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LATERAL REHABILITATION OPTIONS AND THEIR COST:BENEFIT COMPARISON- ONE UTILITY'S PERSPECTIVE

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ABSTRACT: New Castle County embarked on a comprehensive sewer rehabilitation program for their Brandywine Hundred Sewersheds in 2005. As part of that program, NCC determined that as much of the lateral as possible must be rehabilitated in order to achieve the aggressive I&I reduction goals dictated by both their DNREC Secretary's Order and their specific circumstances regarding peak flow. Under the Brandywine Hundred Program, NCC has evaluated and used a number of lateral rehabilitation technologies that address all or parts of the lateral from the tap connection to the building foundation, including technologies that do and don't require cleanouts. After 6 years, NCC has developed a Lateral Technology Cost:Benefit Tool that allows them to assess the I&I reduction, O&M, and structural benefits of various lateral technologies and combinations of technologies. This tool assigns utility-specific life cycle costs to each lateral technology to allow a cost:benefit analysis to be conducted for both initial capital cost and life cycle cost when selecting which technology to install. NCC is currently doing this for contingent lateral rehabilitation line items and is assessing ways to administer a full scale cost:benefit selection process for all lateral rehabilitation under their bidding rules.

This paper will present the Lateral Technology Cost:Benefit Tool as a way of discussing the benefit values attributed to various lateral technologies.

1. INTRODUCTION

New Castle County is located in northern Delaware. The New Castle County Department of Special Services (NCC) operates a sanitary sewer system containing over 1800 miles of sewer mains serving 112,000 customers. The northernmost portion of their system, called the Brandywine Hundred, surrounds the City of Wilmington and contains the oldest portions of NCC's sewer system. Largely built by developers during the 40's, 50's, and 60's of terracotta pipe and brick manholes, with initial interceptors built in 40's and 50's and parallel interceptors built in 50's, 60's, and 70's with federal funds, the system is characteristic of many systems of similar vintage --- broken and collapsing pipes and manholes, chronic root intrusion/blockages, and leaking pipe joints and manholes.

What is unusual about the system is the high level of inflow and infiltration, especially rainfall derived inflow and infiltration (RDII), suffered by the system. While the interceptors and pump stations were built to 10 States Standards, most of them are undersized for the wet weather hydraulic load demand. For example, a 2" rain event can lead to 10X increases at the bottom of the system, with basin peaking rates well into the 20X for many areas. As a consequence of age and construction, leakage is continuously increasing, basement backups are increasing (as do customer complaints and cleanup costs), manhole overflows are increasing, and the structured overflows built into the system activate more frequently.

In 2003, the Brandywine Hundred sewer system was put under a Delaware Department of Natural Resources and Environmental Conservation (DNREC) Secrtetary's Order to "safely eliminate the two overflow structures without creating system problems such as backup and blockages in other parts of the sewer system". Based on a cost:benefit evaluation, the stipulated level of control for this system was determined using a synthetic 3 year-24 hour storm event under high groundwater conditions, which corresponds to a 6 year return frequency event.

NCC discharges sewage flow to the City of Wilmington WWTP, which cannot be readily expanded, and there are limited options, due to space, for storage. Additionally, DNREC has a stated preference for source removal as a remedy for high flows. In the end, it was determined that a 35% reduction in peak wet weather flow under the above storm conditions would be required; this translates to a 50% reduction in RDII. The Brandywine Hundred Sewer Rehabilitation and Capacity Assurance Program was initiated to achieve that goal.

As part of that program, NCC believed, then proved via rehabilitation effectiveness flow monitoring, that their laterals must be rehabilitated in order to achieve the aggressive I&I reduction goals. NCC and Malcolm Pirnie have evaluated and used a number of lateral rehabilitation technologies that address all or parts of the lateral from the tap connection to the building foundation, including technologies that do and don't require cleanouts. After 6 years experience trialing and installing various technologies, Malcolm Pirnie developed a Lateral Technology Cost:Benefit Tool that allows NCC to assess the I&I reduction, O&M, and structural benefits of various lateral technologies and combinations of technologies on a bid by bid basis. This tool assigns utility-specific life cycle costs to each lateral technology to allow a cost:benefit analysis to be conducted for both initial capital cost and life cycle cost when selecting which technology to install.

For the Brandywine Hundred Program, flow reduction goals will be best met if the entire lateral (or as much as can be feasibly be done) is rehabilitated, so the majority of laterals are completely rehabilitated, including most of the private lateral to near the house foundation. For laterals that can't be entirely rehabilitated (typically due to access problems), NCC uses this tool to evaluate contingent lateral rehabilitation line items on a bid by bid basis, selecting the most cost effective solution based on actual site constraints and actual project costs. In programs where the flow reduction demands are less rigorous, and where bidding rule allow all items to be bid on an indefinite quantity basis, this tool can be used for selecting all lateral rehabilitation technologies. In the case of NCC, the socio-political costs and the dollar cost of open cut lateral work have eliminated pursuing flow reductions in that manner, but this tool can also be expanded to include open cut alternatives so long as the benefit value scheme is modified to include social/homeowner impact issues.

2. TECHNOLOGIES/VENDORS EVALUATED

Only technology providers that have been successfully vetted are included in the evaluation. This technology vetting is a five step process.

The first step is an evaluation of the material test performance data for chemical resistivity and for long term structural strength. Independent third party ISO 17025 certified laboratory test reports demonstrating that the exact resin/liner combination to be used meets the requirements for initial structural properties (performed in accordance with ASTM F1216 and ASTM D790 and/or ISO 178 with a wall thickness measured per DIN EN 13566-4) and chemical resistance (performed in accordance with ASTM F1216-Appendix X2 or ASTM D5813) are required. Data are required to demonstrate that material strength does not degrade more than 20% in the presence of the F1216 chemical cocktails.

Additionally, independent third party certified laboratory test reports demonstrating that the exact resin and liner to be used has been tested for long-term flexural modulus of elasticity and long-term flexural strength (i.e., 10,000 hour minimum creep testing performed in accordance with ASTM D2990 or DIN EN 761). When filled resins are proposed, complementary data of the same data for unfilled resin must also be provided. Tests must be performed for a minimum of 10,000 hours under the following test conditions and loadings:

- Temperature: 21 to 25°C

- Relative humidity: 50% minimum
- Load: Equivalent to 25% of the initial yield stress measured in accordance with ASTM D790 or ISO 178

Independent third party test data of the entire ASTM D-2990/DIN EN 761 data set are required. However, determination of long-term strength of the liner is determined using the only the data points from 1,000 hours to 10,000 hours of the Long-term Flexural Modulus extrapolated using a Microsoft Excel log-log scale linear regression analysis, unless the data set is determined to be better suited to another regression method (i.e., Second order polynomial). Despite multiple requests for the above data, many liner manufacturers have not provided these data, and are thus excluded from the approved vendors list.

The second step is an evaluation of the technology's ability to handle the angles, bends, offsets, and transitions of a typical lateral. This includes how the technology handles the 6":4" transitions, including concentric reducers, eccentric reducers, donut connections, and shove-in connections.

The third step is an evaluation of the technology's ability to stop leakage, especially at the tap connection, in the riser section, under the ROW section, at the transition, under the private property portions of the lateral, and at the upstream terminus. This includes bench testing of hydrophilic bands and grouts used to seal ends and interfaces and laboratory testing of shear strengths of joints for overlapped multiple-shot liners. For liners installed in multiple pieces/shots, whether constructed of identical materials or dissimilar materials, independent third party certified laboratory test reports demonstrating that the overlap joint between the exact resins and are tested for lap shear testing in accordance with ASTM D5868 or ASTM D3163 to demonstrate that the joint exhibits shear properties equal to or greater than the weaker of the two overlapped liner materials (i.e. that the substrate fails before the lapped joint).

Steps 1-3 sometimes include factory visits to understand the manner of construction of the tubes and the preparation and promotion of the resins before shipping, and the quality control steps that are employed in the manufacture of the products.

The fourth step is pilot testing of the technology by actual contractor crews to evaluate the reliability of installation. (Factory crews are typically not allowed as they don't usually represent the crew mix found on an actual rehab project). This includes an evaluation of how well field crews follow the factory installation and field quality control steps, including the monitoring controls used, and the "idiot-proofness" engineered into the installation methods, tools, and equipment. Some technologies have passed the first 3 steps only to fail at this stage due to the overwhelming skill and craftsmanship needed to consistently install a defect-free liner.

The final step of the evaluation process follows the actual full scale installation of the technology. This step evaluates the laboratory test results for the same parameters provided by the factory in Step 1; experience has shown that actual field performance is slightly to very much worse than indicated by the factory-provided data state. This step also evaluates the liner's field ability to stop leakage, handle transitions and bends, and be installed with minimal dig-up failures or with acceptable non-dig-up defect rate. The final stage of this step is an evaluation of the installed product based on CCTV inspections conducted 3-5 years after installation. Based on these Step 5 reviews, a previously accepted technology can be delisted from the approved list. (Variations of this same multi-step approach are used by Malcolm Pirnie for all pipeline technologies and products, including manhole rehab products, pipe materials, and lining/coating products.)

Below are the technologies and approved vendors currently in the suite of lateral technologies that have passed the first 4 steps of the technology evaluation and have not been delisted by step 5. The last three technologies (dark grey) are not commercially available.

Technology	Description	Vetted and Approved Vendor(s)
Logiball w/ Acrylimide	6' packer grouting w/ acrylimide	Logiball, Avanti, DaNeef
Logiball w/ Urethane	6' packer grouting w/ urethane	Logiball, Avanti, DaNeef
PIRTS	Pressure injected resin tap seal	Jansenn, Prokasro
CIPLC - Tophat	9" cured in place lateral connection without mainline wrap	Trelleborg Epros, BLD
CIPLC - Stubby	9" cured in place lateral connection with mainline wrap	Trelleborg Epros Drain LCR, LMK Stubby, Easy Liner Saddle Liner
CIPLS - Tophat	3' cured in place lateral liner without mainline wrap	BLD
CIPLS - T Liner	3' cured in place lateral liner with mainline wrap	LMK Shorty
CIPLL - Tophat	30' cured in place lateral liner without mainline wrap	BLD
CIPLL - T Liner	50' cured in place lateral liner with mainline wrap	LMK T-Liner
CIPLL - Tophat Blindshot	25' cured in place lateral liner without mainline wrap without a cleanout	BLD Blindshot
CIPLL COS	50' cured in place lateral liner installed through cleanout with no tap seal	Easy Liner Cleanout Shot, LMK Cleanout Shot
CIPLL COS - PIRT	50' cured in place lateral liner installed through cleanout with pressure injected resin tap seal	Easy Liner Cleanout Shot, LMK Cleanout Shot with Jansen, Prokasro
CIPLL - PIRT w/o CO	25' cured in place lateral liner without mainline wrap without a cleanout with pressure injected resin tap seal	Modified BLD Blindshot with Jansen, Prokasro
CIPLL - Tophat Blindshot -full length	50' cured in place lateral liner without mainline wrap without a cleanout	BLD Blindshot
CIPLL - T Liner Blindshot	50' cured in place lateral liner with mainline wrap without cleanout	LMK T-Liner Blindshot

Figure 1. Technologies included in the lateral cost:benefit evaluation.

3. ASSESSMENT COST:BENEFIT CONCEPT

In addressing laterals, a straight forward cost evaluation is not possible because the various technologies available offer such differing advantages, weaknesses, limits, and benefits. Also, prices for lateral technologies varied widely from bid to bid depending on the available contractor base and on the specific technologies pre-qualified to be installed. Accordingly, to evaluate the best "bang for the buck" technology, a cost:benefit evaluation is required.

3.1 Benefit Weightings

Under this system, the greatest benefit a technology can provide is 100%. These benefits are broken into 3 main categories: Structural Improvement, Leakage Reduction, and Operability Improvement. The relative weightings assigned these three categories in NCC's Brandywine Hundred Program is 15%, 75%, and 10%, respectively; remember, this is an I&I driven program.

Structural benefits are divided between Tap Improvements and Lateral Improvements.

Leakage benefits are divided between Annular Space/Tap Improvements, Riser Improvements To ROW Improvements, 6":4" Transition Improvements, and ROW to House (Private) Improvements.

Operability Improvements are divided between Cleanouts (most of the system has no external cleanout) and O&M value.

The below figure illustrates the relative breakdown assignment of value by category.

Tap Structural Value	Lateral Structural Value	Annular Space/ Tap Leakage Value	Riser Leakage Value	ROW Leakage Value	6":4" Leakage Value	Private Leakage Value	Cleanout Value	O&M Value
15		75					10	
8	7	20	15	15	10	15	6	4

Figure 2. Value breakdown by benefit category.

Each technology considered for implementation is graded on its ability to deliver benefit under each of these nine categories. A technology that delivers maximum benefit would receive full marks; a technology that does not address a category would receive zero. The total of the scores in these nine categories is the value (i.e., the numerical benefit) for a given technology.

Trial	Tap Structural Value	Lateral Structural Value	Annular Space/ Tap Leakage Value	Riser Leakage Value	ROW Leakage Value	6":4" Leakage Value	Private Leakage Value	Cleanout Value	O&M Value
Weighting (Total of 100)	8	7	20	15	15	10	15	6	4
Technology	**Portion of Value**								
Logiball w/ Acrylimide	0	0	12	12	0	0	0	0	0
Logiball w/ Urethane	2	0	15	15	0	0	0	0	0
PIRTS	6	0	15	0	0	0	0	0	1
CIPLC - Tophat	4	0	15	0	0	0	0	0	1
CIPLC - Stubby	5	0	20	0	0	0	0	0	1
CIPLS - Tophat	4	2	15	12	0	0	0	0	2
CIPLS - T Liner	5	2	20	12	0	0	0	0	2
CIPLL - Tophat	4	7	15	15	15	8	4	6	3
CIPLL - T Liner	7	7	20	15	15	10	15	6	4
CIPLL - Tophat Blindshot	4	5	15	15	15	8	0	0	3
CIPLL COS	1	7	0	12	15	10	15	6	3
CIPLL COS - PIRT	8	7	15	14	15	10	13	6	4
CIPLL Blindshot - PIRT	8	7	15	15	15	8	0	0	4
CIPLL - Tophat Blindshot -full length	8	7	15	15	15	8	15	0	4
CIPLL - T Liner Blindshot	7	7	20	15	15	10	15	0	4

Figure 3. Benefit values for each technology.

3.2 Life Cycle

Different technologies have different expected effective life periods. The estimation of life cycle is an opinion-based activity, specific to each engineer and each utility. The Lateral Technology Cost:Benefit Tool allows a utility to adjust the life cycle for a given technology or technology combination. This is important when considering the life cycle cost and the life cycle cost:benefit ratio of a given technology. (These, rather than initial cost and initial cost:benefit ratio, should drive most purchase decisions). Below are the life cycles assigned by NCC to the various technologies they and Malcolm Pirnie have vetted and approved for installation.

Technology	Description	Life Cycle
Logiball w/ Acrylimide	6' packer grouting w/ acrylimide	8
Logiball w/ Urethane	6' packer grouting w/ urethane	20
PIRTS	Pressure injected resin tap seal	45
CIPLC - Tophat	9" cured in place lateral connection without mainline wrap	30
CIPLC - Stubby	9" cured in place lateral connection with mainline wrap	50
CIPLS - Tophat	3' cured in place lateral liner without mainline wrap	35
CIPLS - T Liner	3' cured in place lateral liner with mainline wrap	50
CIPLL - Tophat	30' cured in place lateral liner without mainline wrap	40
CIPLL - T Liner	50' cured in place lateral liner with mainline wrap	50
CIPLL - Tophat Blindshot	25' cured in place lateral liner without mainline wrap without a cleanout	40
CIPLL COS	50' cured in place lateral liner installed through cleanout with no tap seal	50
CIPLL COS - PIRT	50' cured in place lateral liner installed through cleanout with pressure injected resin tap seal	45
CIPLL Blindshot- PIRT	**25' cured in place lateral liner without mainline wrap without a cleanout with pressure injected resin tap seal**	45
CIPLL - Tophat Blindshot -full length	**50' cured in place lateral liner without mainline wrap without a cleanout**	40
CIPLL - T Liner Blindshot	**50' cured in place lateral liner with mainline wrap without cleanout**	50

Figure 4. Life cycle for approved technologies.

3.3 Costs

Cost for each technology is determined by the sum of the costs required to fully install each item. For example, the base cost of Logiball with Acrylimide is $650, but to this must be added the cost for derooting those laterals to be grouted that are filled with roots. Experience has shown that one in eight laterals requires derooting. At a price of

$650 per lateral for derooting from the mainline, that yields a per lateral adder cost of $80. So the total initial cost for this technology is $730 per lateral.

Life cycle costs are determined by adjusting the initial cost by the life cycle period. For the purposes of this evaluation, inflation and the time value of money are assumed to be the equal.

4. LIFE CYCLE COST:BENEFIT

The life cycle cost is divided by the total value of a technology to determine a cost:benefit number whose value is given in dollars per benefit point. The lower the life cycle cost:benefit number, the better cost value is provided by a given technology.

In the below example of the tool, the most attractive options from a life cycle cost:benefit standpoint are the CIPLS–Tophat and the CIPLL–T Liner options at $103/benefit point. The initial cost:benefit of the CIPLS–Tophat is $72/benefit point, versus $103/benefit point for the CIPLL–T Liner, indicating that the best value is for the CIPLS–Tophat for this particular bid. Keep in mind that these are two options provide very different flow reduction characteristics. In the case of NCC, the CIPLS–Tophat simply would not provide sufficient flow reduction if used extensively. But in situations where the full T-Liner cannot be installed, the CIPLS–Tophat provides the best value for shorter lateral rehabilitation options for this particular project example. Notice that this is markedly different from the initial cost:benefit conclusion, which would indicate Logiball with Acrylimide is the best value at only $30/benefit value.

The power of this tool is in conducting what-if and sensitivity analyses regarding benefit values, life cycle periods, and cost changes when evaluating technologies to specify for rehabilitation.

Trial

Technology	Description	Vetted and Approved Vendor(s)	Life Cycle Cost:Benefit	Life Cycle Cost	Initial Cost:Benefit	Initial Cost	Base Cost	Adder Cost	Cleanout Cost	Life Cycle	Value	Tap Structural Value	Lateral Structural Value	Annular Space/ Tap Leakage Value	Riser Leakage Value	ROW Leakage Value	6":4" Leakage Value	Private Leakage Value	Cleanout Value	O&M Value
												15		75					10	
											Weighting (Total of 100)	8	7	20	15	15	10	15	6	4
												Portion of Value								
Logiball w/ Acrylimide	6' packer grouting w/ acrylimide	Logiball, Avanti, DaNeef	$ 190	$ 4,563	$ 30	$ 730	$ 650	$ 80		8	24	0	0	12	12	0	0	0	0	0
Logiball w/ Urethane	6' packer grouting w/ urethane	Logiball, Avanti, DaNeef	$ 133	$ 4,267	$ 40	$ 1,280	$ 1,200	$ 80		15	32	2	0	15	15	0	0	0	0	0
PIRTS	5" Pressure injected resin tap seal	Jansenn, Prokasro	$ 116	$ 2,556	$ 105	$ 2,300	$ 2,300			45	22	6	0	15	0	0	0	0	0	1
CIPLC - Tophat	9" cured in place lateral connection without mainline wrap	Trelleborg Epros, BLD	$ 182	$ 3,633	$ 109	$ 2,180	$ 2,100	$ 80		30	20	4	0	15	0	0	0	0	0	1
CIPLC - Stubby	9" cured in place lateral connection with mainline wrap	Trelleborg Epros Drain LCR, LMK Stubby, Easy Liner Saddle Liner	$ 142	$ 3,680	$ 142	$ 3,680	$ 3,600	$ 80		50	26	5	0	20	0	0	0	0	0	1
CIPLS - Tophat	3' cured in place lateral liner without mainline wrap	BLD	$ 103	$ 3,607	$ 72	$ 2,525	$ 2,400	$ 125		35	35	4	2	15	12	0	0	0	0	2
CIPLS - T Liner	3' cured in place lateral liner with mainline wrap	LMK Shorty	$ 113	$ 4,625	$ 113	$ 4,625	$ 4,500	$ 125		50	41	5	2	20	12	0	0	0	0	2
CIPLL - Tophat	30' cured in place lateral liner without mainline wrap	BLD	$ 145	$ 11,184	$ 116	$ 8,947	$ 5,000	$ 300	$ 3,647	40	77	4	7	15	15	15	8	4	6	3
CIPLL - T Liner	50' cured in place lateral liner with mainline wrap	LMK T-Liner	$ 103	$ 10,167	$ 103	$ 10,167	$ 4,600	$ 1,920	$ 3,647	50	99	7	7	20	15	15	10	15	6	4
CIPLL - Tophat Blindshot	25' cured in place lateral liner without mainline wrap without a cleanout	BLD Blindshot	$ 135	$ 8,800	$ 108	$ 7,040	$ 6,000	$ 1,040		40	65	4	5	15	15	15	8	0	0	3
CIPLL COS	50' cured in place lateral liner installed through cleanout with no tap seal	Easy Liner Cleanout Shot, LMK Cleanout Shot	$ 104	$ 7,147	$ 104	$ 7,147	$ 3,500		$ 3,647	50	69	1	7	0	12	15	10	15	6	3
CIPLL COS - PIRT	50' cured in place lateral liner installed through cleanout with pressure injected resin tap seal	Easy Liner Cleanout Shot, LMK Cleanout Shot with Jansen, Prokasro	$ 114	$ 10,497	$ 103	$ 9,447	$ 5,800		$ 3,647	45	92	8	7	15	14	15	10	13	6	4
CIPLL Blindshot - PIRT	25' cured in place lateral liner without mainline wrap without a cleanout with pressure injected resin tap seal	Modified BLD Blindshot with Jansen, Prokasro	$ 132	$ 9,489	$ 119	$ 8,540	$ 8,300	$ 240		45	72	8	7	15	15	15	8	0	0	4
CIPLL - Tophat Blindshot -full length	50' cured in place lateral liner without mainline wrap without a cleanout	BLD Blindshot EL	$ 100	$ 8,688	$ 80	$ 6,950	$ 6,650	$ 300		40	87	8	7	15	15	15	8	15	0	4
CIPLL - T Liner Blindshot	50' cured in place lateral liner with mainline wrap without cleanout	LMK T-Liner Blindshot	$ 100	$ 9,300	$ 100	$ 9,300	$ 9,000	$ 300		50	93	7	7	20	15	15	10	15	0	4

Denotes Technologies not yet commercially available

Figure 4. Example of tool.