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Best Practices for Production Flow Data Management for Water Utilities

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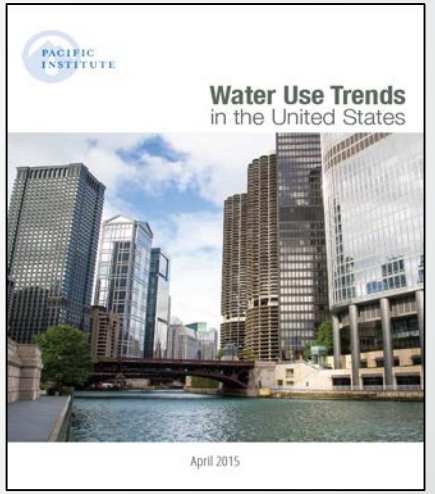
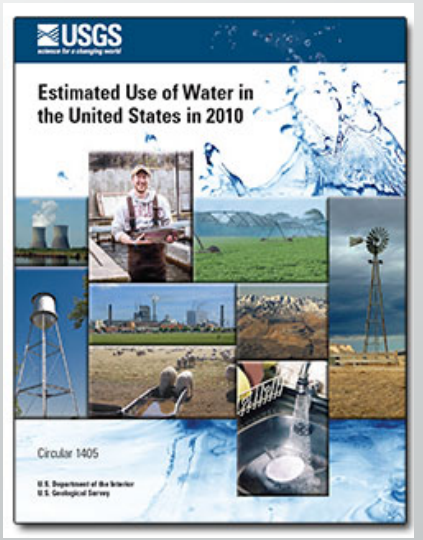
Water "Use" Reporting and Trends

- Pacific Institute Report: Water Use Trends in the United States (2015)
- United States Geologic Survey Report: Estimated Water Use of Water in the United States in 2010 (published every 5 years)
  - Both reports highlight the distinct drop in the estimate of water used from 2005 to 2010; water use is now lower than 1970 levels
    - Thermoelectric power – down 20%
    - Agriculture – down 9%
    - Public water supply – down 5%
  - Water "Use" vs. water "Used"
  - These reports actually document estimates of water withdrawals by "category of use"
  - Water "use" in the Public Water Supply sector is recognized to include system leakage, and various occurrences of unauthorized consumption, and unbilled authorized consumption





Water "Use" Across the Sectors

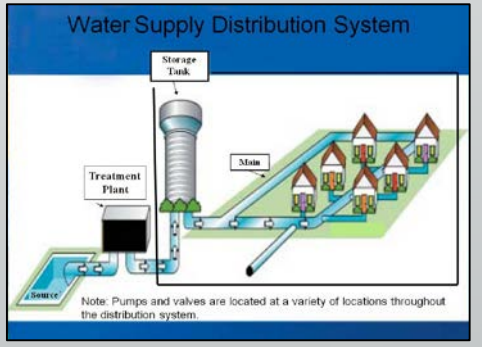
- Thermoelectric Power, Agricultural Irrigation are the largest sectors for use of water
  - These uses employ mostly untreated water
- Public Water Supply is 3rd largest, however:
  - Public water supply is the highest value resource since water has been treated and energized for distribution
  - Public water supply is supported by the most extensive infrastructure of the 3 largest sectors
  - Public water supply collects revenues from large numbers of customer compared to power and agriculture
- **But, how accurate is the data reported to USGS? Let's look closer at the public water supply sector**

Thermoelectric Power 161 bgd

Photo source: USGS

Agriculture 115 bgd

Photo source: Environment Magazine

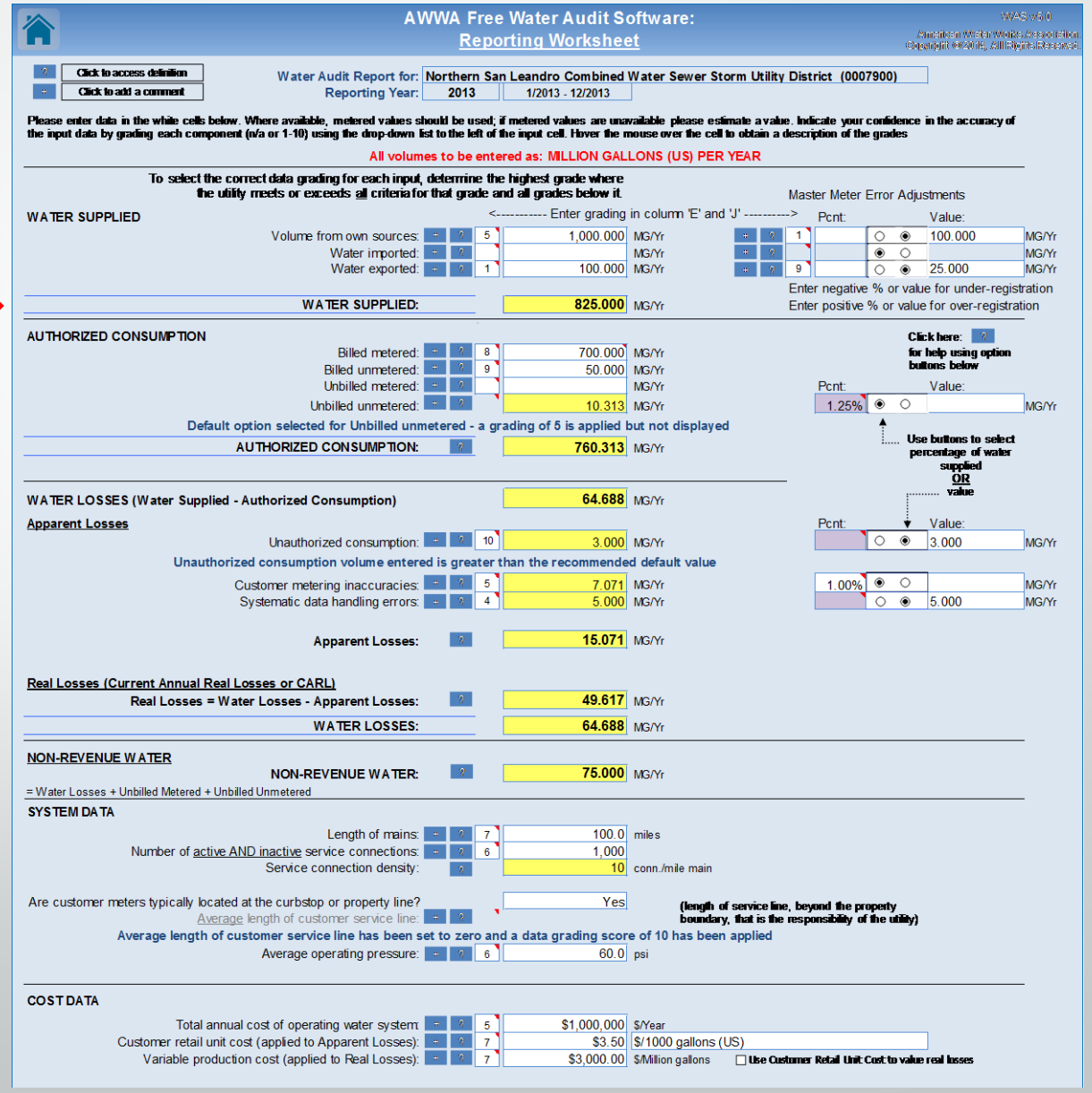


Public Water Supply 42 bgd

Graphic Source: USEPA

AWWA Free Water Audit Software

- Water Supplied Volume includes:
  - Volume from own sources
  - Water Imported
  - Water Exported
  - Master Meter Error Adjustments for each of these subcomponents
- Collectively the largest volumes in the water audit
- Usually measured by the largest flowmeters in the water utility
- Most Important Volume in the Water Audit



AWWA Free Water Audit Software:
Reporting Worksheet

Water Audit Report for: Northern San Leandro Combined Water Sewer Storm Utility District (0007900)
Reporting Year: 2013 (1/2013 - 12/2013)

Please enter data in the white cells below. Where available, metered values should be used; if metered values are unavailable please estimate a value. Indicate your confidence in the accuracy of the input data by grading each component (n/a or 1-10) using the drop-down list to the left of the input cell. Hover the mouse over the cell to obtain a description of the grades

All volumes to be entered as: MILLION GALLONS (US) PER YEAR

To select the correct data grading for each input, determine the highest grade where the utility meets or exceeds all criteria for that grade and all grades below it.

Master Meter Error Adjustments

WATER SUPPLIED

			Pcnt:	Value:	
Volume from own sources:	5	1,000.000 MG/Yr	1	100.000	MG/Yr
Water imported:		MG/Yr			MG/Yr
Water exported:	1	100.000 MG/Yr	9	25.000	MG/Yr

Enter negative % or value for under-registration
Enter positive % or value for over-registration

WATER SUPPLIED: 825.000 MG/Yr

AUTHORIZED CONSUMPTION

Click here: for help using option buttons below

			Pcnt:	Value:	
Billed metered:	8	700.000 MG/Yr			
Billed unmetered:	9	50.000 MG/Yr			
Unbilled metered:		MG/Yr			
Unbilled unmetered:		10.313 MG/Yr	1.25%		MG/Yr

Default option selected for Unbilled unmetered - a grading of 5 is applied but not displayed

AUTHORIZED CONSUMPTION: 760.313 MG/Yr

Use buttons to select percentage of water supplied OR value

WATER LOSSES (Water Supplied - Authorized Consumption) 64.688 MG/Yr

Apparent Losses

			Pcnt:	Value:	
Unauthorized consumption:	10	3.000 MG/Yr		3.000	MG/Yr

Unauthorized consumption volume entered is greater than the recommended default value

Customer metering inaccuracies:	5	7.071 MG/Yr	1.00%		MG/Yr
Systematic data handling errors:	4	5.000 MG/Yr		5.000	MG/Yr

Apparent Losses: 15.071 MG/Yr

Real Losses (Current Annual Real Losses or CARL)

Real Losses = Water Losses - Apparent Losses: 49.617 MG/Yr

WATER LOSSES: 64.688 MG/Yr

NON-REVENUE WATER

NON-REVENUE WATER: 75.000 MG/Yr

= Water Losses + Unbilled Metered + Unbilled Unmetered

SYSTEM DATA

Length of mains:	7	100.0	miles
Number of active AND inactive service connections:	6	1,000	
Service connection density:		10	conn./mile main

Are customer meters typically located at the curbstop or property line? Yes

Average length of customer service line: (length of service line, beyond the property boundary, that is the responsibility of the utility)

Average length of customer service line has been set to zero and a data grading score of 10 has been applied

Average operating pressure: 6 60.0 psi

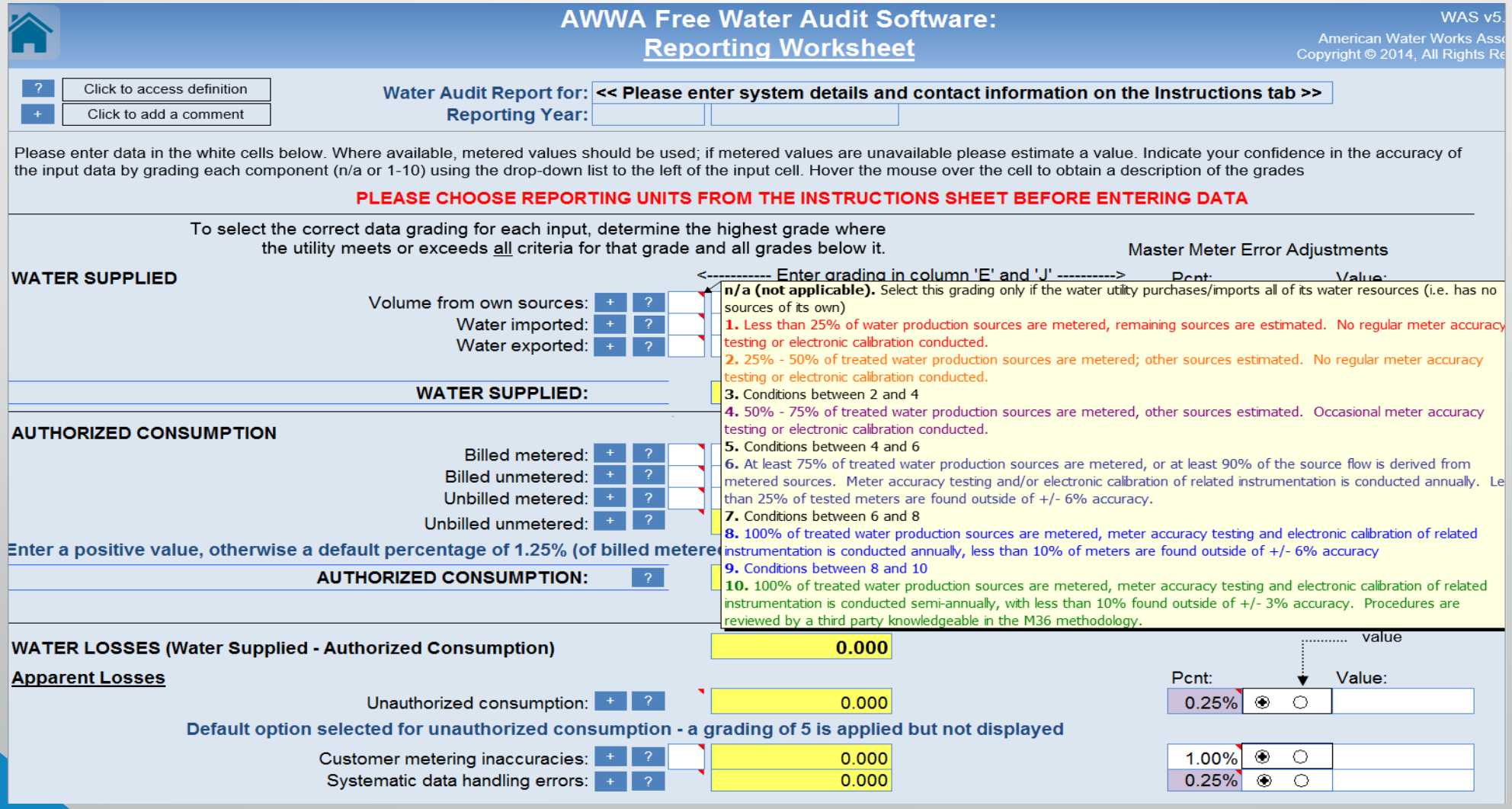
COST DATA

Total annual cost of operating water system:	5	$1,000,000	$/Year
Customer retail unit cost (applied to Apparent Losses):	7	$3.50	$/1000 gallons (US)
Variable production cost (applied to Real Losses):	7	$3,000.00	$/Million gallons

Use Customer Retail Unit Cost to value real losses

AWWA Free Water Audit Software
Data Grading and Validation

- Grading reflects the level of proper management of meters and data

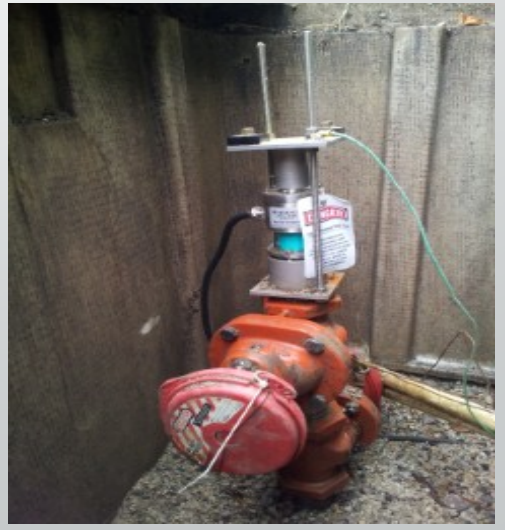


Production Flowmeters Used in Water Utilities

- Meters used in high flowrate applications
  - Venturi meters
  - Orifice meters
  - Magnetic meters
  - Ultrasonic meters
- Meters used in medium, low flowrate applications
  - Turbine
  - Propeller
  - Positive Displacement

36-inch Venturi Meter
(Courtesy of Primary Flow Control)

60-inch magnetic flowmeter being installed in Philadelphia, PA



Insertion magnetic flowmeter in use on a 30-in. pipeline in Birmingham, Al

Production Meters
Selection, Installation and Accuracy Testing

- Unfortunately, many flowmeters installations are:
  - Improper typed
  - Poorly sited
  - Rarely have maintenance conducted on the meter
  - Seldom tested for accuracy
  - Data produced is taken verbatim as accurate
- Unfortunately flowmeter data is not always reliably balanced across the distribution system to produce an accurate Water Supplied volume
- Production Meter Accuracy testing in State of GA
  - 78 flowmeter installations considered for testing
  - 49% failed, 33% Untestable, 18% passed

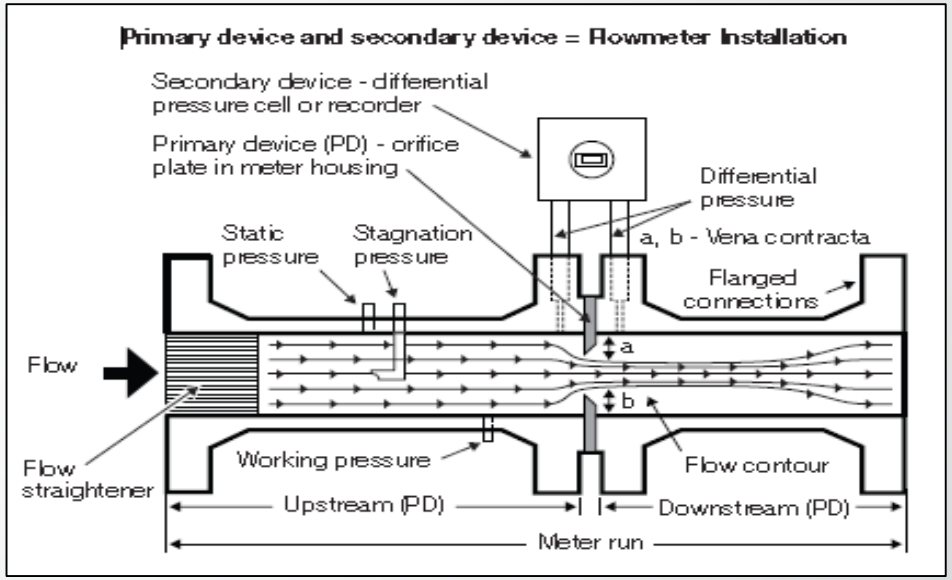
Venturi meter with valve in the throat

Maze of pipe bends downstream of above meter

Flowmeter Accuracy Testing

Verification vs. Calibration

- Verification confirms the accuracy of the primary device – the element that measures the flow of water
- 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 meter accuracy testing. Thus, inaccuracies can be carried through to reports

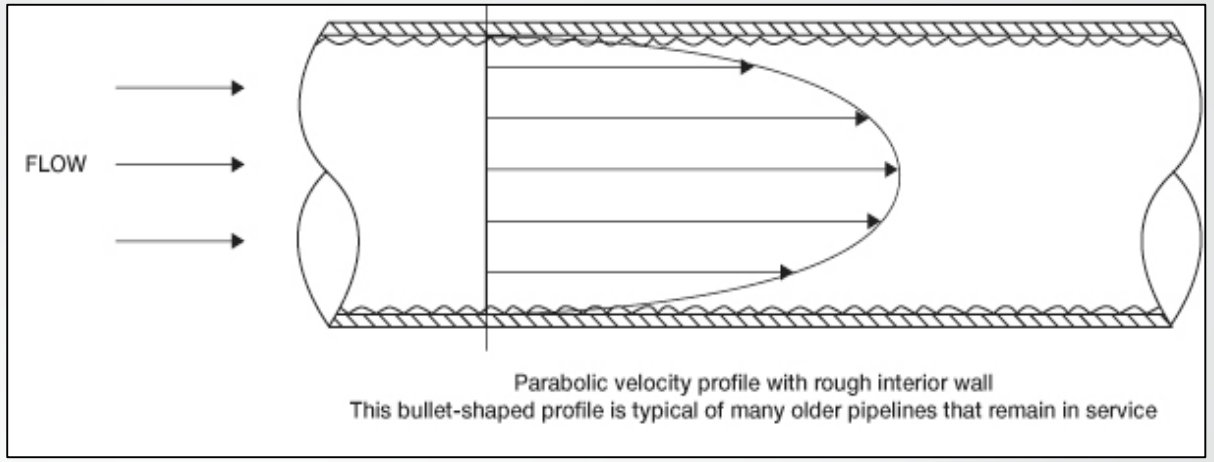


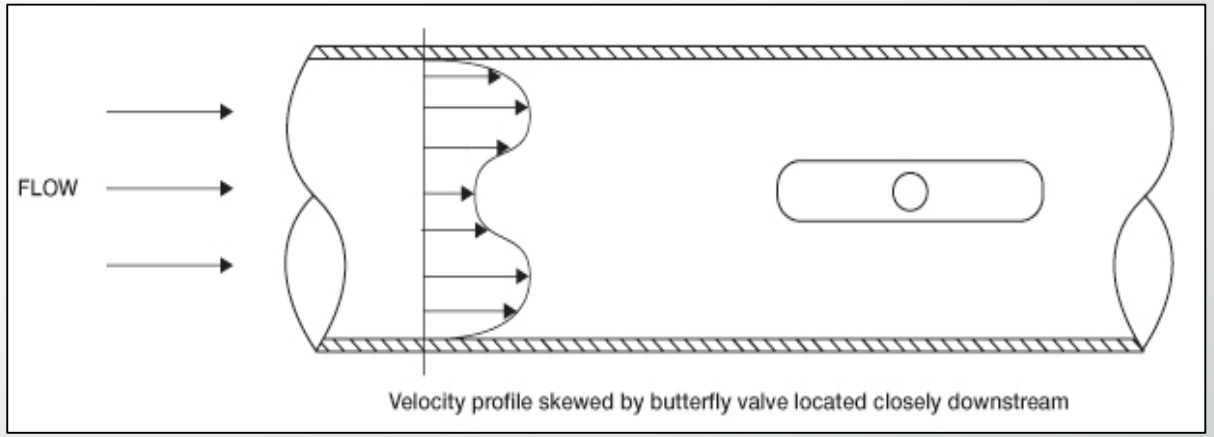
Orifice Plate Flowmeter components

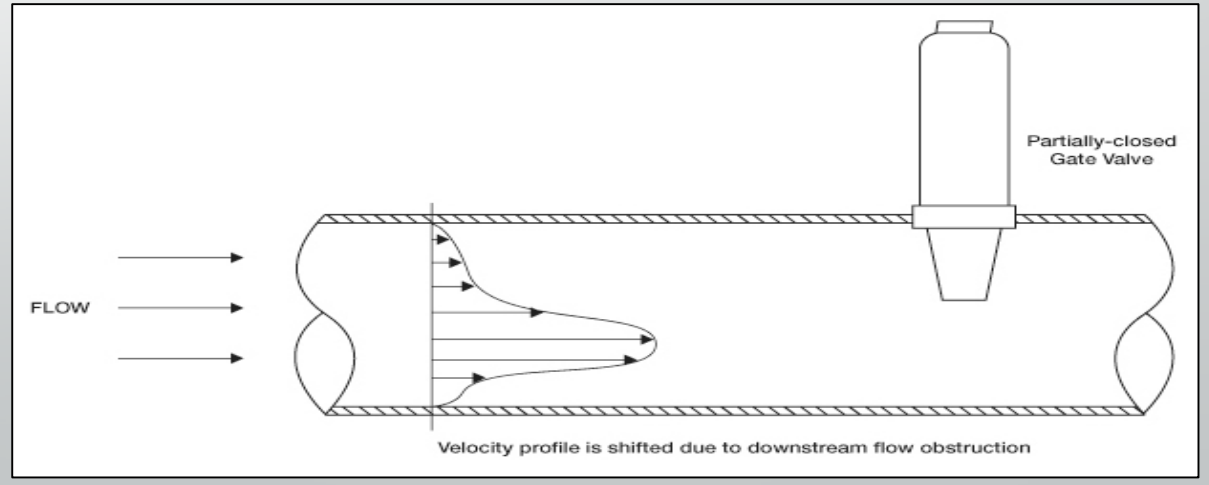
Bank of Differential Pressure Cells connected to flowmeters (Courtesy of Louisville Water Company)

Basic Pipeline Hydraulics

- Friction forces along the pipe wall slow the flow often giving the bullet-shaped velocity profile at top
- Obstructions close to a point of measurement (such as a flowmeter) cause a distorted velocity profile
- Good design will avoid the occurrence of distorted flow profiles
- Knowing the true velocity profile near a flowmeter is important to obtaining a representative meter accuracy test







Testing Large Flowmeters for Accuracy

- Large flowmeters - can use insertion or strap-on portable meters in series with the host meter
- Smaller flowmeters – can test with truck mounted meter testing apparatus (same as testing large customer meters)
- Small flowmeters – rotate out and test at meter accuracy test bench

Pitot rod inserted into large pipeline

Meter testing via truck mounted apparatus
(Courtesy of Louisville Water Company)

Poor meter configuration that doesn't allow testing

Recommendations for proper meter siting

- Flowmeter designers should allow for ample upstream (and downstream) distance in order to provide for a smooth flow profile
- Flowmeter considerations should be a primary part of the design process – not a secondary consideration left to chance of the installer

Flowmeter Type	Recommended Lengths of Straight Pipe* (stated in terms of number of upstream pipe diameters for the given metering application)
Venturi	4–10 diameters—depending on the type of any flow-disturbing obstruction in the pipeline
Orifice	5 diameters
Flow tube	4–10 diameters—depending on the type of any flow-disturbing obstruction in the pipeline
Pitot tube	10 diameters
Propeller	5 diameters
Turbine	10 diameters—assuming a flow-straightening element is used (25 to 30 pipe diameters otherwise)
Magnetic	5 diameters
Ultrasonic (Doppler shift)	7–10 diameters
Ultrasonic (pulse transmission†)	7–10 diameters (and 5 diameters downstream)

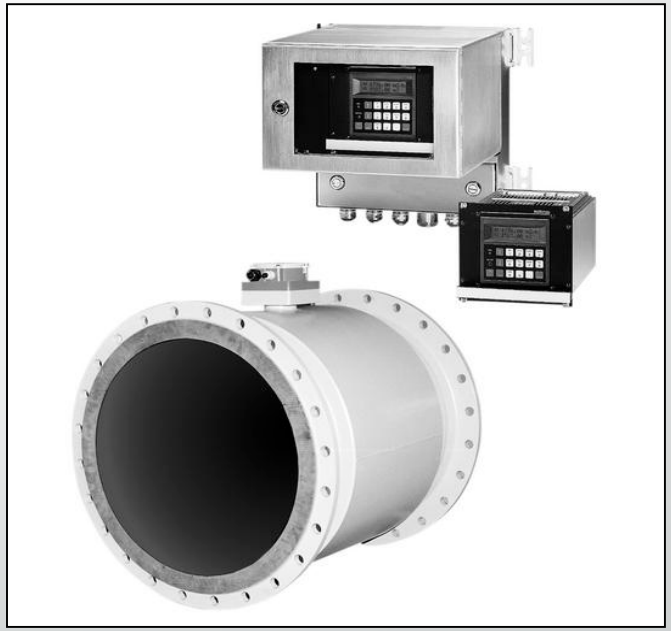
*Information is based on engineering judgment and conservative best practice observed in the water industry by AWWA Water Loss Control Committee members

†Includes transit time flowmeters

Accurately Quantifying the Water Supplied Volume

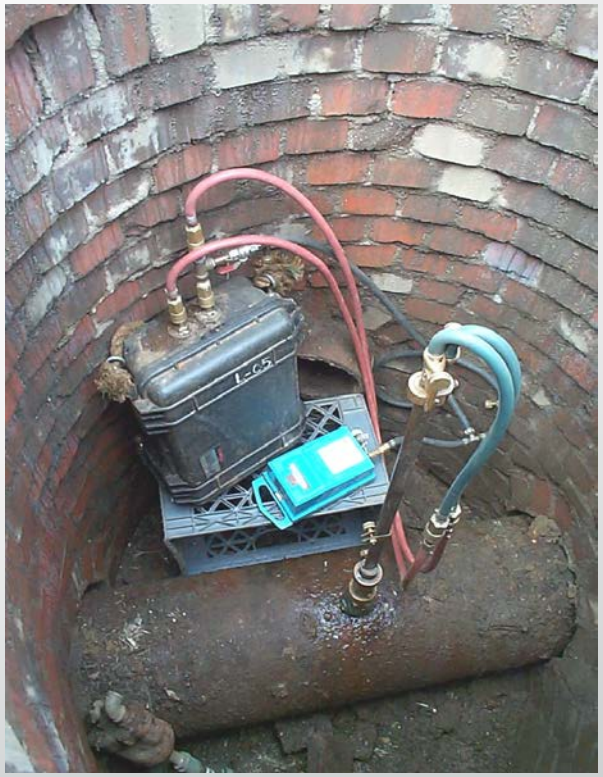
Several steps can exist to reliably quantify the Water Supplied Volume

1. Source water, imported water and exported water should always be metered
    a. Ideally, these meters should be the continuously recording type ideally linked to a Supervisory control and data acquisition (SCADA) System
    b. If meters are not linked to a SCADA System, then data should be collected as frequently as possible, at least weekly
    c. If meters are not continuously recording type, and are read infrequently, plan to upgrade the metering installation as soon as possible



Accurately Quantifying the Water Supplied Volume

2. Meters should be regularly verified for accuracy
    a. Large meters can be compared with an inline insertion or strap-on meter measuring flow downstream of the primary meter
        i. Make certain that the temporary metering location is representative and accurate
        ii. Strive for minimum 24-hr period if using this method
        iii. Philadelphia Water Department conducts over 50 verifications each year in this manner
    b. Smaller meters might be tested using field test apparatus as is conducted on large customer meters
    c. Document/store the inaccuracy values to serve as a basis for data adjustments



Insertion pitot rod measuring and recording flow

Accurately Quantifying the Water Supplied Volume

3. Meters should be tested, recalibrated, repaired or replaced regularly to maintain reliable performance
    a. New, current-technology meters should replace dated or defective meters
    b. Permanently installed insertion type meters can be a less costly means of establishing or renewing reliable metering
    c. Refer to AWWA M33 guidance manual "Flowmeters in Water Supply" for information on meter selection
    d. Many dated meters exist throughout the North American water industry

Magnetic Flow meter replacement on 48-inch untreated water line 2008 in Philadelphia

Accurately Quantifying the Water Supplied Volume

4. Determine the Master Meter Error Adjustment
   a. Adjust for recorded inaccuracy levels of given meters – accuracy testing results define the level of inaccuracy for each tested flowmeter
   b. Aggregate master meter error is:
      i. Added if source meter under-registration exists
      ii. Subtracted if source meter over-registration exists

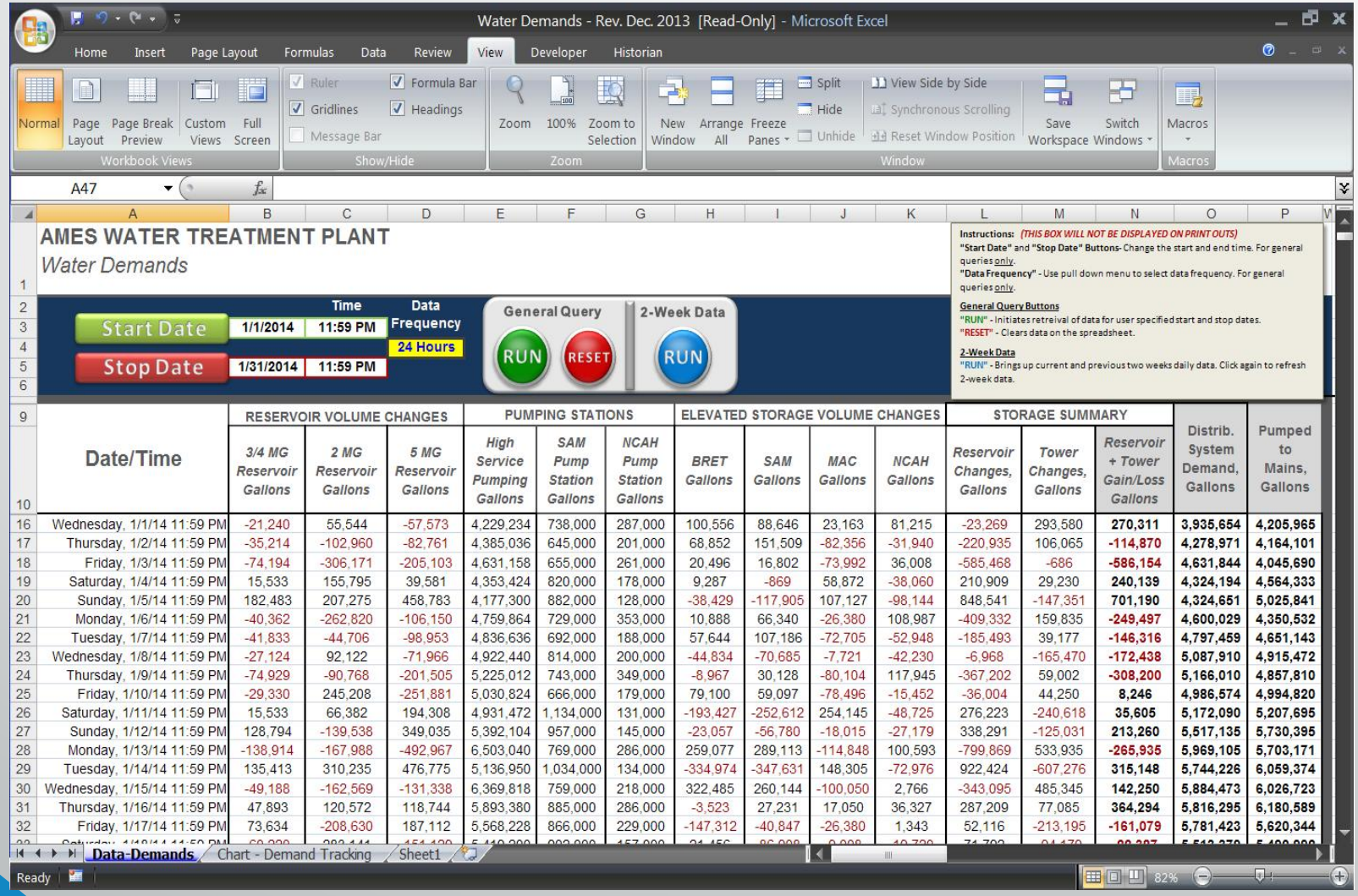
16-inch turbine meter on wholesale water supply pipeline being verified via inline pitot rod

Accurately Quantifying the Water Supplied Volume

5. Regularly balance supplies across the water distribution system to arrive at the Water Supplied Volume
    a. Use spreadsheet reports to tabulate water flowing in/out of all parts of the distribution system – on a daily basis
    b. Data should be reviewed at least weekly, but ideally, each business day, for trends/anomalies
    c. Storage tank/reservoir levels should be monitored and recorded, and influent/effluent metered as practical
    d. Water transfers among pressure zones or District Metered Areas (DMA) should be metered and recorded
    e. Make adjustments to correct data errors
    f. Make adjustments to correct data gaps

Philadelphia "Map Board" showing pressure districts, pressures and storage elevations (Courtesy of the Philadelphia Water Department)

Detailed Monitoring of Supply across the distribution system



Date/Time	RESERVOIR VOLUME CHANGES			PUMPING STATIONS			ELEVATED STORAGE VOLUME CHANGES				STORAGE SUMMARY			Distrib. System Demand, Gallons	Pumped to Mains, Gallons
	3/4 MG Reservoir Gallons	2 MG Reservoir Gallons	5 MG Reservoir Gallons	High Service Pumping Gallons	SAM Pump Station Gallons	NCAH Pump Station Gallons	BRET Gallons	SAM Gallons	MAC Gallons	NCAH Gallons	Reservoir Changes, Gallons	Tower Changes, Gallons	Reservoir + Tower Gain/Loss Gallons		
Wednesday, 1/1/14 11:59 PM	-21,240	55,544	-57,573	4,229,234	738,000	287,000	100,556	88,646	23,163	81,215	-23,269	293,580	270,311	3,935,654	4,205,965
Thursday, 1/2/14 11:59 PM	-35,214	-102,960	-82,761	4,385,036	645,000	201,000	68,852	151,509	-82,356	-31,940	-220,935	106,065	-114,870	4,278,971	4,164,101
Friday, 1/3/14 11:59 PM	-74,194	-306,171	-205,103	4,631,158	655,000	261,000	20,496	16,802	-73,992	36,008	-585,468	-686	-586,154	4,631,844	4,045,690
Saturday, 1/4/14 11:59 PM	15,533	155,795	39,581	4,353,424	820,000	178,000	9,287	-869	58,872	-38,060	210,909	29,230	240,139	4,324,194	4,564,333
Sunday, 1/5/14 11:59 PM	182,483	207,275	458,783	4,177,300	882,000	128,000	-38,429	-117,905	107,127	-98,144	848,541	-147,351	701,190	4,324,651	5,025,841
Monday, 1/6/14 11:59 PM	-40,362	-262,820	-106,150	4,759,864	729,000	353,000	10,888	66,340	-26,380	108,987	-409,332	159,835	-249,497	4,600,029	4,350,532
Tuesday, 1/7/14 11:59 PM	-41,833	-44,706	-98,953	4,836,636	692,000	188,000	57,644	107,186	-72,705	-52,948	-185,493	39,177	-146,316	4,797,459	4,651,143
Wednesday, 1/8/14 11:59 PM	-27,124	92,122	-71,966	4,922,440	814,000	200,000	-44,834	-70,685	-7,721	-42,230	-6,968	-165,470	-172,438	5,087,910	4,915,472
Thursday, 1/9/14 11:59 PM	-74,929	-90,768	-201,505	5,225,012	743,000	349,000	-8,967	30,128	-80,104	117,945	-367,202	59,002	-308,200	5,166,010	4,857,810
Friday, 1/10/14 11:59 PM	-29,330	245,208	-251,881	5,030,824	666,000	179,000	79,100	59,097	-78,496	-15,452	-36,004	44,250	8,246	4,986,574	4,994,820
Saturday, 1/11/14 11:59 PM	15,533	66,382	194,308	4,931,472	1,134,000	131,000	-193,427	-252,612	254,145	-48,725	276,223	-240,618	35,605	5,172,090	5,207,695
Sunday, 1/12/14 11:59 PM	128,794	-139,538	349,035	5,392,104	957,000	145,000	-23,057	-56,780	-18,015	-27,179	338,291	-125,031	213,260	5,517,135	5,730,395
Monday, 1/13/14 11:59 PM	-138,914	-167,988	-492,967	6,503,040	769,000	286,000	259,077	289,113	-114,848	100,593	-799,869	533,935	-265,935	5,969,105	5,703,171
Tuesday, 1/14/14 11:59 PM	135,413	310,235	476,775	5,136,950	1,034,000	134,000	-334,974	-347,631	148,305	-72,976	922,424	-607,276	315,148	5,744,226	6,059,374
Wednesday, 1/15/14 11:59 PM	-49,188	-162,569	-131,338	6,369,818	759,000	218,000	322,485	260,144	-100,050	2,766	-343,095	485,345	142,250	5,884,473	6,026,723
Thursday, 1/16/14 11:59 PM	47,893	120,572	118,744	5,893,380	885,000	286,000	-3,523	27,231	17,050	36,327	287,209	77,085	364,294	5,816,295	6,180,589
Friday, 1/17/14 11:59 PM	73,634	-208,630	187,112	5,568,228	866,000	229,000	-147,312	-40,847	-26,380	1,343	52,116	-213,195	-161,079	5,781,423	5,620,344

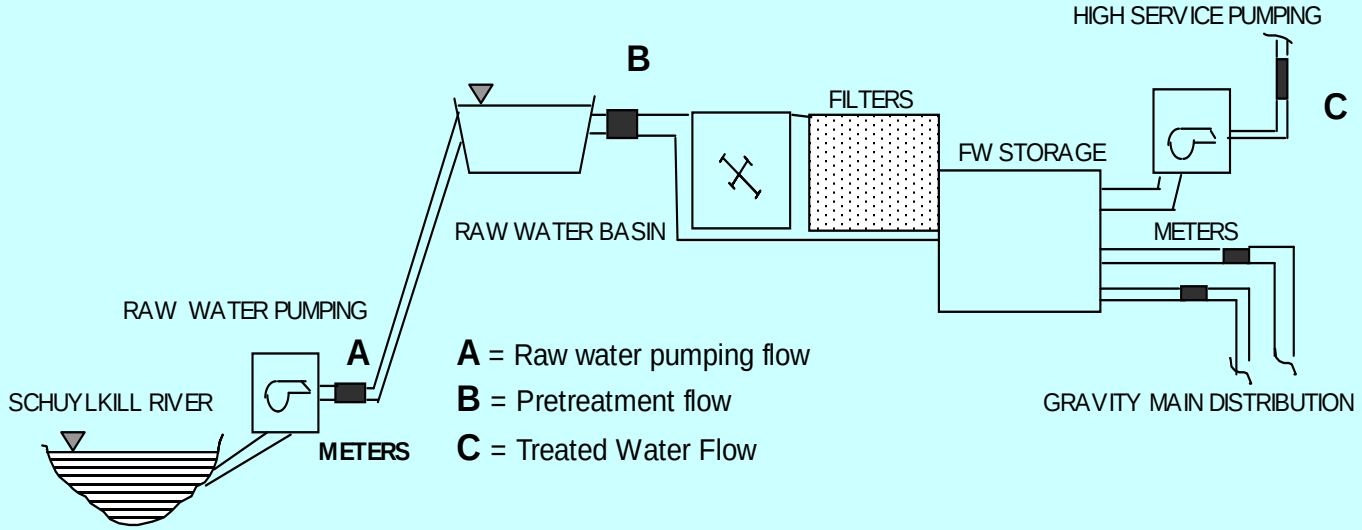
Daily tracking allows unusual variations to be detected and data corrected

Instrument outages, tank draining/filling, tank overflows can be detected and/or observed by closely watching data

Courtesy of the City of Ames, IA

Philadelphia's "Mass Balance" Technique to Monitor Production Meter Performance

PHILADELPHIA WATER DEPARTMENT
QUEEN LANE WATER TREATMENT PLANT CONFIGURATION



Plant Output = Meter Rates **C** +/- Changes in Volume of Filtered Water Storage Basins

SYSTEM LOSSES

A to **B:** Loss in transmission mains, flume, and raw water basin leakage; typically 1% - 2% of raw water pumped

B to **C:** Loss in treatment process; chemical application, filter backwash, typically 5% - 8% of raw water pumped

A to **C:** Overall total = sum of **A** to **B** and **B** to **C** and metering inaccuracies; typically 7% - 10%

(Note: changes in raw water basin and filtered water storage basins are included when determing loss)

Philadelphia's "Mass Balance" Technique to Monitor Production Meter Performance

PHILADELPHIA WATER DEPARTMENT
QUEEN LANE WATER TREATMENT PLANT
FILTER PLANT MASS BALANCE REPORT

DATE	PLANT MASTER METERS			WATER LOSS					
	A RAW WATER +/- EVEV (MG)	**B** PRETREAT (MG)	**C** FILTER EFFLUENT (MG)	**A - B** (MG)	(%)	**B - C** (MG)	(%)	**A - C** (MG)	(%)
06/01/12	56.82	55.90	51.55	0.92	1.61	4.35	7.78	5.27	9.27
06/02/12	57.69	56.60	52.17	1.09	1.89	4.43	7.83	5.52	9.57
06/03/12	58.16	57.10	52.75	1.06	1.82	4.35	7.62	5.41	9.31
06/04/12	56.77	55.90	51.56	0.87	1.53	4.34	7.76	5.21	9.17
06/05/12	58.50	57.50	53.02	1.00	1.71	4.48	7.80	5.48	9.37
06/06/12	57.82	56.80	52.33	1.02	1.77	4.47	7.86	5.49	9.50
06/07/12	57.03	56.00	52.03	1.03	1.81	3.97	7.10	5.01	8.78
06/08/12	57.19	56.30	51.99	0.89	1.55	4.31	7.65	5.19	9.08
06/09/12	57.92	56.90	52.81	1.02	1.76	4.09	7.19	5.11	8.82
06/10/12	58.01	57.00	52.57	1.01	1.75	4.43	7.78	5.45	9.39
TOTAL	575.9	566.0	522.8	9.9		43.2		53.1	
AVERAGE	57.6	56.6	52.3	1.0	1.7	4.3	7.6	5.3	9.2
MAXIMUM	58.5	57.5	53.0	1.1	1.9	4.5	7.9	5.5	9.6
MINIMUM	56.8	55.9	51.6	0.9	1.5	4.0	7.1	5.0	8.8

Adjusting for Data Gaps

- 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

Example of Water Pumping Data Gaps and Adjustments			
8/15/2012, hrs	High Service Pumping Rate, mgd actual flow	High Service Pumping Rate, mgd raw recorded data	High Service Pumping Rate, mgd adjusted data
0:00	8.69	8.69	8.69
1:00	8.65	8.65	8.65
2:00	8.32	8.32	8.32
3:00	8.11	8.11	8.11
4:00	7.94	0	8
5:00	8.02	0	8
6:00	8.44	0	8
7:00	8.98	0	9
8:00	9.34	0	9.3
9:00	9.25	0	9.3
10:00	9.17	0	9.3
11:00	9.12	9.12	9.12
12:00	9.27	9.27	9.27
13:00	9.22	9.22	9.22
14:00	9.08	9.08	9.08
15:00	8.99	8.99	8.99
16:00	9.14	9.14	9.14
17:00	9.18	9.18	9.18
18:00	9.25	9.25	9.25
19:00	9.22	9.22	9.22
20:00	8.82	8.82	8.82
21:00	8.78	8.78	8.78
22:00	8.75	8.75	8.75
23:00	8.71	8.71	8.71
0:00	8.68	8.68	8.68
Total	**212.43**	**151.29**	**212.19**
Average	**8.85**	**6.30**	**8.84**
Difference		**2.55**	**0.01**

Assembling Data for the Annual Water Audit

SCADA “A” history: raw data from the field

SCADA “B” history: corrected, final data

Philadelphia Water Department

Composite Water System Input Adjustments - Fiscal Year 2011

Month	Number of days	Original SCADA System data: unedited daily average water system input based on SCADA A history	Monthly total system input volume based on original (unedited) total delivery - MG	Average daily system input volume based on edited SCADA B history report-MGD*	Monthly total system input volume based on edited SCADA B history report-MG	Difference
July'10	31	276.9	8583.2	276.0	8556.4	-0.9
Aug'10	31	263.1	8155.9	262.3	8131.7	-0.8
Sep'10	30	257.7	7732.0	253.2	7594.5	-4.6
Oct'10	31	244.6	7582.5	239.0	7408.5	-5.6
Nov'10	30	243.6	7309.1	239.9	7196.1	-3.8
Dec'10	31	252.5	7828.5	251.4	7792.4	-1.2
Jan'11	31	264.1	8186.7	262.7	8143.1	-1.4
Feb'11	28	258.5	7237.9	256.8	7191.0	-1.7
Mar'11	31	248.0	7687.4	239.0	7408.6	-9.0
Apr'11	30	238.4	7151.9	231.0	6929.4	-7.4
May'11	31	241.1	7473.2	237.3	7355.8	-3.8
Jun'11	30	256.2	7684.7	251.7	7551.6	-4.4
Sum	365		92613.0		91259.1	1353.9
Average			**253.7**		**250.0**	3.7

*Adjustments are based upon several factors including regular master meter verification testing, mass balance comparisons of flows into and out of water treatment plants, operational histories at facilities and instrumentation history.

Summary

- USGS Water "Use" Report reveals a notable declining trend in water withdrawals for all major sectors
- Water withdrawal data in public water supplies is not always managed with strong accuracy due to
  - Inappropriate, dated, poorly monitored flowmeters
  - Insufficient surveillance of production data and lack of proper QA/QC on the data
- Accurate water withdrawal data is needed to assess water resources management at the macro-level, and to assist water efficiency efforts at the micro-level
- Drinking water utilities have the opportunity to investigate the performance of their supply sources and flowmeters and bring their practices up-to-date
- Forthcoming 4th Edition of the AWWA M36 manual will provide detailed guidance on production flowmeters and production data management