2018 REPORTING TEMPLATE WORKSHOP
CALCULATION OF UNKNOWN LEAKS

Ed Newton 01/17/2019

Overview – Proposed Revisions to Calculation of Unknown Leaks

- Appendix 4 Distribution Leaks – Unknown Leaks Tab
- Unknown Leaks Calculation Methodology and Formulas
  - Formula Correction to allow use of actual survey mileage rather than average mileage (approved and used for 2017 report)
  - Formula Correction to calculate number of Unknown Leaks
    - Original equation incorrectly used total system mileage rather than the portion of the system not surveyed
  - Propose approach to smooth Year-over-Year Variation of Calculated System Leak Rates

Unknown Leaks Equation Improvement

» Improvement #1: Using Actual Survey Mileage

- Original Equation used to estimate the number of Unknown Leaks (used in 2016 & 2017 Annual Report)
  - $\boldsymbol{N_{X,unk} = R_X \times C_I \times M_{X,I} \times I}$
    - R_X= Annual Leak Rate [Leaks/Mile/Yr], $R_X = \frac{N_{X,L}}{M_{X,A}+(I \times M_{X,I})}$
    - C_I= Multi-year Constant
    - $M_{X,I}$= Average Miles Surveyed Annually from Multi-year Survey cycle
    - I= Survey Interval
- Revised Equation (used in 2018 Annual Report)
  - $\boldsymbol{N_{X,unk} = R_X \times C_I \times M_X^{Tot}}$
    - M_X^{Tot}= Total Miles on Multi-year Survey Cycles
- Justification:
  - The factors $M_{X,I} \times I$ in the original equation calculates the total miles on multi-year survey (M_X^{Tot})
  - When using actual survey miles the result would over or underestimate the system total by the difference between the straight percentage and the actual mileage times the interval of the cycle ($M_{X,I}^{actual} \times I \neq M_X^{Tot}$).

Unknown Leaks Equation Correction

» Improvement #2: Unsurveyed Portion of the System

- Original Equation (used in 2016 & 2017 Annual Report)
  - $N_{X,unk} = R_X \times C_I \times M_{X,I} \times I$
- Proposed Equation
  - $N_{X,unk} = R_X \times C_I \times M_{X,I} \times I \xrightarrow{Substitute\ M_{X,I} = \frac{M_X^{Tot} - M_{X,I}}{I-1}} N_{X,unk} = R_X \times C_I \times \left(\frac{M_X^{Tot} - M_{X,I}}{I-1}\right) \times I$ **(Form 1)**

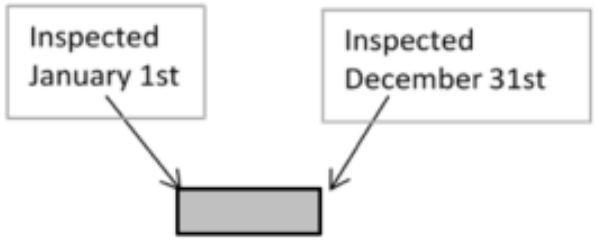
$$\xrightarrow{Substitute\ C_I = \frac{I-1}{2}} N_{X,unk} = R_X \times \left(\frac{I-1}{2}\right) \times \left(\frac{M_X^{Tot} - M_{X,I}}{I-1}\right) \times \frac{I}{2}$$

$$\xrightarrow{Simplify\ (I-1)} N_{X,unk} = R_X \times \left(M_X^{Tot} - M_{X,I}\right) \times \frac{I}{2}$$ **(Form 2)**

- Justification:
  - Multi-year Constant C_I derived from Unsurveyed portion of the system (see next slide)

Unknown Leaks – Derivation of Interval Constant

- Inspection Frequency = 5 years
- Leak Odds = the rate that leakage develops over time for the portion of the system not surveyed in the report year.



Yr 1	Yr 2	Yr 3	Yr 4	Yr 5

Pipe Section	On January 1st			On December 31st			Yearly Average**
	Leak odds		Length Average*	Leak odds		Length Average*	
	Start	End		Start	End		
Length 1	$\frac{4}{5}$	$\frac{3}{5}$	$\frac{3.5}{5}$	$\frac{5}{5}$	$\frac{4}{5}$	$\frac{4.5}{5}$	$\frac{4}{5}$
Length 2	$\frac{3}{5}$	$\frac{2}{5}$	$\frac{2.5}{5}$	$\frac{4}{5}$	$\frac{3}{5}$	$\frac{3.5}{5}$	$\frac{3}{5}$
Length 3	$\frac{2}{5}$	$\frac{1}{5}$	$\frac{1.5}{5}$	$\frac{3}{5}$	$\frac{2}{5}$	$\frac{2.5}{5}$	$\frac{2}{5}$
Length 4	$\frac{1}{5}$	0	$\frac{0.5}{5}$	$\frac{2}{5}$	$\frac{1}{5}$	$\frac{1.5}{5}$	$\frac{1}{5}$
Total							$C_5 = \frac{10}{5} = 2$

*Length Average = (Start + End)/2
**Yearly Average = (Length Average$_{\text{Jan 1st}}$+Length Average$_{\text{Dec 31st}}$)/2

System Leak Rates - Moving (Trailing) Average

Facility/Material	Annual Leak Rate [Leaks / Mile / Yr] $R_X = \frac{N_{X,L}}{M_{X,A} + (I \times M_{X,I})}$ 2015 Annual Leak Rate [$R_{X,1}$]	2016 Annual Leak Rate [$R_{X,2}$]	2017 Annual Leak Rate [$R_{X,3}$]	3-Year Average Leak Rate [Leaks / Mile / Yr] $\overline{R_X} = \frac{1}{3}\sum_{i=1}^{3} R_{X,i}$	# of Unknown Leaks using 3-Year Average Leak Rate $N_{X,unk} = \overline{R_X} \times C_I \times M_X^{Tot}$	# of Unknown Leaks using 3-Year Average Leak Rate & Proposed Equation for Unk. Leak $N_{X,unk} = \overline{R_X} \times C_I \times \left(\frac{M_X^{Tot} - M_{X,I}}{I-1}\right) \times I$ $N_{X,unk} = \overline{R_X} \times (M_X^{Tot} - M_{X,I}) \times \frac{I}{2}$
Main/Plastic	0.0196	0.0188	0.0207	0.0197	714	693
Main/Unprotected Steel	0.2294	0.2354	0.2232	0.2294	997	934
Main/Protected Steel	0.0039	0.0068	0.0078	0.0061	119	117
Service/Plastic	0.0260	0.0240	0.0233	0.0244	1,015	950
Service/Unprotected Steel	0.1239	0.1109	0.1360	0.1236	756	849
Service/Protected Steel	0.0126	0.0184	0.0215	0.0175	186	174
			N/A	N/A	**3,787**	**3,718**

- For 2018 report, data will be used from 2016 and 2017 reports to calculate the average
- Does not correct for cases where leak survey cycles were accelerated
- By using simplified form of the equation the column for the interval constant could be eliminated

Appendix 4 – Unsurveyed Pipeline Leaks
Example of Proposed Revised Table

Facility/Material	Total System Miles per material type	Miles on Annual Survey [$M_{X,A}$]	Miles on Multi-Year Survey Cycles [M^{Tot}_{X}]	Survey Interval (yrs) [I]	Miles Surveyed Annually from Multi-Year Survey Cycles [$M_{X,I}$]	Total # of Leaks Detected from Survey [$N_{X,L}$]	2016 Annual Leak Rate [$R_{X,1}$]	2017 Annual Leak Rate [$R_{X,2}$]	2018 Annual Leak Rate [$R_{X,3}$] $R_{X,3} = \frac{N_{X,L}}{M_{X,A} + (I \times M_{X,I})}$	3-year Average Leak Rate [Leaks / Mile / Yr] $\overline{R_X} = \frac{1}{3}\sum_{i=1}^{3} R_{X,i}$	# of Unknown Leaks $N_{X,unk} = \overline{R_X} \times (M_X^{Tot} - M_{X,I}) \times \frac{I}{2}$
Main/Plastic				3					-	-	-
Main/Plastic				4					-	-	-
Main/Plastic				5					-	-	-
Main/Unprotected Steel				3					-	-	-
Main/Unprotected Steel				4					-	-	-
Main/Unprotected Steel				5					-	-	-
Main/Protected Steel				3					-	-	-
Main/Protected Steel				4					-	-	-
Main/Protected Steel				5					-	-	-
Service/Plastic				3					-	-	-
Service/Plastic				4					-	-	-
Service/Plastic				5					-	-	-
Service/Unprotected Steel				3					-	-	-
Service/Unprotected Steel				4					-	-	-
Service/Unprotected Steel				5					-	-	-
Service/Protected Steel				3					-	-	-
Service/Protected Steel				4					-	-	-
Service/Protected Steel				5					-	-	-
Service/Copper				3					-	-	-
Service/Copper				4					-	-	-
Service/Copper				5					-	-	-
Total				**N/A**					**-**	**-**	**-**

- By using simplified form of the equation the column for the interval constant can be eliminated

Ed Newton
Research & Materials Manager
ENewton@semprautilities.com