UNDERGROUND CONSTRUCTION TECHNOLOGY
THE UNDERGROUND UTILITIES EVENT | JANUARY 25-27, 2022 | FORT WORTH, TEXAS

EVERYTHING IS EASIER BY THE FOOT: UNIT COSTING BY LINEAR FOOT

Jordan D. Eades, E.I.T | Phillip L. Cook, P.E.

January 26, 2022

10:00 am – 10:25 am

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Unit Costing by Linear Foot

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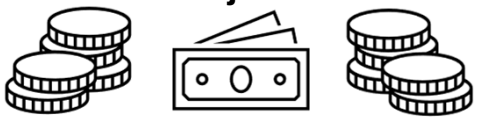
Background

Aging Water Infrastructure

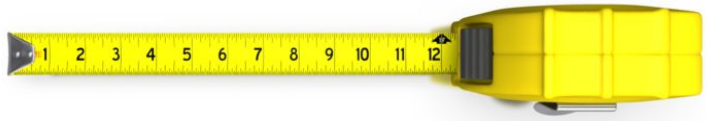
Capital Improvement Projects



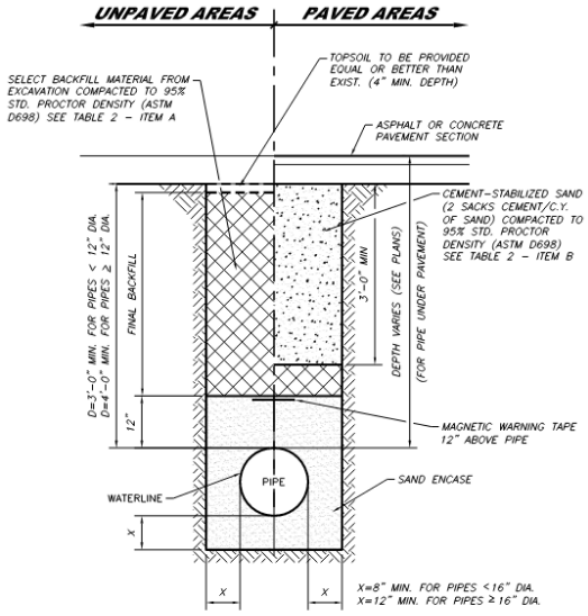
Sustainable Distribution System Replacement

Components of Unit Costing for Distribution System

- **Unit Costs based on:**
  - **Pipe Size**
  - **Length**



- **Installation Types:**
  - **Open Cut without pavement replacement**
  - **Open Cut with pavement replacement**
  - **Trenchless Methodologies**



TYP. PIPE TRENCHING, BEDDING AND BACKFILL FOR WATERLINE

NOT TO SCALE

Distribution System Reinvestment Estimate

Open Cut without Pavement Replacement

	Typ. Bid Item Average Unit Cost per Linear Foot																							
Pipe Diameter (Inch)	Furnish and Install New Water Line by Open Cut	Furnish and Install New Water Line by Trenchless (5% of LF)	Remove, Dispose or Abandon Existing Water Line	Trench Safety for Remove and Install Water Line & Boring Pits	Preconstruction Exploratory Excavation	Gate Valve (300-FT Spacing)	Butterfly Valve (1-MI Spacing)	Ductile Iron Fittings (100-FT Spacing)	Ductile Iron Fittings (1-MI Spacing)	Service Connection (50-FT Spacing)	Connection to Existing Water Line (300-FT Spacing)	Connection to Existing Water Line (1-MI Spacing)	Fire Hydrant Assembly (300-FT Spacing)	Subtotal Average Unit Cost	Traffic Control (1.5%)	Erosion Control & Site Work (1.5%)	Miscellaneous (2%)	Bonds & Insurance (1%)	Construction Subtotal Average Unit Cost	Engineering (10%)	Average Unit Cost
4	$58	---	$29	$4	$5	$3	---	$2	---	$41	$8	---	$29	$179	$3	$3	$4	$2	$190	$19	$209
6	$82	---	$41	$4	$5	$4	---	$4	---	$41	$9	---	$29	$220	$3	$3	$4	$2	$234	$23	$257
8	$98	---	$46	$4	$5	$6	---	$6	---	$41	$11	---	$29	$247	$4	$4	$5	$2	$262	$26	$288
10	$102	---	$49	$4	$5	$9	---	$8	---	$41	$12	---	$29	$260	$4	$4	$5	$3	$276	$28	$303
12	$150	---	$55	$4	$5	$10	---	$9	---	$41	$25	---	$29	$329	$5	$5	$7	$3	$349	$35	$384
14	$163	---	$57	$4	$5	$20	---	$13	---	$41	$35	---	$29	$368	$6	$6	$7	$4	$390	$39	$429
16	$176	---	$58	$8	$5	$30	---	$17	---	$41	$45	---	$29	$411	$6	$6	$8	$4	$435	$44	$479
18	$183	$518	$59	$8	$5	---	$3	---	$1	---	---	$3	---	$279	$4	$4	$6	$3	$296	$30	$325
20	$190	$591	$62	$8	$5	---	$4	---	$1	---	---	$4	---	$294	$4	$4	$6	$3	$312	$31	$343
24	$210	$601	$70	$8	$5	---	$5							$323	$5	$5	$6	$3	$342	$34	$377
30	$288	$809	$70	$8	$5	---	$7							$411	$6	$6	$8	$4	$436	$44	$480
36	$463	$969	$85	$8	$5	---	$6							$604	$9	$9	$12	$6	$640	$64	$704
42	$490	$1,128	$93	$10	$5	---	$8							$656	$10	$10	$13	$7	$695	$69	$764
48	$518	$1,287	$102	$10	$5	---	$10							$706	$11	$11	$14	$7	$748	$75	$823
54	$583	$1,447	$111	$10	$5	---	$12							$790	$12	$12	$16	$8	$838	$84	$922
60	$647	$1,606	$119	$10	$5	---	$14							$875	$13	$13	$18	$9	$928	$93	$1,020
72	$776	$1,925	$137	$10	$5	---	$16							$1,038	$16	$16	$21	$10	$1,100	$110	$1,210

Development of Average Unit Cost per Linear Foot (LF)

- **Average unit cost for typical bid items**
- **Average costs not in LF, transformed into LF through assumptions to represent the frequency of occurrence per LF.**

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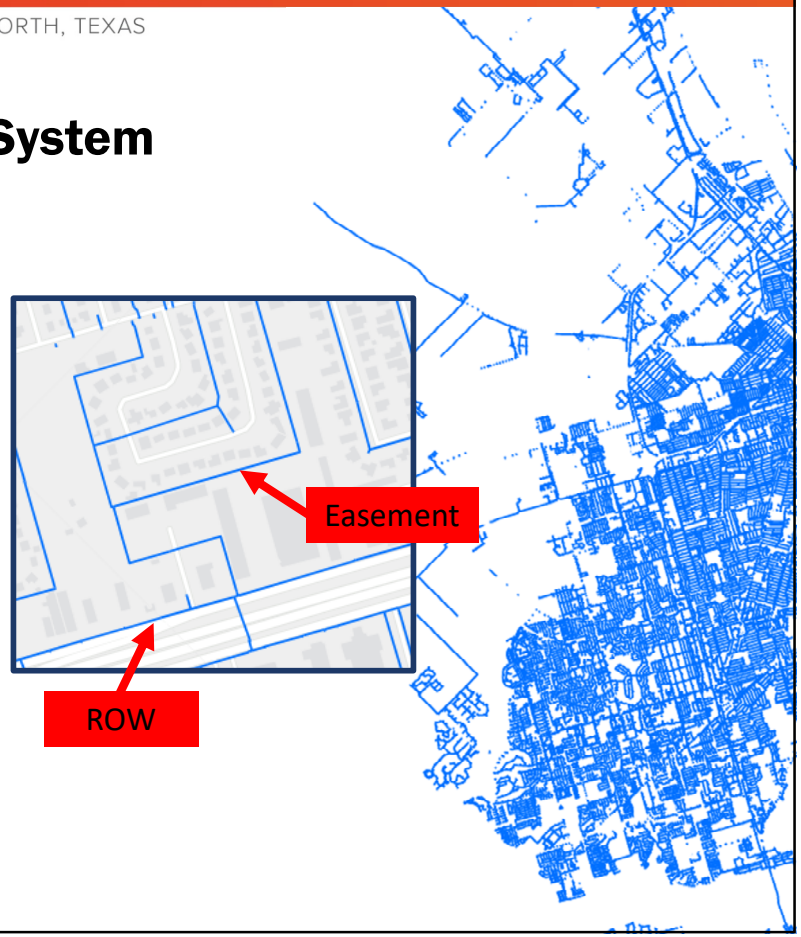
Pipe Diameter (Inch)	Average Unit Costs		
	Open Cut without Pavement Replacement	Open Cut with Pavement Replacement	Trenchless
4	$209	$561	$300
6	$257	$609	$349
8	$288	$641	$410
10	$303	$656	$486
12	$384	$737	$580
14	$429	$783	$680
16	$479	$833	$785
18	$325	$678	$683
20	$343	$696	$770
24	$377	$730	$794
30	$480	$834	---
36	$704	$1,060	---
42	$764	$1,122	---
48	$823	$1,180	---
54	$922	$1,280	---
60	$1,020	$1,380	---
72	$1,210	$1,571	---

Weighting Unit Costs for a Distribution System

- GIS data of the percentage of pipe length located:
  - Easement
  - Right-of-way (ROW)

- The weighted unit costs represents the frequency of the pipe to be replaced by each installation type by using where the pipe is located within the distribution system.



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Pipe Size (inches)	Estimated ROW (LF)	Estimated ROW%	Estimated Easement (LF)	Estimated Easement %
1	2,149.00	26.6%	5,932.00	73.4%
1.5	6,280.00	39.0%	9,826.00	61.0%
2	137,186.00	42.7%	184,217.00	57.3%
2.5	1,073.00	6.7%	14,857.00	93.3%
3	3,961.00	9.6%	37,122.00	90.4%
4	125,596.00	23.9%	399,254.00	76.1%
6	2,851,570.00	82.0%	626,321.00	18.0%
8	2,155,569.00	84.1%	406,290.00	15.9%
10	53,811.00	91.0%	5,295.00	9.0%
12	792,049.00	89.8%	90,279.00	10.2%
14	19.00	100.0%	-	0.0%
16	294,370.00	91.2%	28,381.00	8.8%
18	11,684.00	68.5%	5,365.00	31.5%
20	72,242.00	94.0%	4,592.00	6.0%
24	124,101.00	87.1%	18,334.00	12.9%
30	91,962.00	83.9%	17,613.00	16.1%
36	77,000.00	85.3%	13,301.00	14.7%
42	62,253.00	57.1%	46,814.00	42.9%
48	104,566.00	63.7%	59,577.00	36.3%
54	2,676.00	6.2%	40,810.00	93.8%
60	6,629.00	15.0%	37,513.00	85.0%
72	1,643.00	25.4%	4,838.00	74.6%
Total	6,978,389.00	77.2%	2,056,531.00	22.8%

Pipe Diameter (Inch)	Open Cut without Pavement Replacement (Percentage in Easement)[1]	Open Cut with Pavement Replacement (Percentage in ROW)[1]	Trenchless (30%)
4	53%	17%	30%
6	13%	57%	30%
8	11%	59%	30%
10			30%
12			30%
14			30%
16			30%
18			30%
20			30%
24			30%
30			---
36			---
42	43%	57%	---
48	36%	64%	---
54	94%	6%	---
60	85%	15%	---
72	75%	25%	---

Example pipe size 4" (76% Easement vs. 24% ROW):

Open Cut w/o PR = 76% - (76% x 30%) = 53%

Open Cut w/ PR = 24% - (24% x 30%) = 17%

Trenchless (Est.30%) = 30%

[1] Percentages for Pipe located within Easement and ROW from GIS has 30% removed to account to trenchless installation.

	Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column G
							Column A x Column D	Column B x Column E	Column C x Column F	Column G + Column H + Column I
	Average Unit Costs						Weighted Unit Costs			
Pipe Diameter (Inch)	Open Cut without Pavement Replacement	Open Cut with Pavement Replacement	Trenchless	Open Cut without Pavement Replacement (Percentage in Easement)	Open Cut with Pavement Replacement (Percentage in ROW)	Trenchless (30%)	Open Cut without Pavement Replacement	Open Cut with Pavement Replacement	Trenchless	Weighted Unit Cost Values
4	$209	$561	$300	53%	17%	30%	$111	$94	$90	**$295**
6	$257	$609	$349	13%	57%	30%	$32	$350	$105	**$487**
8	$288							$377	$123	**$532**
10	$303							$418	$146	**$583**
12	$384							$463	$174	**$664**
14	$429							$548	$204	**$752**
16	$479							$532	$236	**$797**
18	$325							$325	$205	**$602**
20	$343							$458	$231	**$703**
24	$377							$445	$238	**$717**
30	$480							$700	---	**$777**
36	$704							$904	---	**$1,008**
42	$764							$640	---	**$968**
48	$823	$1,180	---	36%	64%	---	$299	$752	---	**$1,051**
54	$922	$1,280	---	94%	6%	---	$865	$79	---	**$944**
60	$1,020	$1,380	---	85%	15%	---	$867	$207	---	**$1,074**
72	$1,210	$1,571	---	75%	25%	---	$903	$398	---	**$1,301**

Example pipe size 4" for Weighted Unit Cost:

Open Cut w/o PR (53%)= $209 x 53% = $111

Open Cut w/ PR (17%) = $561 x 17% = $94

Trenchless (30%) = $300 x 30% = $90

Weighted Unit Cost for 4" = $111 + $94 + $90 = **$295**

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Distribution Reinvestment Analysis

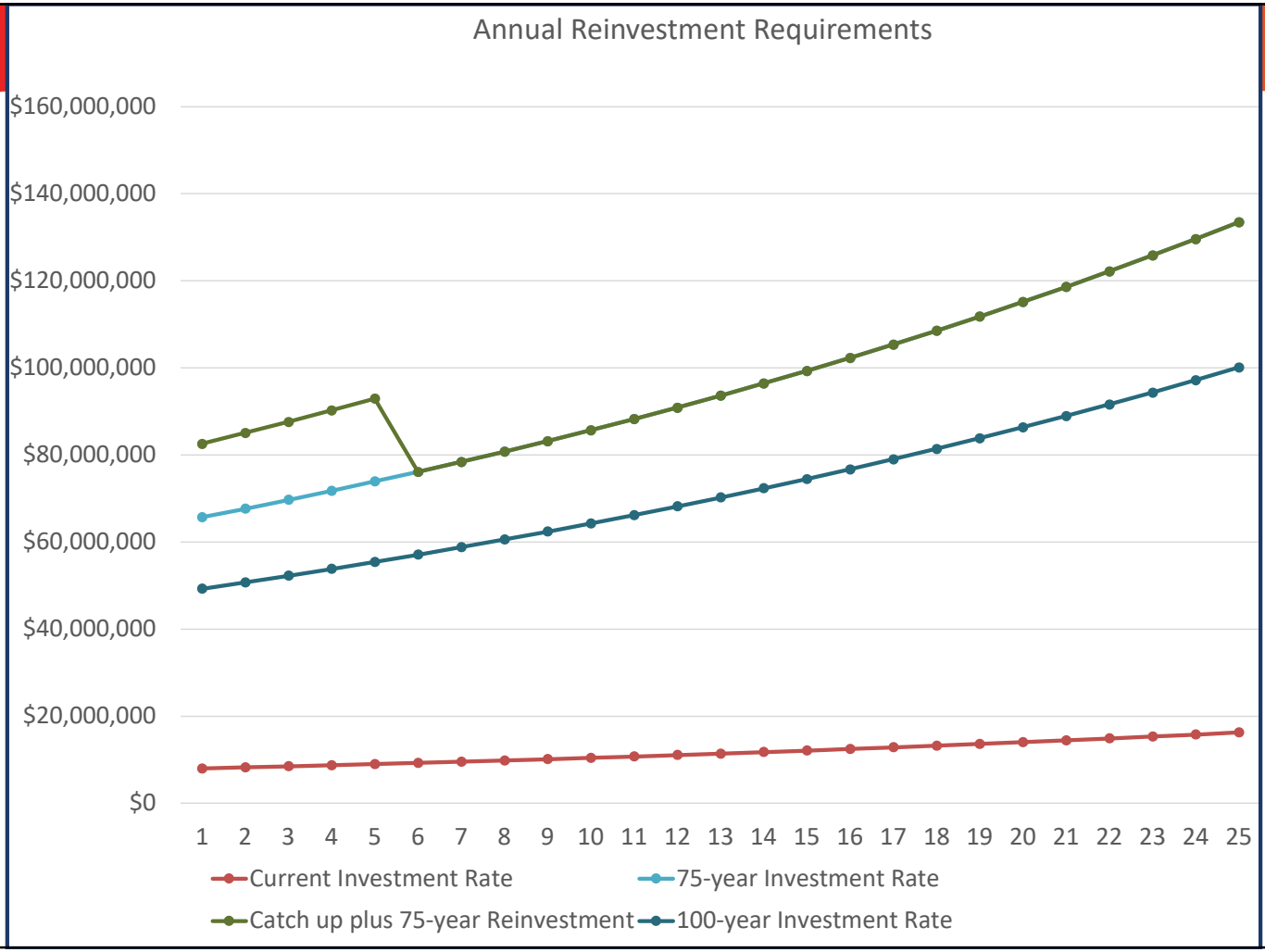
Pipe Diameter (Inches)	Total Length Pre-1945	Total Length Post-1945	Total Overall Length in System.	Unit Price to Replace Pipe (4" minimum)	Estimated Replacement Cost of System	Estimated Replacement Cost for Pipe Pre-1945
1	446	7,637	8,083	$295	$2,384,485	$131,570
1.5	1,071	15,035	16,106	$295	$4,751,270	$315,945
2	4,950	316,454	321,404	$295	$94,814,180	$1,460,250
2.5		15,929	15,929	$295	$4,699,055	$0
3	5,547	35,536	41,083	$295	$12,119,485	$1,636,365
4	27,644	497,206	524,850	$295	$154,830,750	$8,154,980
6	29,958	3,447,938	3,477,896	$487	$1,693,735,352	$14,589,546
8	28,242	2,533,630	2,561,872	$532	$1,362,915,904	$15,024,744
10	994	58,236	59,230	$583	$34,531,090	$579,502
12	1,569	881,115	882,684	$664	$586,102,176	$1,041,816
14		20	20	$752	$15,040	$0
16	2,176	320,576	322,752	$797	$257,233,344	$1,734,272
18		17,050	17,050	$602	$10,264,100	$0
20	16,641	60,192	76,833	$703	$54,013,599	$11,698,623
24	2,907	139,528	142,435	$717	$102,125,895	$2,084,319
30	33,414	76,161	109,575	$777	$85,139,775	$25,962,678
36	200	90,100	90,300	$1,008	$91,022,400	$201,600
42		109,066	109,066	$968	$105,575,888	$0
48		164,143	164,143	$1,051	$172,514,293	$0
54		43,487	43,487	$944	$41,051,728	$0
60		44,142	44,142	$1,074	$47,408,508	$0
72		6,482	6,482	$1,301	$8,433,082	$0
Total:	**155,759**	**8,879,663**	**9,035,422**	**Total**	**$4,925,681,399**	**$84,616,210**

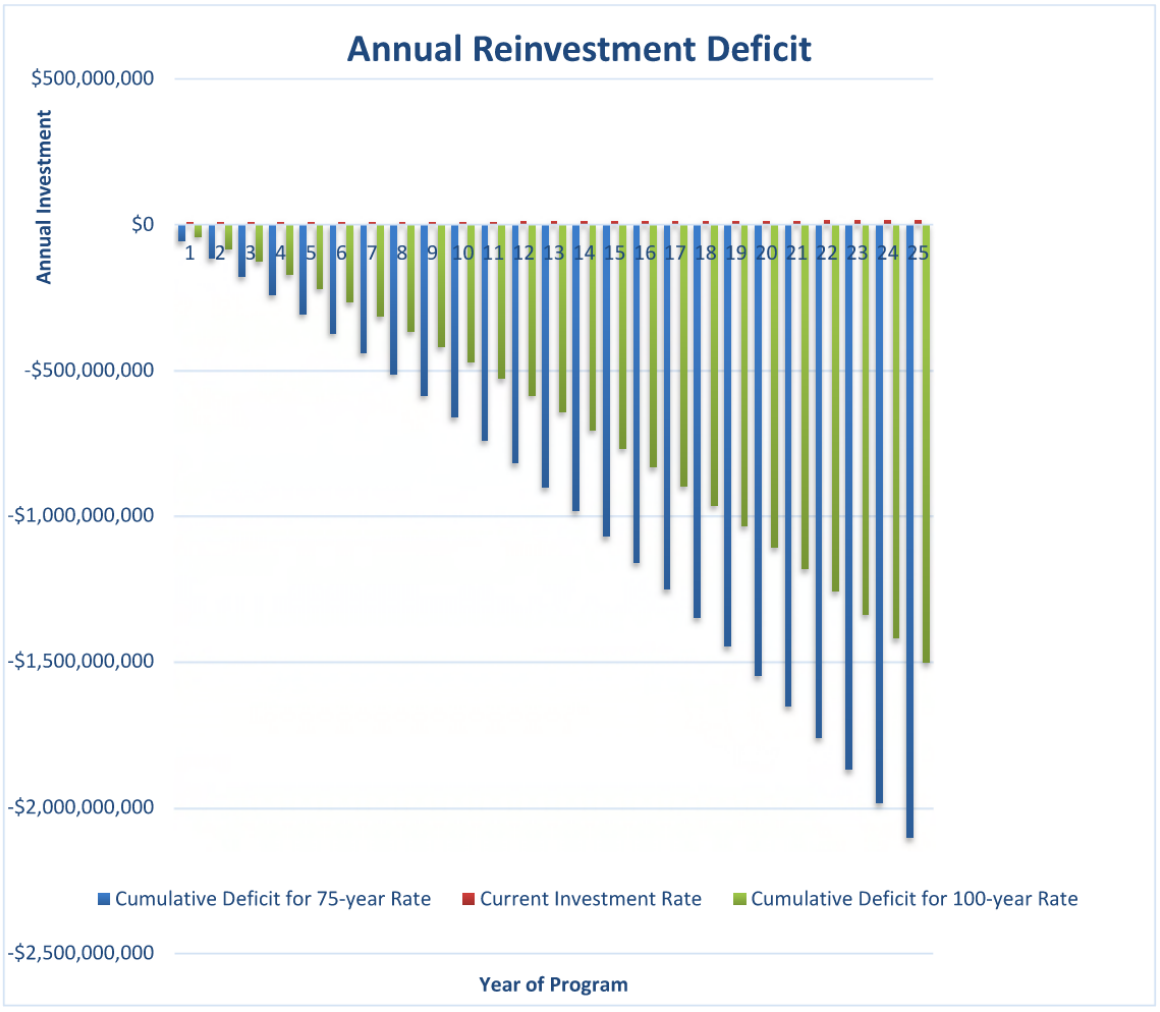
Sustainable Annual Reinvestment Rate:

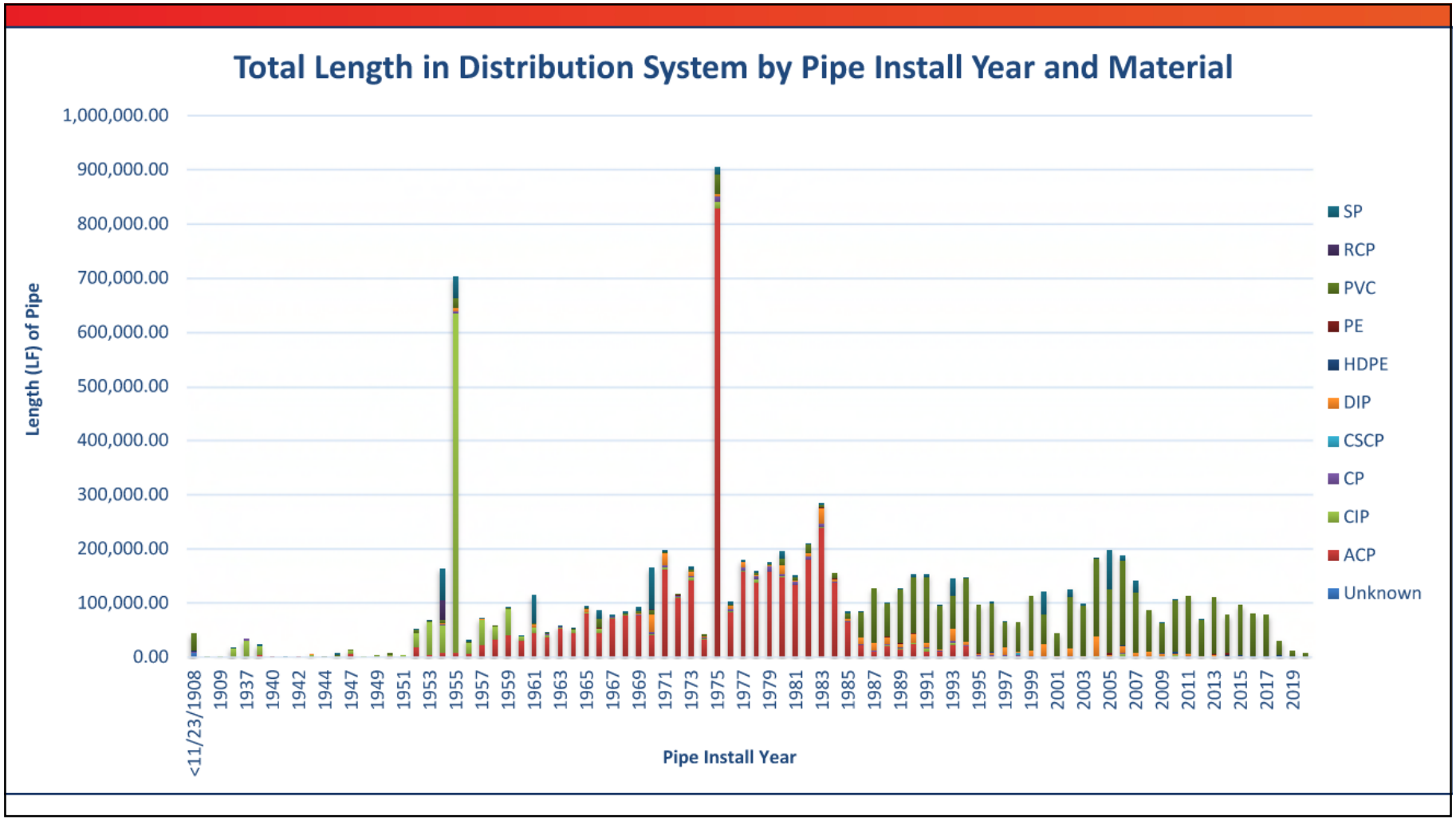
50 Year	$98,513,628
75 Year	**$65,675,752**
100 Year	$49,256,814

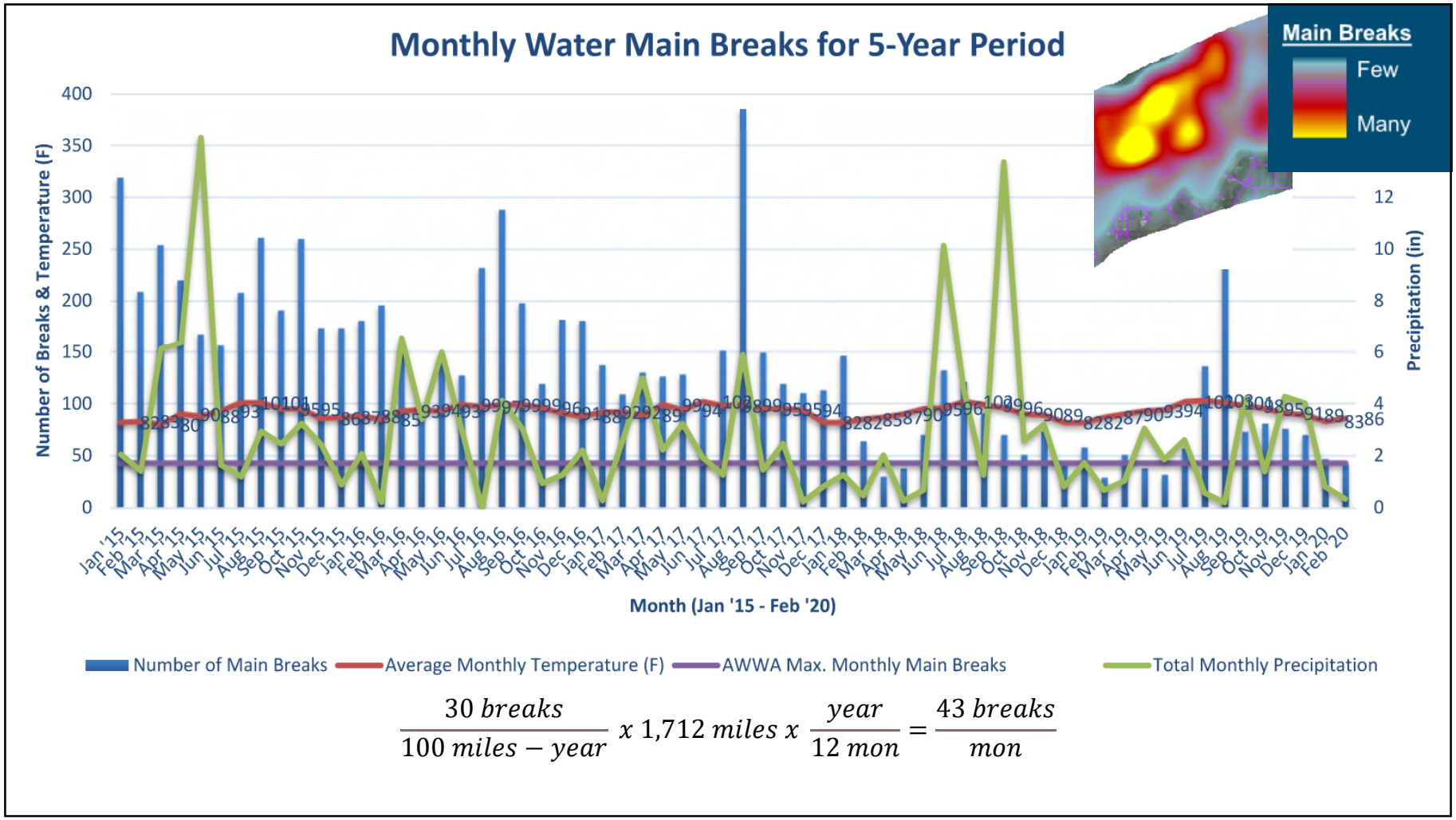
Catch-Up Investment for Pre-1945 Pipe:

5 year dist.:	$16,923,242
10 year dist.:	$8,461,621


Annual Reinvestment Requirements
$160,000,000
$140,000,000
$120,000,000
$100,000,000
$80,000,000
$60,000,000
$40,000,000
$20,000,000
$0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Current Investment Rate
75-year Investment Rate
Catch up plus 75-year Reinvestment
100-year Investment Rate


Annual Reinvestment Deficit
$500,000,000
$0
-$500,000,000
-$1,000,000,000
-$1,500,000,000
-$2,000,000,000
-$2,500,000,000
Annual Investment
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Cumulative Deficit for 75-year Rate
Current Investment Rate
Cumulative Deficit for 100-year Rate
Year of Program


Total Length in Distribution System by Pipe Install Year and Material
Length (LF) of Pipe
1,000,000.00
900,000.00
800,000.00
700,000.00
600,000.00
500,000.00
400,000.00
300,000.00
200,000.00
100,000.00
0.00
<11/23/1908
1909
1937
1940
1942
1944
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
Pipe Install Year
SP
RCP
PVC
PE
HDPE
DIP
CSCP
CP
CIP
ACP
Unknown



$$\frac{30\ breaks}{100\ miles - year}\ x\ 1{,}712\ miles\ x\ \frac{year}{12\ mon} = \frac{43\ breaks}{mon}$$

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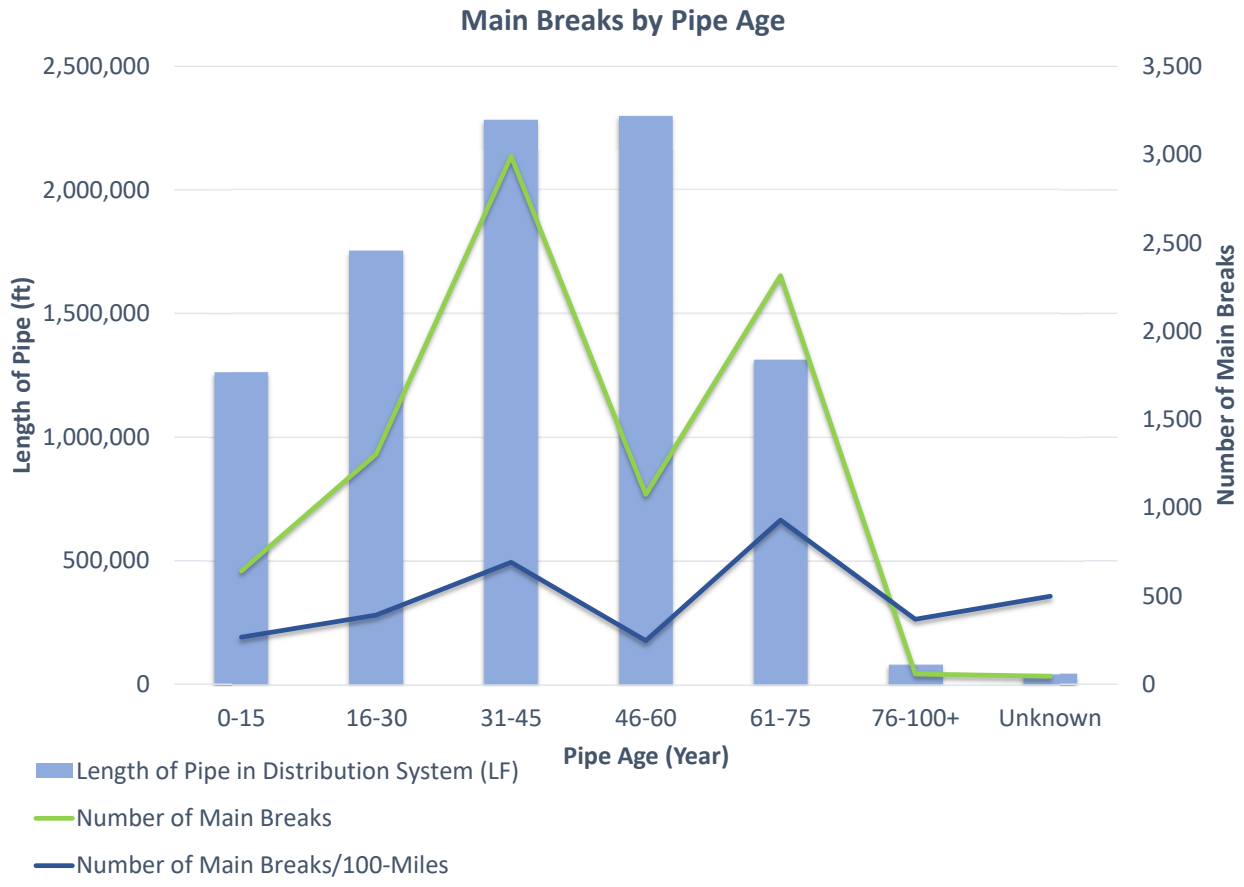

Pipe Age (Year)	Approx. Length of Pipe in Distribution System (LF)	Percentage (%)
0-15	1,262,040	14%
16-30	1,752,600	19%
31-45	2,283,100	25%
46-60	2,298,700	26%
61-75	1,312,500	15%
76-100+	82,710	< 1%
Unknown[1]	43,380	< 1%

Pipe Age (Year)	Number of Main Breaks	Percentage (%)
0-15	558	7%
16-30	1,227	15%
31-45	2,848	35%
46-60	1,035	13%
61-75	2,258	27%
76-100+	59	< 1%
Unknown[1]	28	< 1%

[1] Pipe with unknown installation date and age.

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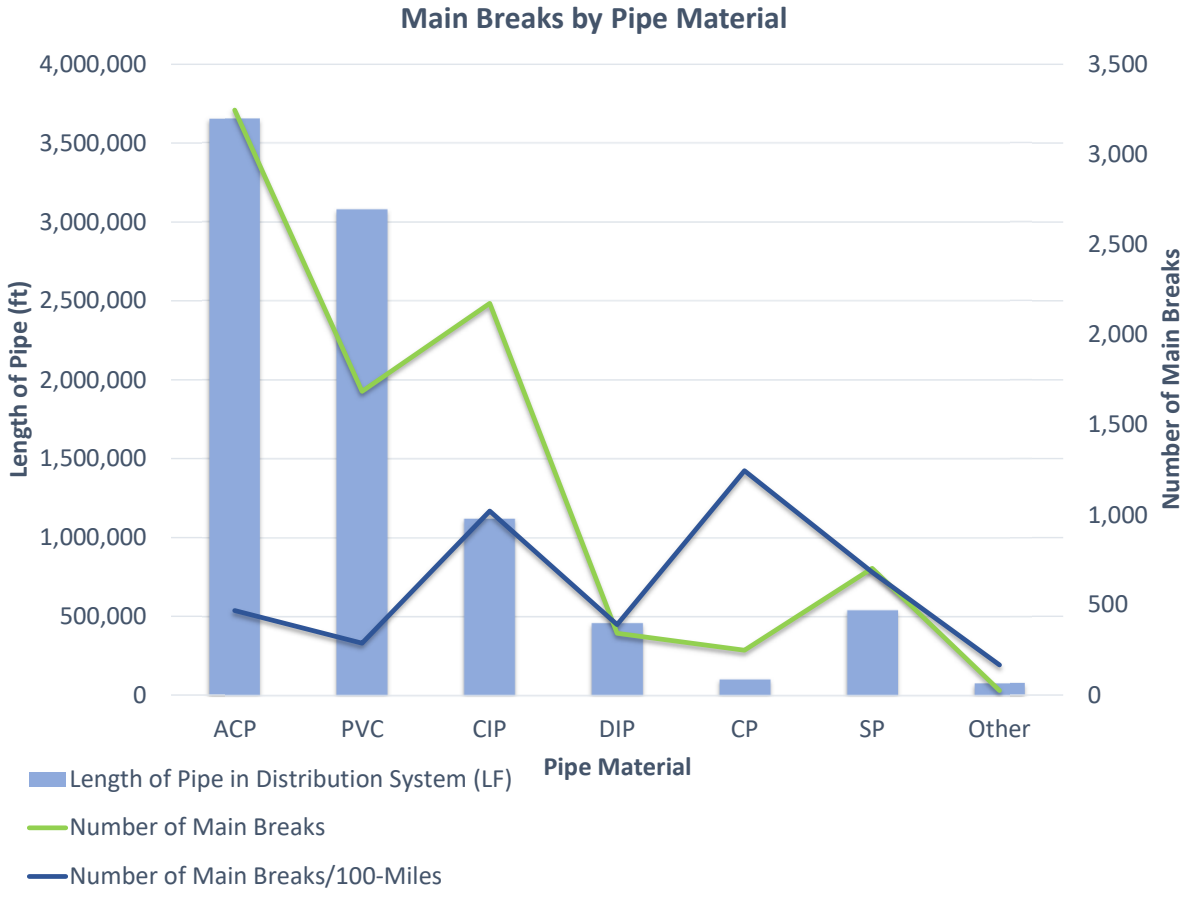

Pipe Material	Approx. Length of Pipe in Distribution System (LF)	Percentage (%)
ACP	3,654,450	41%
PVC	3,079,860	34%
CIP	1,120,350	12%
DIP	459,430	5%
CP	102,640	1%
SP	540,140	6%
Other[1]	78,160	< 1%

Pipe Material	Number of Main Breaks	Percentage (%)
ACP	3,055	38%
PVC	1,593	20%
CIP	2,147	27%
DIP	320	4%
CP	192	3%
SP	691	8%
Other[1]	1	< 1%

[1] CSCP, HDPE, PE, RCP, and Unknown Material.

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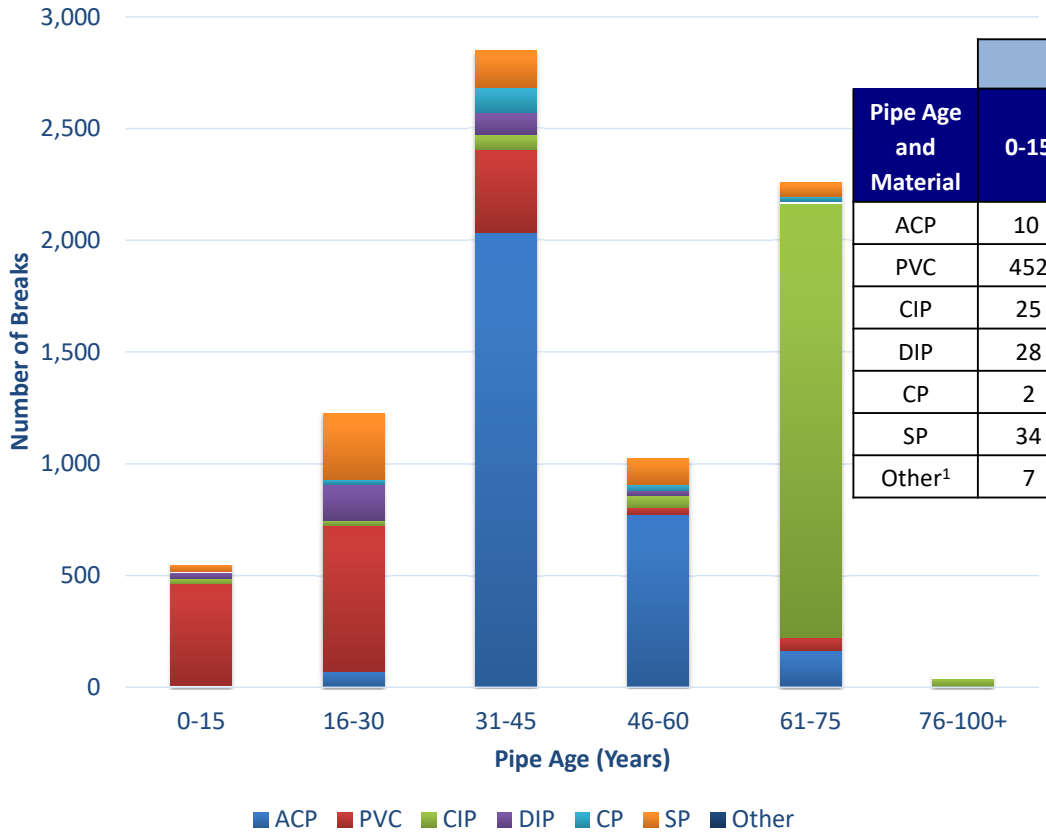
Main Breaks By Pipe Age and Material



Pipe Age and Material	Number of Main Breaks						
	0-15	16-30	31-45	46-60	61-75	76-100+	Unknown[2]
ACP	10	72	**2,033**	772	163	3	2
PVC	452	653	371	32	61	---	24
CIP	25	21	68	54	**1,942**	37	---
DIP	28	163	98	22	9	---	---
CP	2	20	114	28	22	5	1
SP	34	298	164	120	61	14	---
Other[1]	7	---	---	7	---	---	1

[1] CSCP, HDPE, PE, RCP, and Unknown Material.

[2] Pipe without installation date and age.

Recommendations

- 75-year Reinvestment Life Cycle for the Distribution System
  - Incorporate a focused 5-year plan to replace problem piping
    - Copper and Cast Iron aged 60+ years and others
  - Investigate the Asbestos Cement Pipe Failures

- Implement a robust program
  - Develop a staffing plan for a standalone team to administer the pipe replacement program
  - Establish a Program Manager

- Develop muti-year design contracts for replacement packages

Recommendations

- **Refine the CMMS/Maximo data collection**
- **Consider installation and replacement methodologies**
- **Coordinate pipe replacements with wastewater and paving improvements**
- **Determine the financial impact**

Limitations

- **GIS dependent for an efficient analysis**
- **Main Break Data / CMMS**
- **Current Market Conditions**

Summary

This presentation topic covers a unit cost by linear foot estimation methodology to simplify and provide recommendations for the expansion and refinement of a current distribution system reinvestment program. To budget and plan for a sustainable pipe replacement program, the best available data was utilized to develop unit costs per linear foot to be used for the client's overall reinvestment program estimate.

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Thank You

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