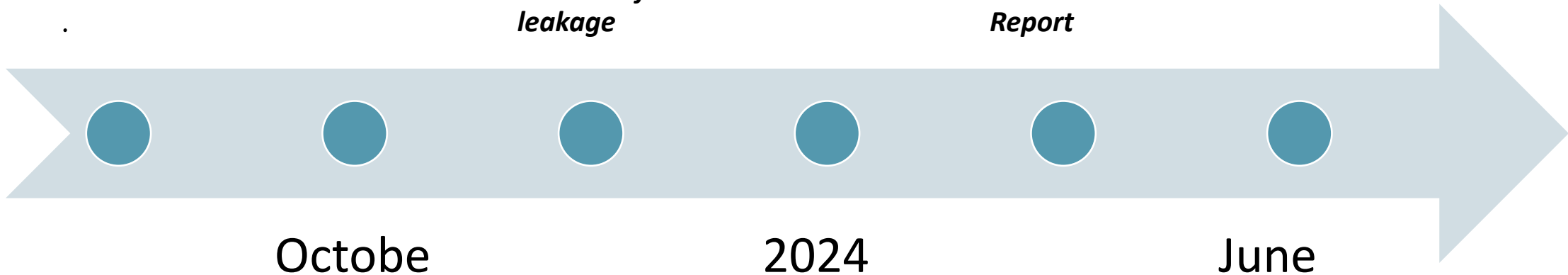
to *quantify the impact that unmanaged leakage has concerning avoidable carbon emissions.*

April 2023

- ***LEI White Paper published with agreed upon methodology for calculating carbon emissions as a result of leakage***

April 2025

- ***AWWA publishes Water Loss Control Committee's Leakage Emissions Initiative Report***



October 2022

- ***Inaugural meeting of the Leakage Emissions Initiative***

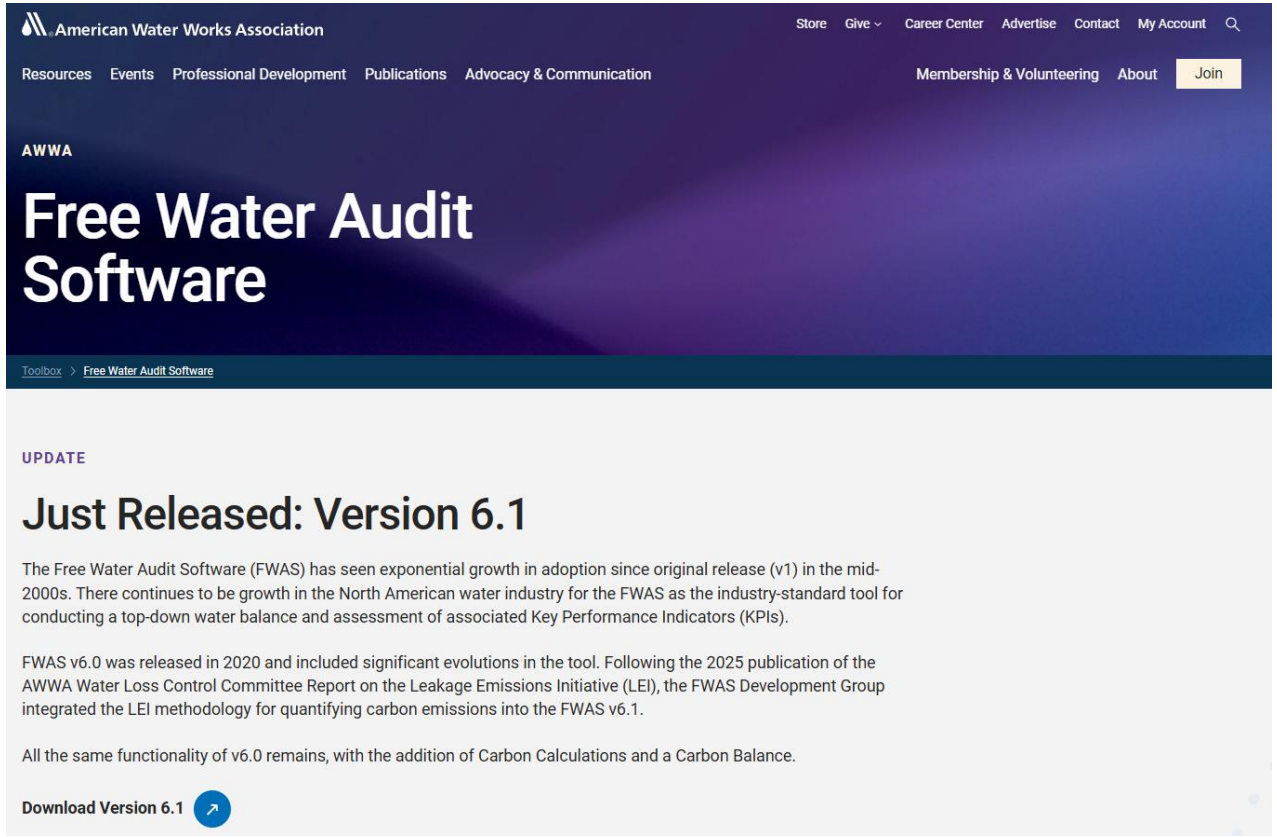
2024

- ***Carbon Balance published with IWA Standard Water Balance***

June 2025

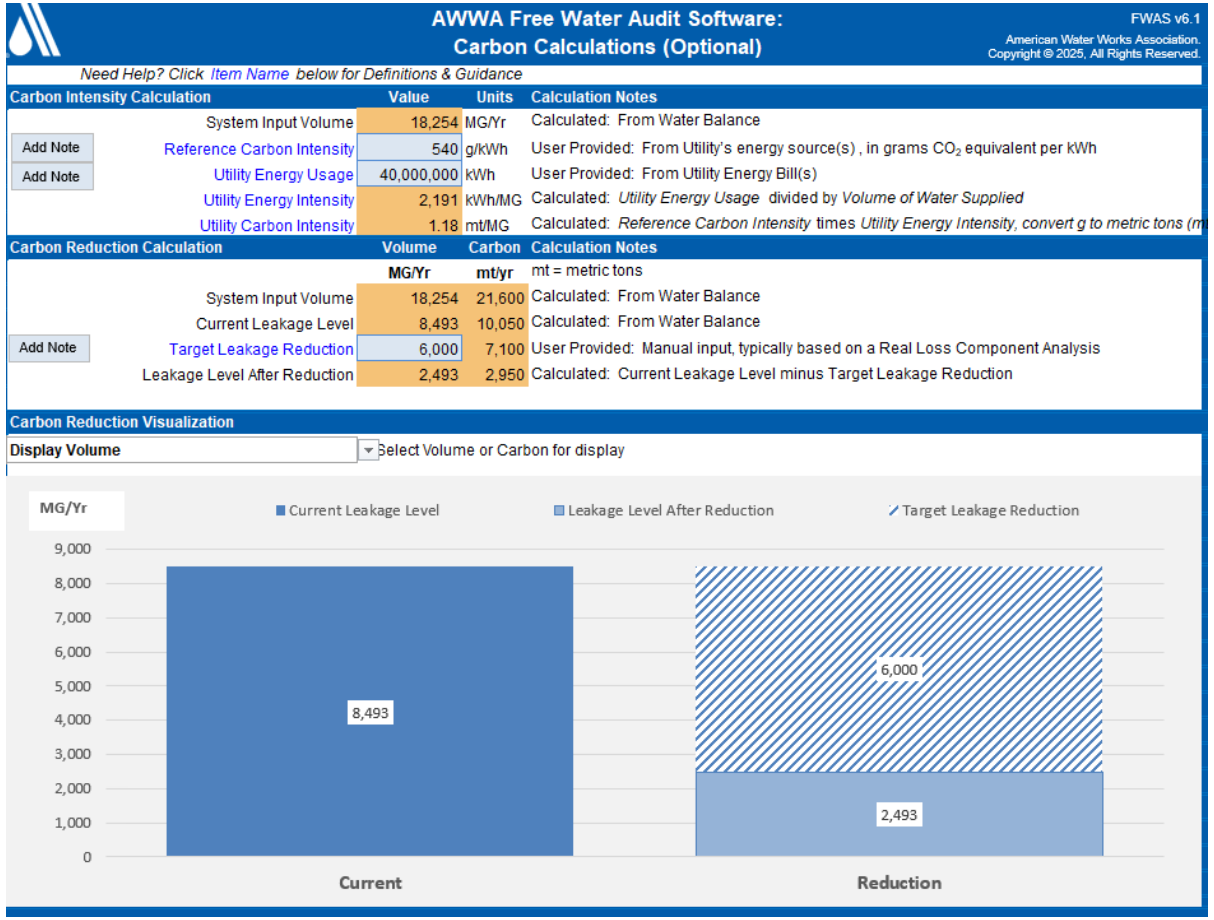
- ***Carbon Balance and Calculations are integrated into Version***

INTRODUCING THE AWWA FREE WATER AUDIT SOFTWARE – VERSION 6.1

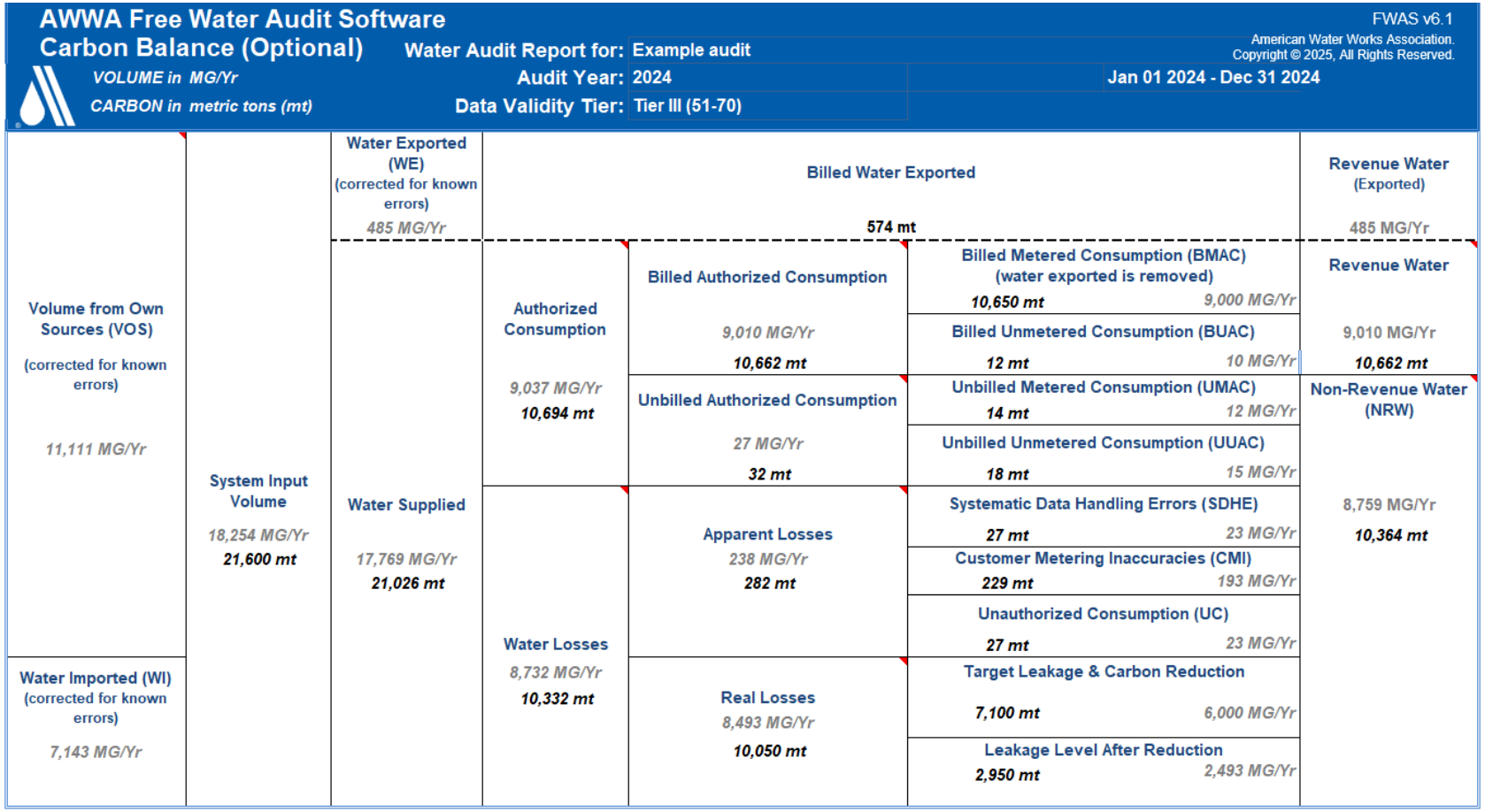


- Version 6.1 integrates the Leakage Emissions Initiative methodology for quantifying carbon emissions

INTRODUCING THE AWWA FREE WATER AUDIT SOFTWARE – VERSION 6.1



INTRODUCING THE AWWA FREE WATER AUDIT SOFTWARE – VERSION 6.1



WHAT ARE OTHER REGIONS DOING TO ADDRESS WATER LOSS?

CAVANAUGH

Washington County Water Conservancy District
Shared Education

AGENDA

OBJECTIVES

WATER BALANCE

BREAK

AWWA FREE WATER AUDIT SOFTWARE

LUNCH

COMMON EXERCISE
DEVELOPING THE INPUTS

DATA VALIDITY

Volume from Own Sources (VOS), Water Exported (WE), and Billed Metered Authorized Consumption (BMAC)

COMMON EXERCISE
DATA GRADING

BREAK

COMMON NEXT STEPS

QUESTIONS?

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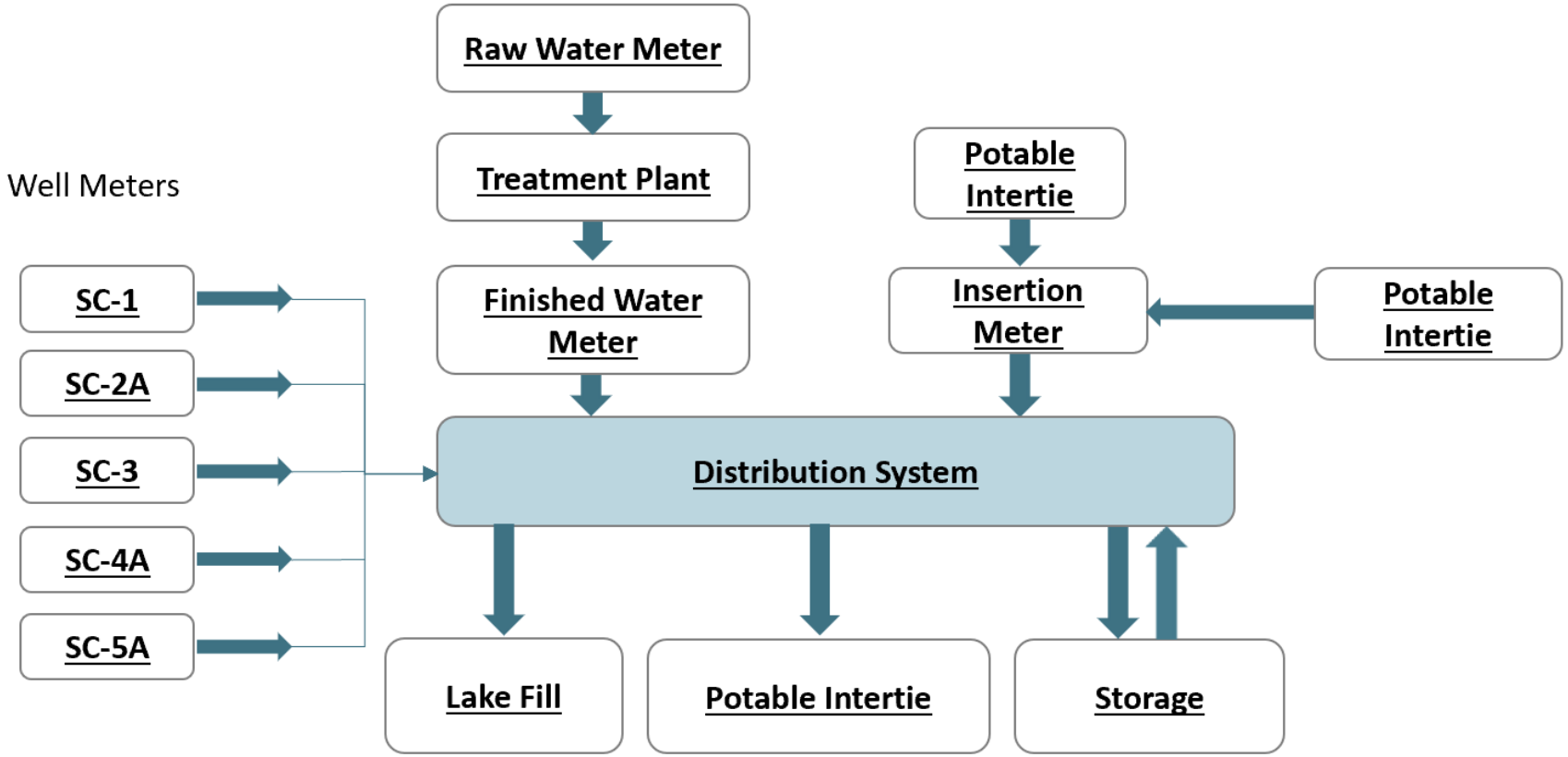
WATER SUPPLIED AUDIT BOUNDARY



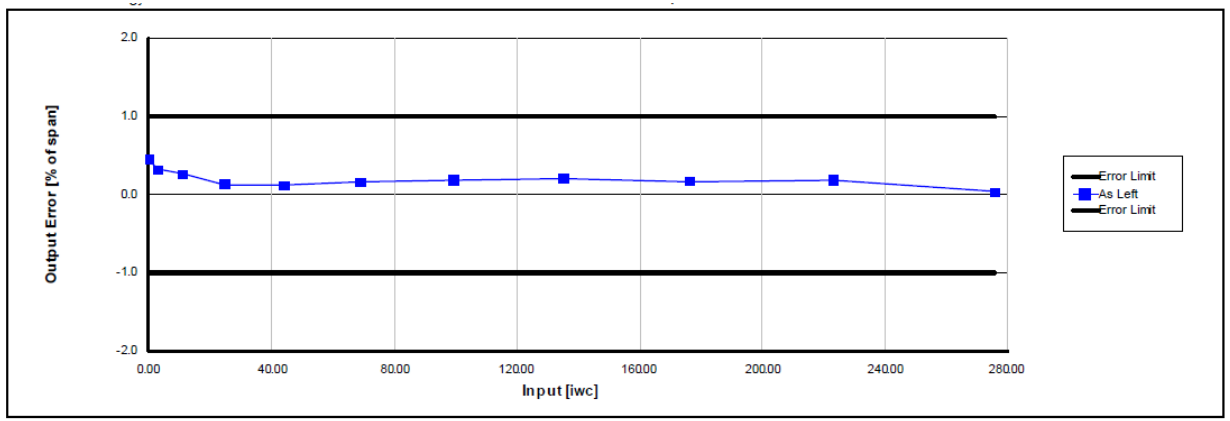
WHAT IS A METER TEST?

- *In-situ*
- *Volumetric comparison*
- *Using a known volume*

METER TEST MISCONCEPTIONS

- *“Got a certificate”*
- *“We have redundant meters”*
- *“Guaranteed it would be accurate”*
- *“Only needs calibration”*

METER CALIBRATION



1. As FOUND **PASSED**

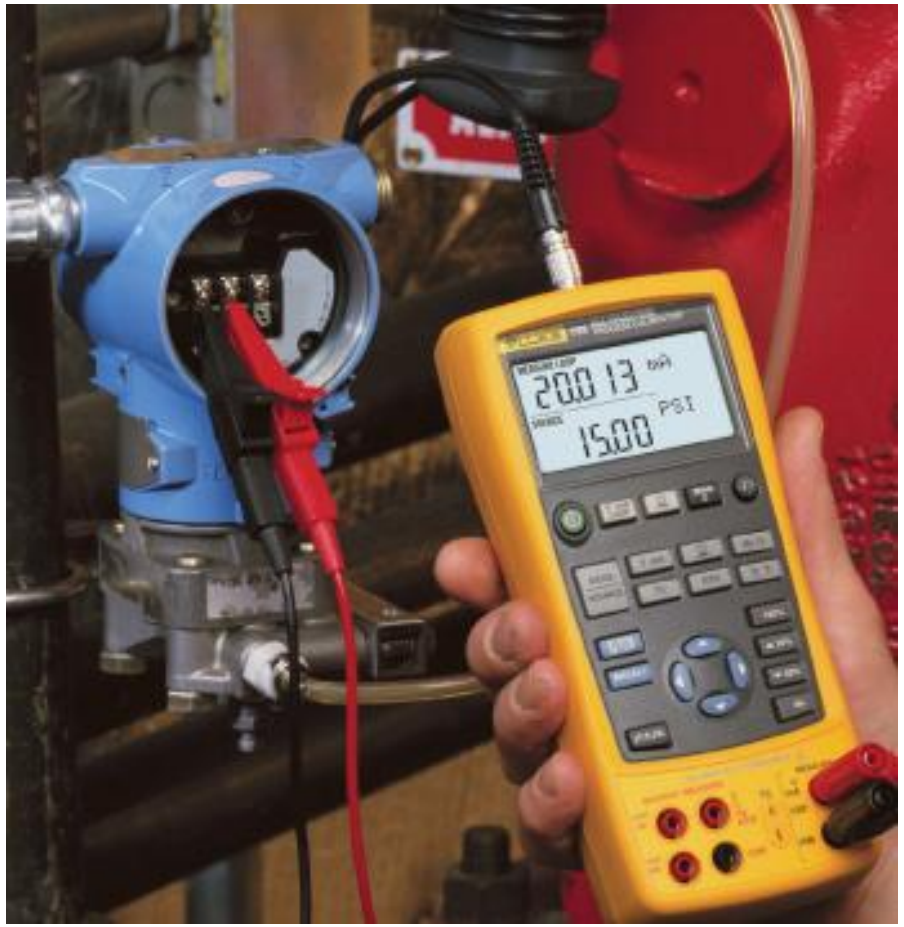
Max Error: 0.44 % of reading

Nominal Input [iwc]	Actual Input [iwc]	Nominal Output [mA]	Actual Output [mA]	Found Error [% of span]
0.00	0.00	4.00	4.0177	0.4425
2.75	2.75	5.60	5.6151	0.3102
11.03	11.02	7.20	7.2163	0.2490
24.82	24.82	8.80	8.8107	0.1218
44.12	44.12	10.40	10.4108	0.1072
68.94	68.94	12.00	12.0175	0.1483
99.28	99.28	13.60	13.6243	0.1790
135.13	135.13	15.20	15.2293	0.1934
176.49	176.48	16.80	16.8264	0.1613
223.38	223.38	18.40	18.4324	0.1764
275.78	275.77	20.00	20.0048	0.0255

2. As Left **PASSED**

Max Error: 0.44 % of reading

Nominal Output [mA]	Actual Input [iwc]	Nominal Output [mA]	Actual Output [mA]	Found Error [% of span]
0.00	0.00	4.00	4.0200	0.4400
2.75	2.75	5.60	5.6200	0.3100
11.03	11.02	7.20	7.2200	0.2500
24.82	24.82	8.80	8.8100	0.1200
44.12	44.12	10.40	10.4100	0.1100
68.94	68.94	12.00	12.0200	0.1500
99.28	99.28	13.60	13.6200	0.1800
135.13	135.13	15.20	15.2300	0.1900
176.49	176.48	16.80	16.8300	0.1600
223.38	223.38	18.40	18.4300	0.1800
275.78	275.77	20.00	20.0000	0.0300



LEVEL 2 VALIDATION BMAC ANALYSIS

Billing Data Validation

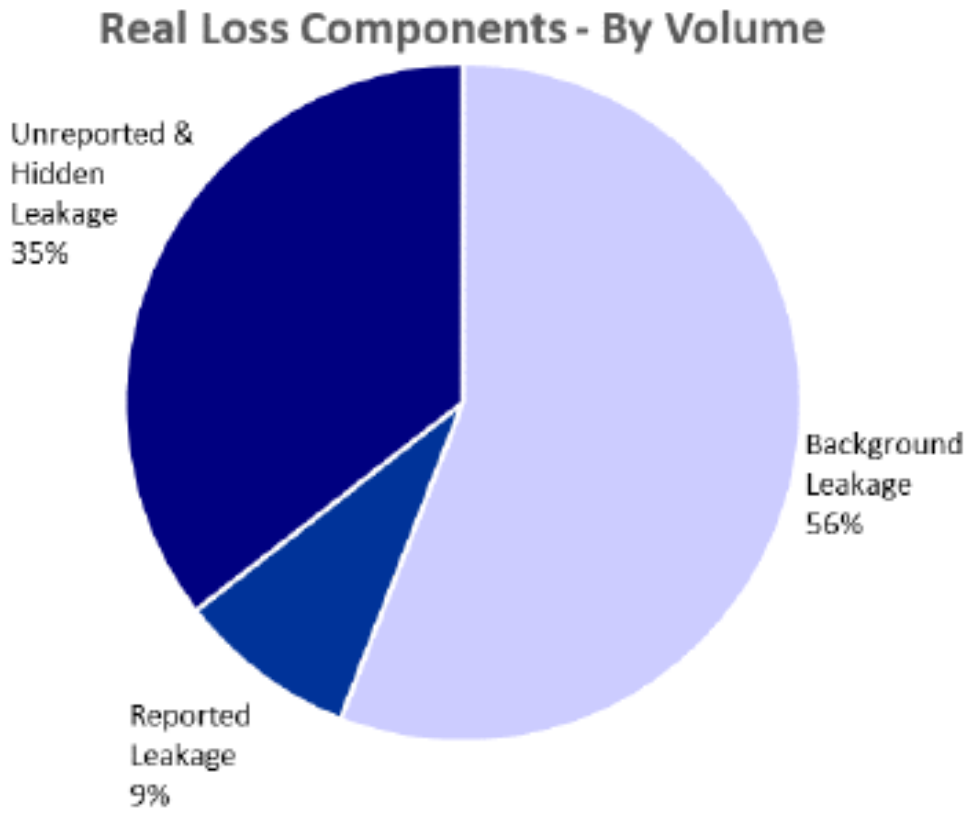
- Account Level analysis

Acct #	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	Total
4202420300	78	45	82	772	135	102	190	75	65	57	54	52	54	70	37	38	1,906
7000051302		0							2,648						0		2,648
4202262300	70	77	2	124	7	7	17	124	362	1,369	19	269	43	115	31	477	3,113
4201134301	37	40	41	1,533	1,190	41	40	44	49	37	43	40	39	47	67	48	3,336
4201974300	128	110	0	3	14	29	4	0	0	0	2,596	473	1,157	458	8	1	4,981
4201982300	0	0	0	0	0	0	0	11,354	0	10,900	0	0	0	0	0	0	22,254
4201669300	1,214	1,148	638	2,761	2,534	1,432	2	2,862	2,862	3,092	3,332	3,674	3,000	3,478	3,180	3,504	38,713
4101833300	3,511	2,546	1,861	1,924	2,244	3,040	3,841	2,389	3,402	4,227	4,079	3,160	733	157	256	467	37,837
4101820300	701	413	15	49	128	1,237	1,501	183	182	614	2,213	873	423	1,640	5	190	10,367
4202303300	158	248	288	1,441	1,344	956	531	568	415	284	178	285	250	207	192	135	7,480
5302916302	898	534	1,373	566	76	505	341	260	358	673	379	387	190	12			6,552
3101392300	522	400	0	0	12	500	566	553	603	645	659	686	366	815	0	0	6,327
7000190306										0		5,757					5,757
7000249301			5,667														5,667
4200866300	120	135	128	148	128	158	38	110	84	7	60	128	214	324	145	210	2,137
4202932304	210	199	179	135	106	88	127	68	10	9	74	135	135	155	80	113	1,823

Lag-time Adjustment

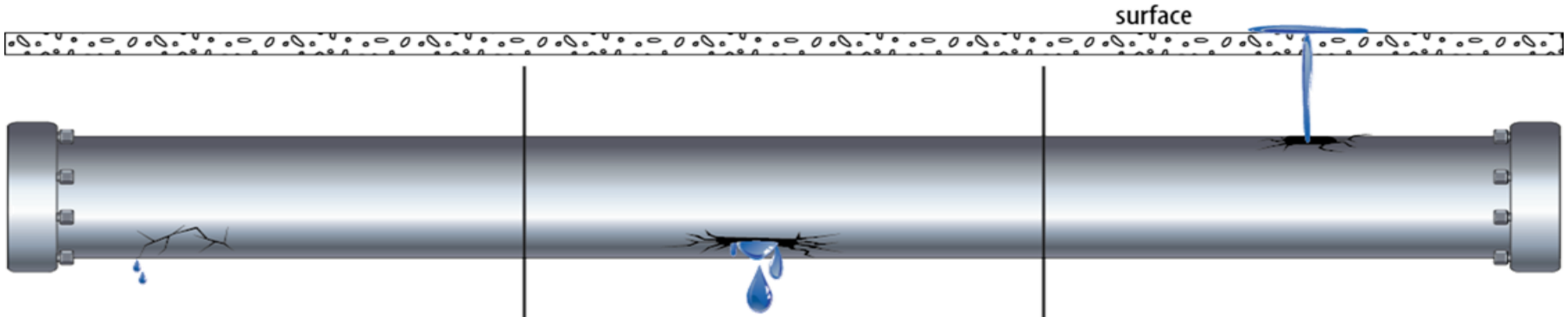
(561,088.11)	volume to subtract from billed metered volume
571,993.87	volume to add to billed metered volume
10,905.75	net adjustment (ccf)
8.16	net adjustment (MG)

REAL LOSS PROFILE - EXAMPLE



REAL LOSS COMPONENT ANALYSIS RESULTS				
System Component	Background Leakage	Reported Failures	Unreported Failures	Total
	(MG)	(MG)	(MG)	(MG)
Reservoirs	0.20	-	-	**0.20**
Mains and Appurtenances	3.38	0.91	-	**4.28**
Service Connections	5.00	0.41	-	**5.41**
Total Annual Real Loss	**8.57**	**1.32**	-	**9.89**
			Real Losses as Calculated by Water Audit	**15.33**
			Hidden Losses/Unreported Leakage Currently Running Undetected	**5.44**

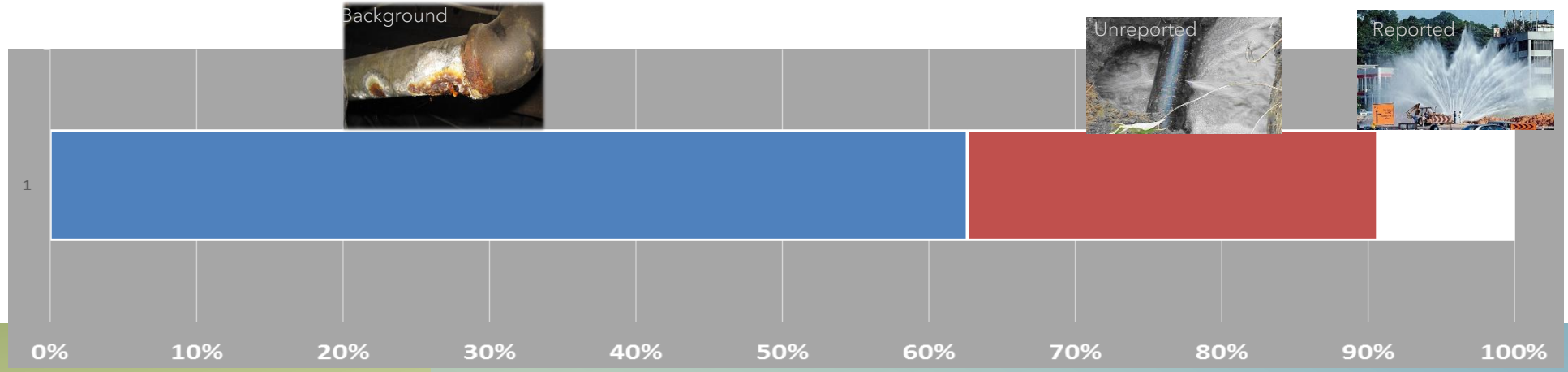
SELECTING THE RIGHT TOOL



Tools
Pressure Management
Main & service replacement
Reduce # of joints/fittings

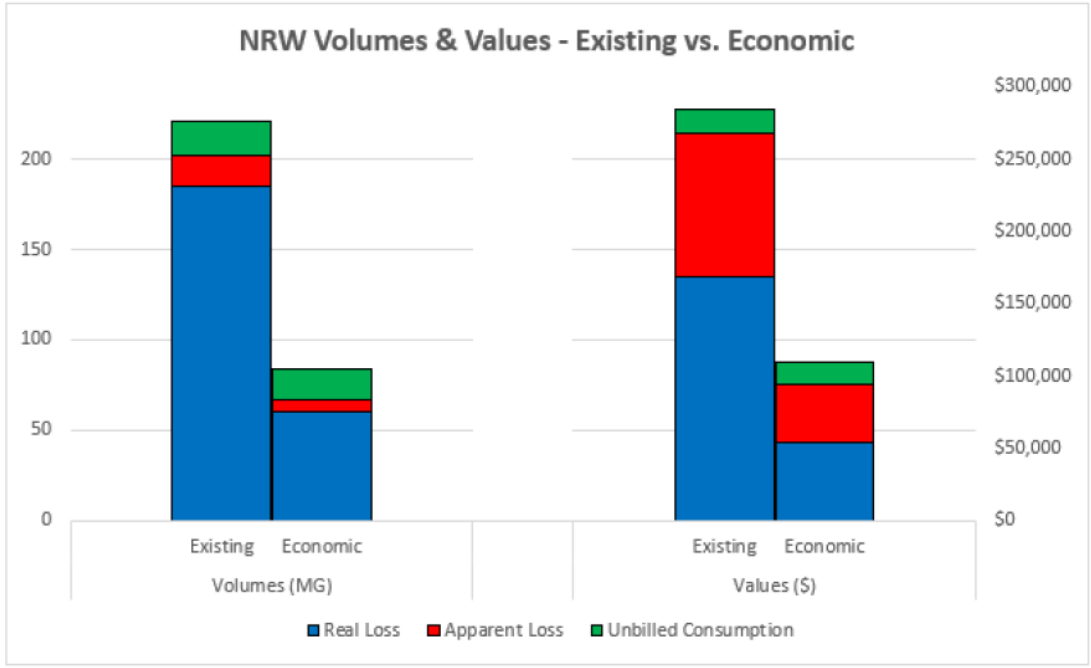
Tools
Pressure Management
Main & service replacement
Reduce # of joints/fittings
Proactive Leak Detection

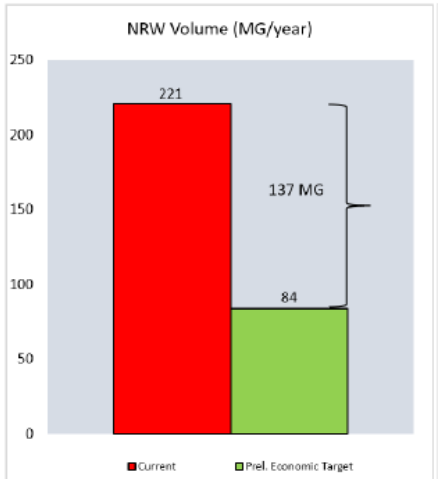
Tools
Pressure Management
Main & service replacement
Optimized repair time

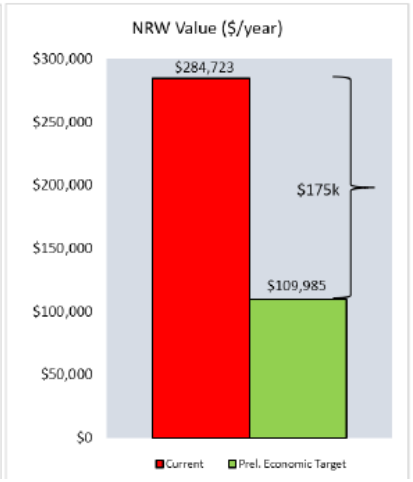


ECONOMIC ANALYSIS - EXAMPLE

Fiscal Year 2017/2018					
			95% Confidence Limits (+/-)		
Economic Metrics	**Volume**		**Low**	**High**	**%**
Non-Revenue Water (Existing)	221	MG/yr	181	261	18.2%
Non-Revenue Water (Economic)	84	MG/yr	67	100	19.7%
Target NRW Recovery ("Gap")	137	MG/yr	110	164	19.7%
	Value (Primary + Secondary)				
Non-Revenue Water $ (Existing)	$284,723	$/yr	$245,580	$323,865	13.7%
Non-Revenue Water $ (Economic)	$109,985	$/yr	$88,345	$131,626	19.7%
Target NRW Recovery $ ("Gap")	$174,737	$/yr	$140,357	$209,118	19.7%
NRW Economic Index	2.6	ratio of current vs optimum NRW cost			
Technical Metrics					
Unbilled Consumption	9.3	gal/conn/day	8.2	10.4	11.6%
Apparent Loss	8.5	gal/conn/day	7.3	9.7	14.0%
Real Loss	92.7	gal/conn/day	73.4	112.1	20.8%
Infrastructure Leakage Index	4.8		3.7	5.8	21.6%
Data Validity Band (Level)	Band III (51-70)				



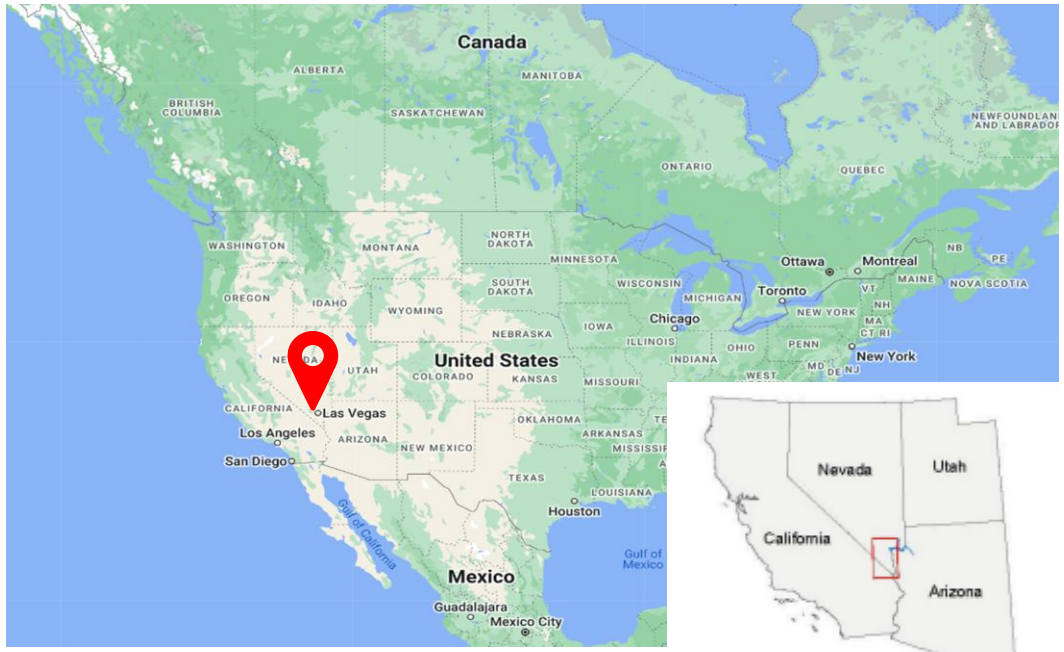


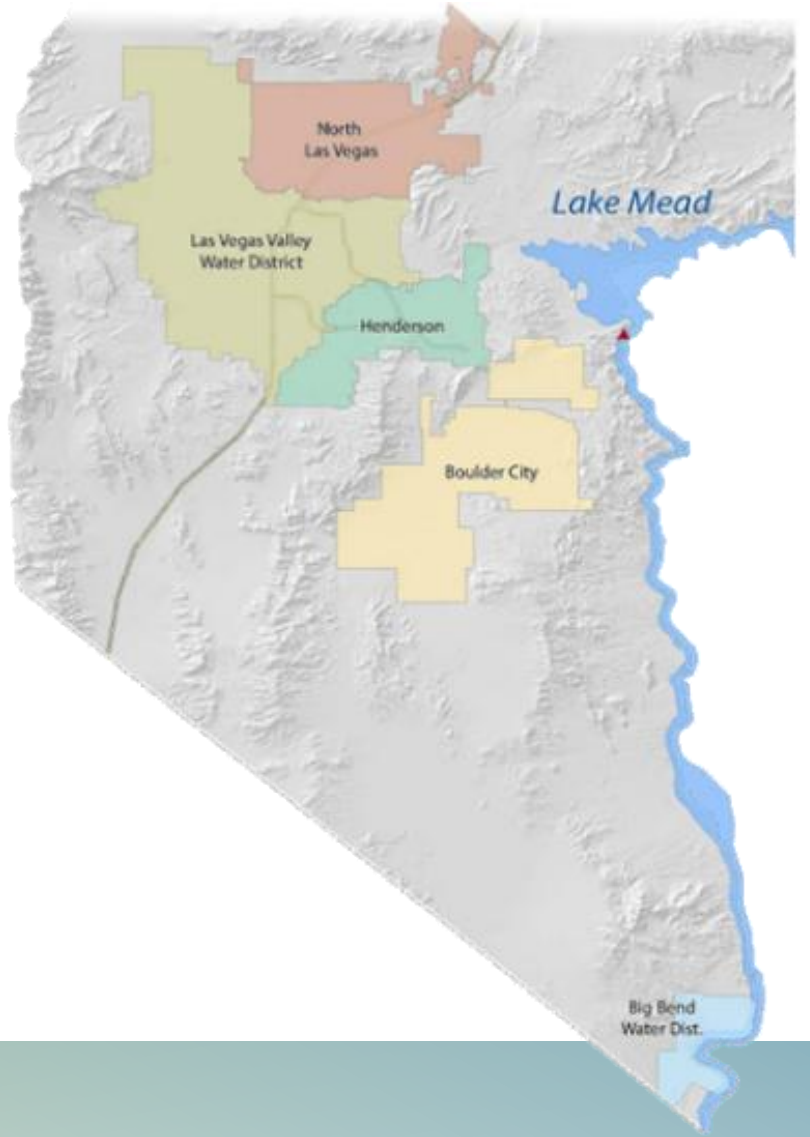


Volumes (MG)	Existing	Economic
Unbilled Consumption	18.6	17.1
Apparent Loss	17.1	6.9
Real Loss	185.3	59.8

Values ($)	Existing	Economic
Unbilled Consumption	$16,932	$15,538
Apparent Loss	$99,331	$40,069
Real Loss	$168,460	$54,379

ACTIVE SOUTHERN NEVADA WATER AUTHORITY WATER LOSS PROGRAM





SOUTHERN NEVADA WATER AUTHORITY

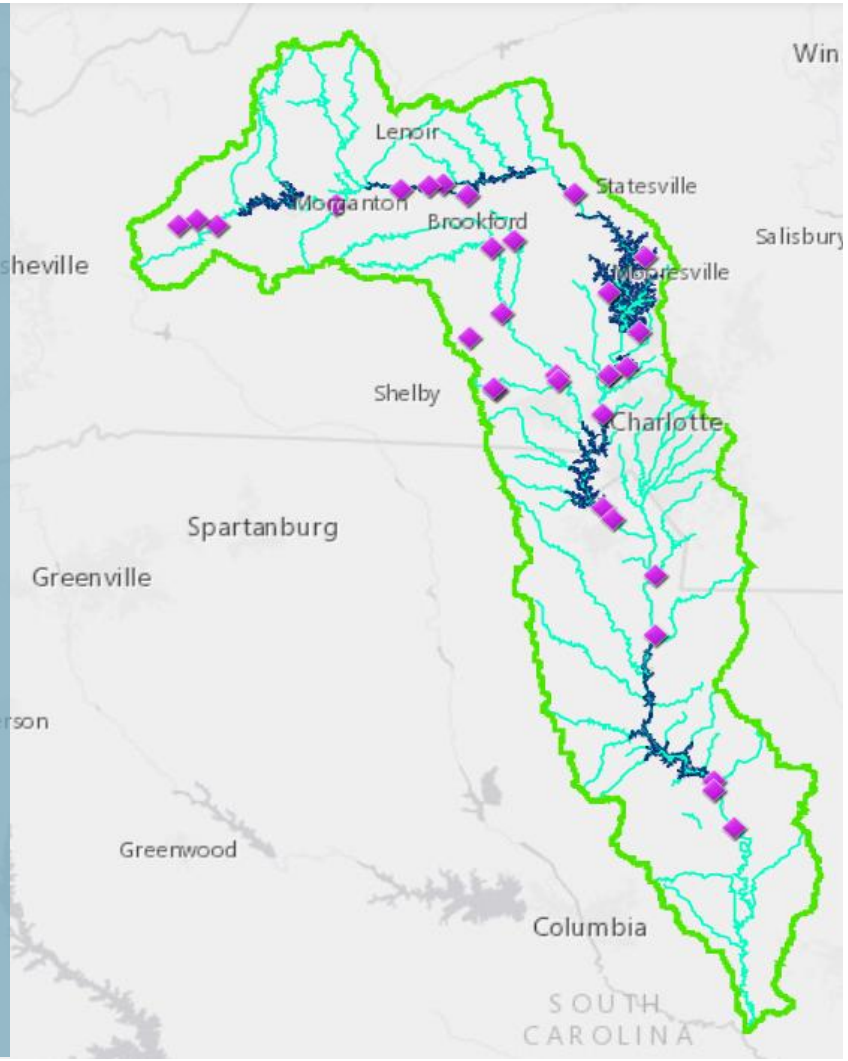
ACTIVE SOUTHERN NEVADA WATER AUTHORITY WATER LOSS PROGRAM

Clark County Nevada
BIG BEND
Water District

Phase 2A & B	Phase 2C	Phase 3	Phase 4	
Baseline	**Technical Analysis**	**Gap Analysis & Targets**	**NRW Program Design**	**Communication**
Annual M36 water audit Apparent & Real Loss volumes Level 1 validation Staff training and capacity building	Advanced Validation •Level 2 Analytics •Evaluation of Supply Meter Testing Programs •Uncertainty Analysis Apparent Loss Profile •Theft •Meter Inaccuracy •Data Handling Real Loss Profile •Reported Leakage •Unreported Leakage •Background Leakage	Gap Analysis • by subcomponent • in aggregate Target Setting • by subcomponent • in aggregate	Evaluation of intervention strategies against system-specific NRW issues System-specific NRW Program Design	Internal Report for SNWA • Report for each Member Agency • Includes all technical detail & program designs Content for SNWA Conservation Plan • Rollup of targets across Member Agencies • Rollup of NRW Program activities to be undertaken to meet targets

CATAWBA -WATEREE'S SYSTEM SPECIFIC ACTION PLAN

- 225 miles of river
- 4,750 square miles of watershed area
- 11 interconnected reservoirs
- 13 hydroelectric stations and many public utilities
- 18 public water utilities are members of the CWWMG



CATAWBA -WATEREE'S SYSTEM SPECIFIC ACTION PLAN

Annual Water Balance

Annual M36 water audit

Apparent & Real Loss volumes

Level 1 validation

baseline

Stage 1

Loss Profiling & Uncertainty

Advanced Validation
- Level 2 Analytics
- Level 3 Field Study
- Margins of Error

Apparent Loss Profile
- Theft
- Meter Inaccuracy
- Data Handling

Real Loss Profile
- Reported Leakage
- Unreported Leakage
- Background Leakage

technical analysis

Stage 2

Cost-Benefit & Targets

Costs of losses
- by subcomponent
- in aggregate
- wholesale & retail

Costs of intervention strategies

Program design

System-specific

economic analysis

Stage 3

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

Stage 4

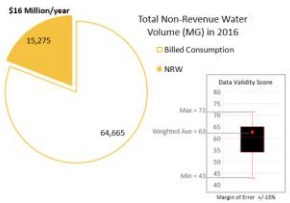
Phases 1 - 4	Phase 5	Phase 6	Phases 7+
2014 - 2017	2018 - 2020	2021-22	2023+

Program Outcomes

To assess uncertainty in the benchmark water balance for further analysis.

Phases 1 - 4 2014 - 2017

Statistics for Basinwide Aggregate

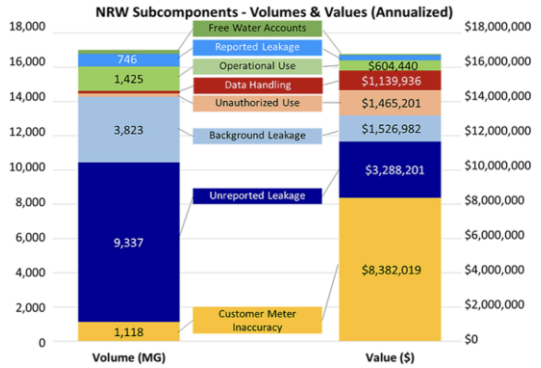


NRW Components - Volumes & Values

Program Outcomes

Phase 5 2019 - 2020

NRW Subcomponents - Volumes & Values (Annualized)

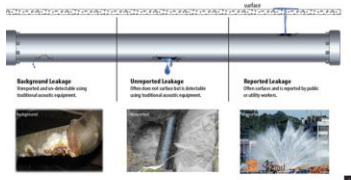


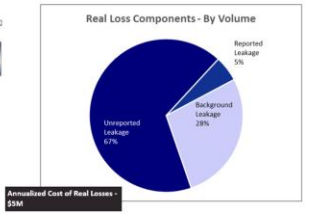
Program Outcomes

Objective Statement: To validate the source data from the originating data systems feeding the water balance inputs and establish statistical confidence levels on the water balance outputs.

Phase 5 2018 - 2019

Types of Leakage

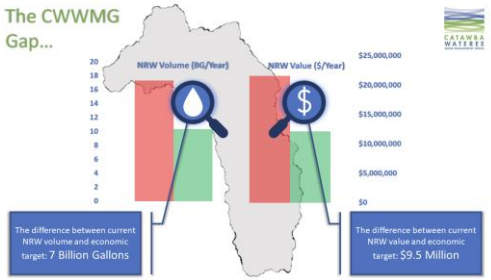




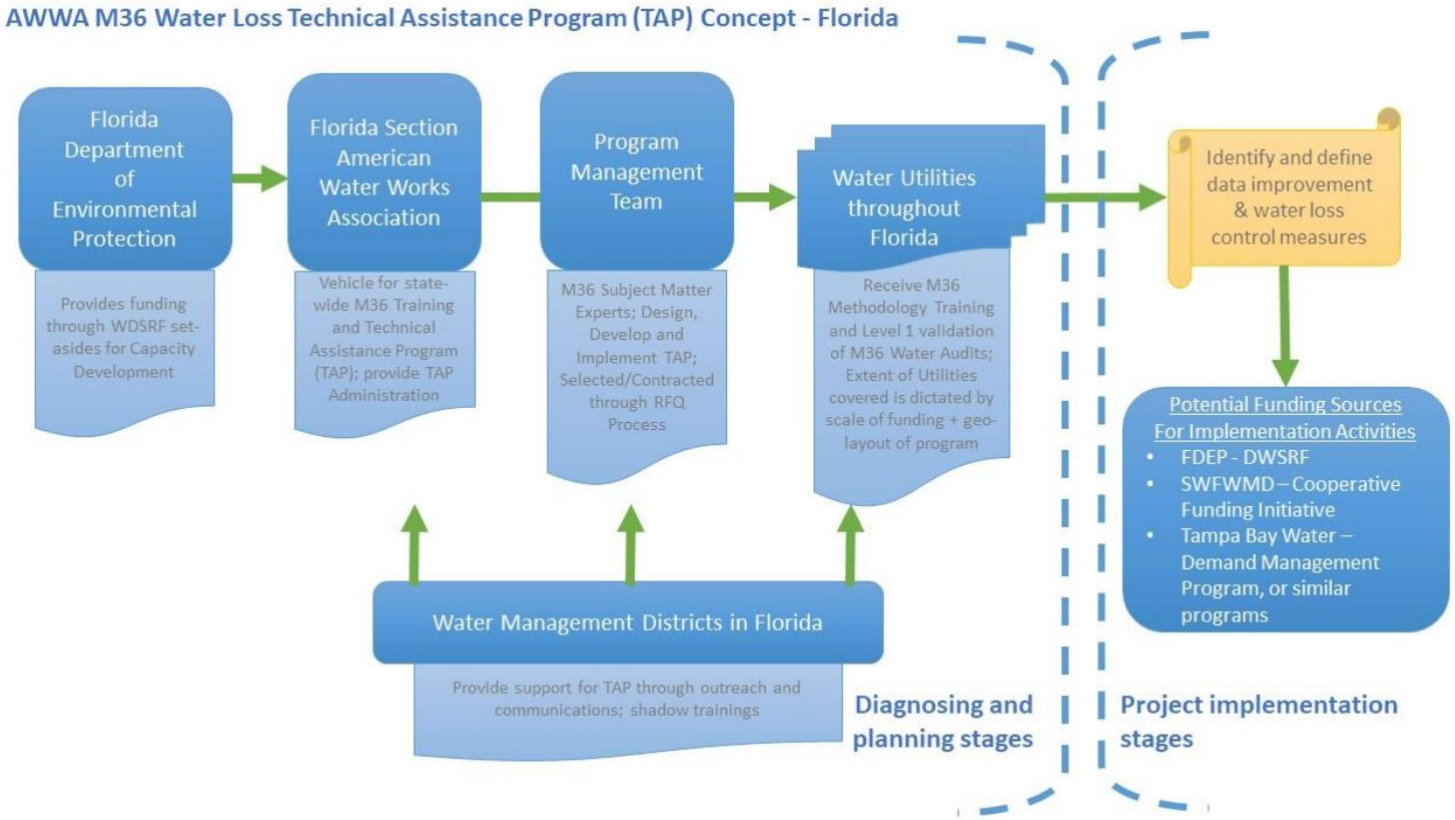
Program Outcomes

Phase 5 2019 - 2020

The CWWMG Gap...



FLORIDA WATER LOSS PILOT TECHNICAL ASSISTANCE PROGRAM



PAVED THE WAY FOR THE FLORIDA WATER LOSS PROGRAM

FLORIDA WATER LOSS PROGRAM

Saving Water – Reducing Costs – Being Proactive

THE BIG PICTURE

Annual Water Balance

Annual M36 water audit

Apparent & Real Loss volumes

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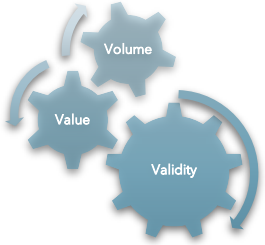
baseline



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cost-effectiveness

Stage 4

American Water Works Association

Louisville, KY
December 2-4, 2025

awwa.org/event/north-american-water-loss/

Tuesday, December 2, 2025	
Noon – 6:30 p.m.	Registration Open
4:30 p.m. – 6:30 p.m.	Welcome Reception in Exhibit Hall

Wednesday, December 3, 2025	
7:00 a.m. – 6:30 p.m.	Registration Open
8:10 a.m. – 9:45 a.m.	Opening General Session
9:30 a.m. – 6:30 p.m.	Exhibit Hall Open
9:30 a.m. – 10:15 p.m.	Coffee Break in Exhibit Hall
10:30 a.m. – 5:30 p.m.	Technical Sessions
Noon – 1:30 p.m.	Lunch in Exhibit Hall
5:30 p.m. – 6:30 p.m.	Social Hour in Exhibit Hall

Thursday, December 4, 2025	
7:30 a.m. – 3:00 p.m.	Registration Open
8:30 a.m. – 4:30 p.m.	Technical Sessions
9:30 a.m. – 1:30 p.m.	Exhibit Hall Open
9:45 a.m. – 10:30 p.m.	Coffee Break
Noon – 1:15 p.m.	Lunch in Exhibit Hall
4:30 p.m. – 5:00 p.m.	Closing Sessions & Awards

QUESTIONS?

Steve Cavanaugh| President/CEO | steve.cavanaugh@cavanaughsolutions.com 336.816.3582