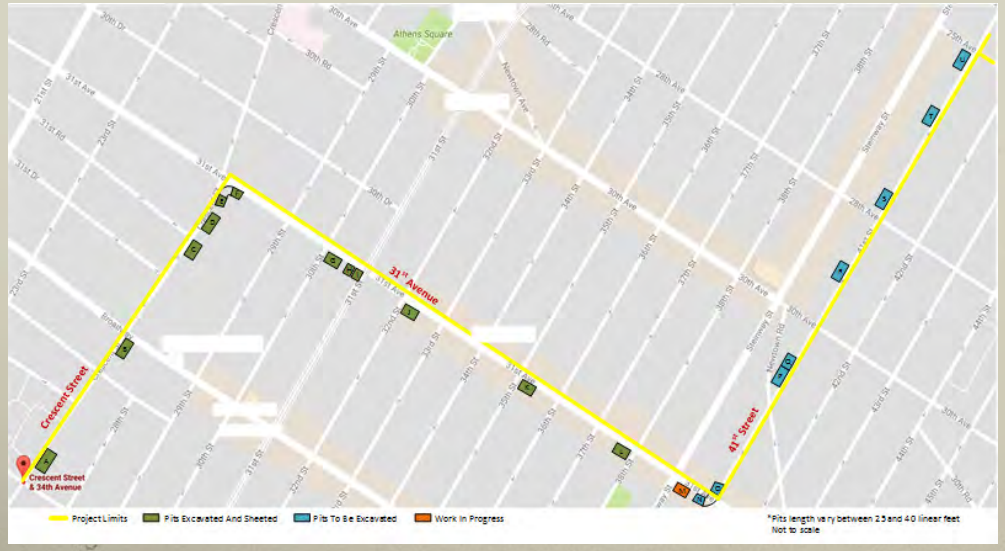
NORTH AMERICAN SOCIETY FOR TRENCHLESS TECHNOLOGY

STRATEGIC SLIP LINE REHABILITATION
OF NEW YORK CITY'S TRUNK WATER MAIN SYSTEM



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Executive Summary

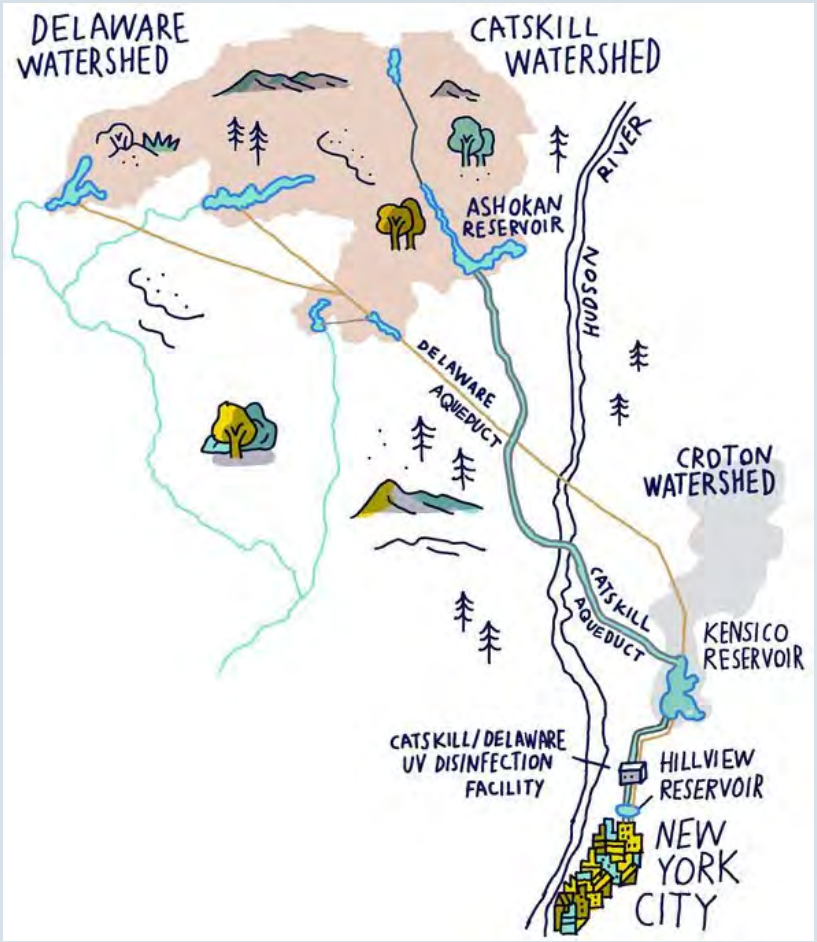
Objective: To reactivate a major trunk water main system after over 20 years of discontinued service and connect to the newly activated Water Tunnel No. 3.

Means & Method: Slip Line through 17 densely populated city blocks (7,016 LF) in Astoria, Queens.

- Liner Pipe is 52" O.D.
  - 1/2" wall steel pipe with mortar interior and polyurethane exterior coatings.
- Host Pipe is 60" I.D.
  - 5/8" wall steel pipe with coal tar interior and exterior coating.
- Slip Line Installation includes:
  - 16 individual runs ranging in length from 81.5' to 773'.
- Open-Cut Restoration limited to
  - approximately 1,100 lf of 52"/60"/72" steel pipe and appurtenances.
- Reduce construction duration and cost by at least **50%** as compared to Open-Cut.

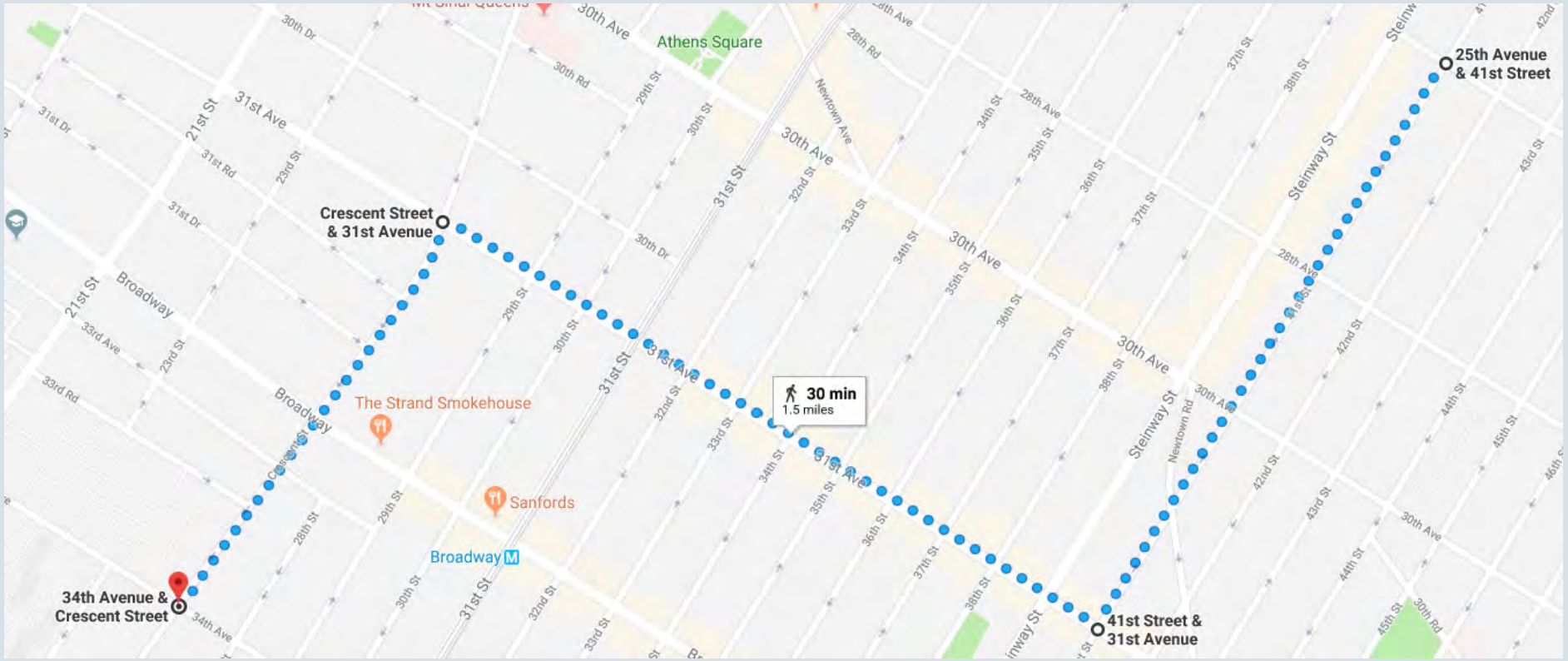
Background of NYC's Water Distribution System

- Two Reservoirs
  - Catskills and Croton
- Three Water Tunnels
  - Nos. 1, 2 and now 3
- Water Tunnels → Shafts
- Shafts → Trunk Mains
- Trunk Mains → Distribution



History of 60” Trunk Water Main

- Installed in Astoria, Queens, in 1989.
- Failed in January 1996.
- Low temperature + Low ductility → Failure!



Chemical Analysis Results

- Low, but within tolerances:
  - low Manganese
  - low Molybdenum
  - \+ low Chromium

While acceptable individually, the low combination of the three resulted in disaster

60" STEEL WATER MAIN IN ASTORIA
Failed Jan. 02, 1996

SUBJECT: **ANALYSIS OF CARBON STEEL FROM FAILED WATER MAIN ASTM A283–88, GRADE C**

Laboratory Nos.: 37919–20

Represents: Spiral–welded pipe from a broken 60" water main at the intersection of 31st Avenue & 33rd Street, Astoria, Queens. The break occurred on January 2, 1996. The pipe was fabricated by Progressive Fabricators, St. Louis, MO under Contract 522B and was to conform to the specifications of ASTM 283, Grade "C" as modified by the Contract. The samples were received from George Andersen, Administrative Engineer II, BWS & WC. Sample No. 37919 is from the bell section whereas Sample No. 37920 is from the spigot end of the adjoining pipe. The samples were analyzed for carbon and sulfur by combustion; all other elements were analyzed by using X–ray fluorescence.

	Percentage Composition (BELL) #37919	(SPIGOT) #37920	ASTM A283–88, Gr. C Specifications	Contract 522B Modifications
Carbon	0.20	0.19	0.24 max.	no requirement
Manganese	0.40	0.71	0.90 max.	no requirement
Phosphorus	0.008	0.003	0.04 max.	0.04 max.
Sulfur	0.027	0.026	0.05 max.	0.05 max.
Silicon	0.01	< 0.01	0.40 max.	no requirement
Copper	0.02	0.03	----	0.15 max.
Nickel	0.02	0.03	----	0.15 max.
Molybdenum	< 0.01	< 0.01	----	0.07 max.
Chromium	0.04	0.02	----	0.09 max.

Consequently, the material analyzed meets the chemical specification limits of both ASTM A283–88 and Contract 522–B.

Charpy V-Notch Results

60-Inch Water Main, Astoria, NY 1996												
WMARK NO.	HEAT NO.	LOCATION	CHARPY TEST RESULTS								COMMENTS
			70 °F				40 °F				
			1	2	3	AVG	1	2	3	AVG	
M1-13	C47460	41st St. // 72' S'S'CL of 28th Ave. IFO C-Town Supermarket	15	16	17	16	12	7	7	9	Tested 3/20/96, S. Anders
M1-31	C50551	41st St. // 152' S'S'CL of 28th Ave. Opposite 28-13 41st Street	10	15	11	12	8	7	7	7	Tested 3/20/96, S. Anders
M1-58	C44520	31st Ave. // 82' W'W'CL of 35th St. IFO 34-14 31st Ave	27	23	28	26	15	15	16	15	Tested 3/15/96, S. Anders
M1-79	C45558	31st Ave. // 132' E'E'CL of 35th St. IFO 35-16 31st Ave	4	4½	4	4	3	2½	2½	2½	Tested 3/15/96, S. Anders
M1-81	C45849	31st Ave. // 113' E'E'CL of 32nd St. IFO 32-12 31st Ave	3	3	3	3	2½	2	3	2½	Tested 3/15/96, S. Anders
M1-90	C45546	41st St. // 46' N'N'CL of 28th Ave. IFO 25-95 28th Ave	20	22	25	22	13	16	16	15	Tested 3/20/96, S. Anders
M2-5	C51458	34th Ave. // 125' E'W'CL of 24th St. IFO 24-14 34th Ave	3½	4	3½	3½	2½	3	2½	2½	Tested 3/25/96, H. Goldenberg
M2-29	14515	31st Ave. // 122' W'W'CL of 35th St. IFO 34-10 31st Ave	25	19	29	24	18	14	20	17	Tested 3/15/96, S. Anders
M2-32	5501860	41st St. // 84' N'N'CL of 28th Ave. Opposite 25-95 28th Ave.	17	14	13	15	7	8	7	7	Tested 3/20/96, S. Anders
M2-38	567937	41st St. // 328' N'N'CL of 28th Ave. IFO 25-70 41st St	23	25	23	24	18	15	18	17	Tested 3/20/96, S. Anders
M2-66	5463718	31st Ave. // 56' E'E'CL of 31st St. IFO 31-04 31st Ave	49	36	40	42	17	29	22	23	Tested 3/15/96, S. Anders
M2-85	C23724	Crescent St. // 69' S'S'CL of 31st Ave. IFO 31-04 Crescent St.	8	5½	6	6½	4	3½	3½	3½	Tested 3/25/96, H. Goldenberg
M2-93	C23720	41st St. // 112' S'S'CL of 28th Ave. IFO 28-12 41st St.	24	28	27	26	18	20	18	19	Tested 3/20/96, S. Anders
Bell M1-78	C45558	Int. of 31st Ave. & 33rd St. Failed Pipe of 1/2/96	3	4	4	4	2½	2½	2½	2½	Tested 3/15/96, S. Anders
Spigot M2-16	C51458	Int. of 31st Ave. & 33rd St. Welded to Failed Pipe of 1/2/96	3	3½	2½	3	3	2½	2½	2½	Tested 3/15/96, S. Anders

Design Challenges

- Requirements
  - Design must be a **Full Structural Solution** while
    - Optimizing flow and minimizing impacts
- Impacts
  - Environmental Considerations
    - Heavily and densely populated community
    - Pollution and particulate matter
  - Financial Considerations
    - Local businesses
    - Heavy traffic for both residential and commercial vehicles
  - Community Considerations
    - Noise and traffic considerations for residences and businesses
    - Mix use commercial and residential zones

What Are the Options?

- Open-Cut
- Carbon Fiber Wrap
- Slip Lining
  - HDPE
  - Steel carrier pipe

Open-Cut

Pros

- Full Structural Solution
- No Flow Capacity Loss

Cons

- Severe Socio-Economic Consequences
- Environmental Impacts
- Limited Work Hours
- Prolonged Schedule
- Expensive

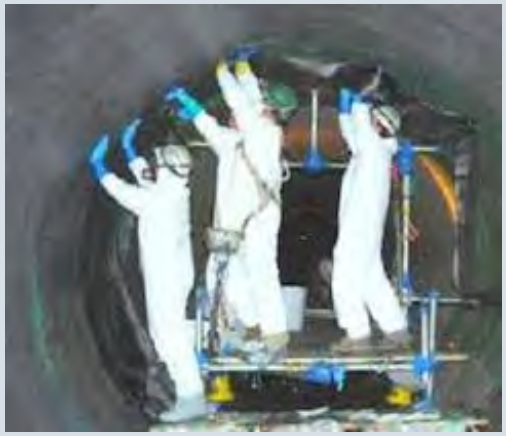
Carbon Fiber Wrap

Pros

- Minimal Disruption to the Community

Cons

- Only semi-structural solution
- Highly Labor intensive
- Expensive



Slip Lining with HDPE

Pros

- Successfully installed previously (Madison Avenue in Manhattan)
  - Proves slip lining as a feasible method for constructability in NYC.
- Drastically reduced construction duration and disturbance to community.

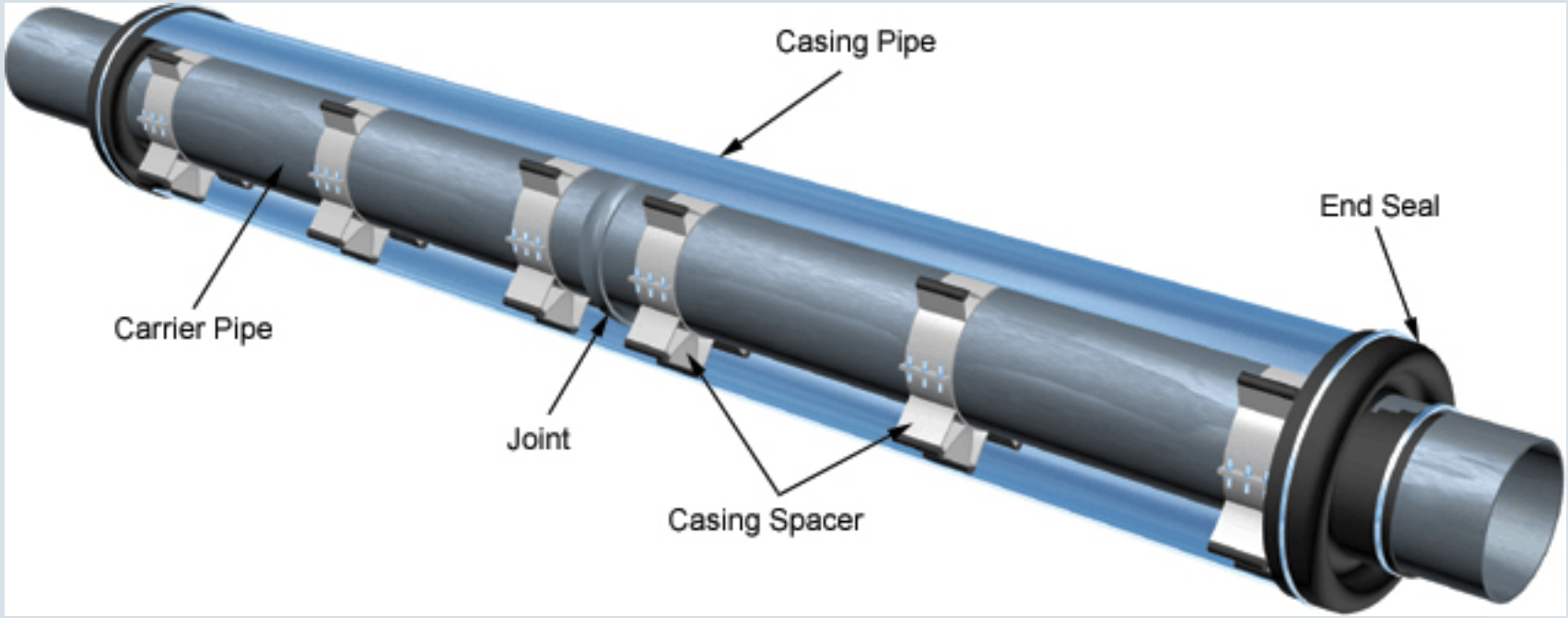
Cons

- Only semi-structural solution
- **HIGH** maintenance due to coupling failures

Lessons Learned

Design Solution

- DDC Design utilized steel pipe as a carrier instead of HDPE.
  - Steel pipe provides a fully structural solution with a full design life.
  - Steel pipe is **cheaper** than customized DIP.



Slip Lining with Steel Pipe

Pros

- Full Structural Solution
- Open-cut reduced by over **80%**
- Minimal loss of capacity
- Most cost effective method
- Reduce construction duration by upwards of **50%**

Cons

- Some loss of capacity
- Still some open-cut

Key Technical Considerations

- Pipe Parameters
  - 52-inch diameter steel pipe with ½ inch thickness
- Pipe Stops
- Casing Spacers
- Grouting of Annular Space
- Jacking and Receiving Pit Utilizations
- Constructability

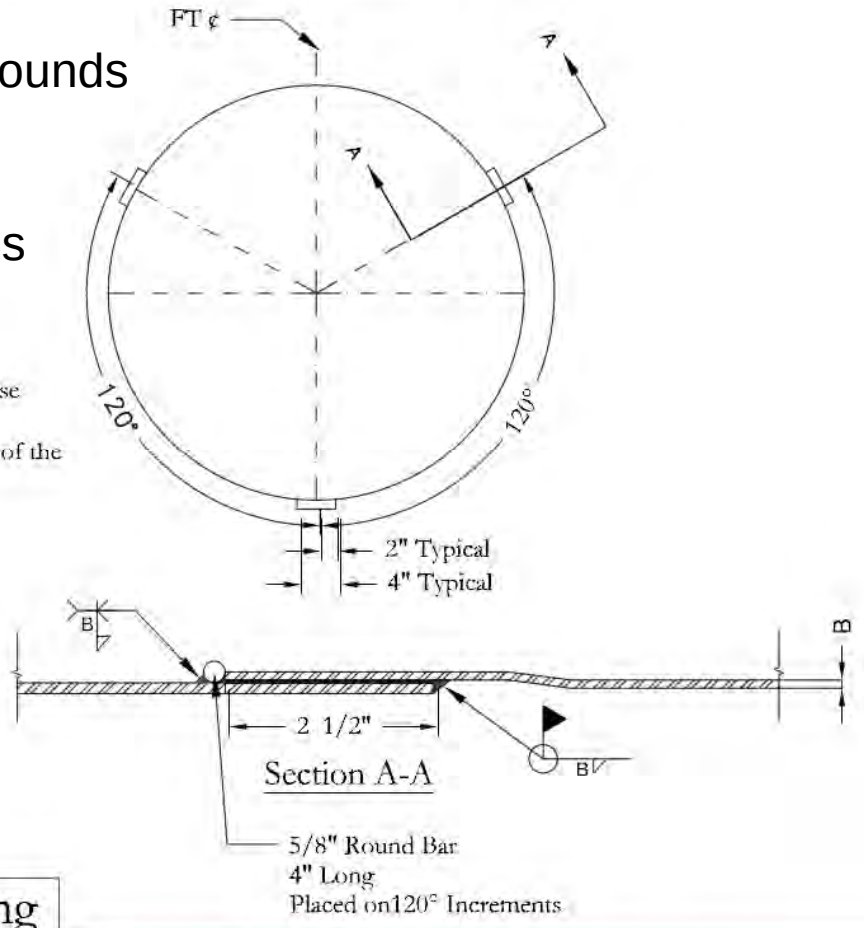
Pipe Stops

PIPE STOP FOR SLIPLINE PIPE

Max. load/pipe stop =
44,500 pounds

3 pipe stops per joint:
3 x 44,500 = 66.75 tons

Notes:
- All dimensions are in inches unless otherwise specified.
- All fillet welds to be the size of the thinner of the two materials being welded.

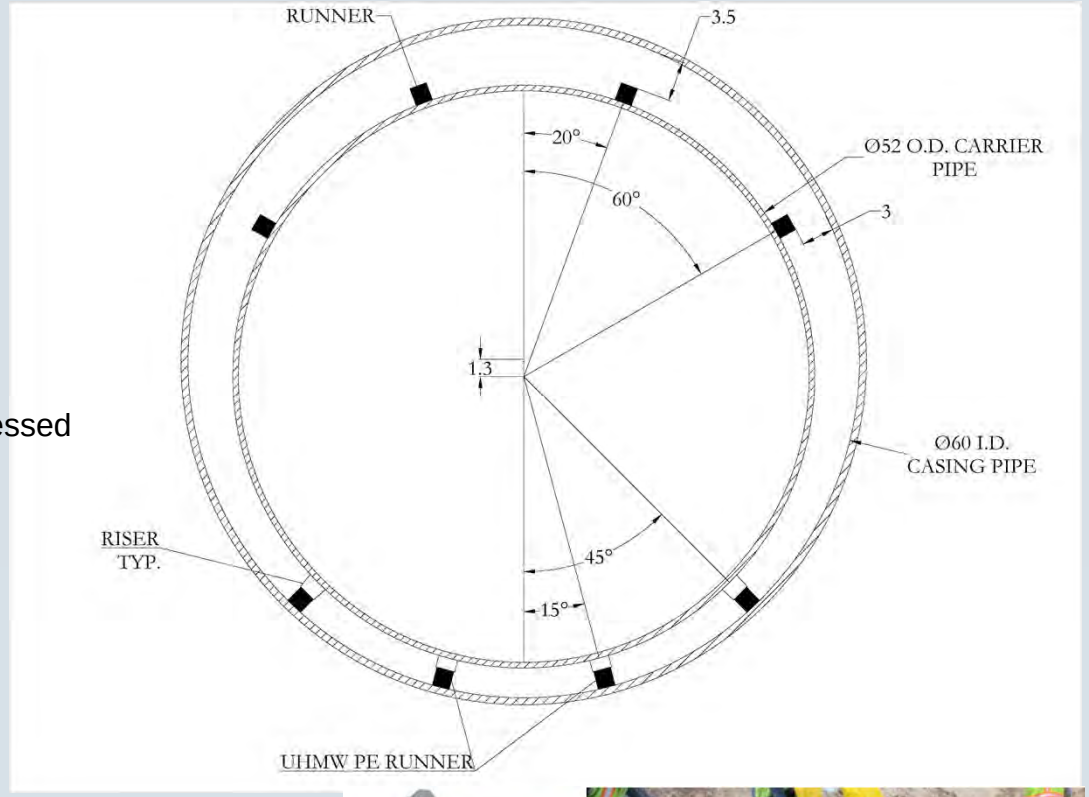


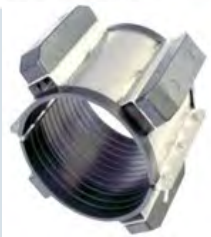
Pipe Lining and Coating

Pipe Stop Detail
Sample Drawing

Casing Spacers

- **UHMWE PE** Runners utilized
  - Lower coeff. of friction
- Constructability
- Corrosion Mitigation





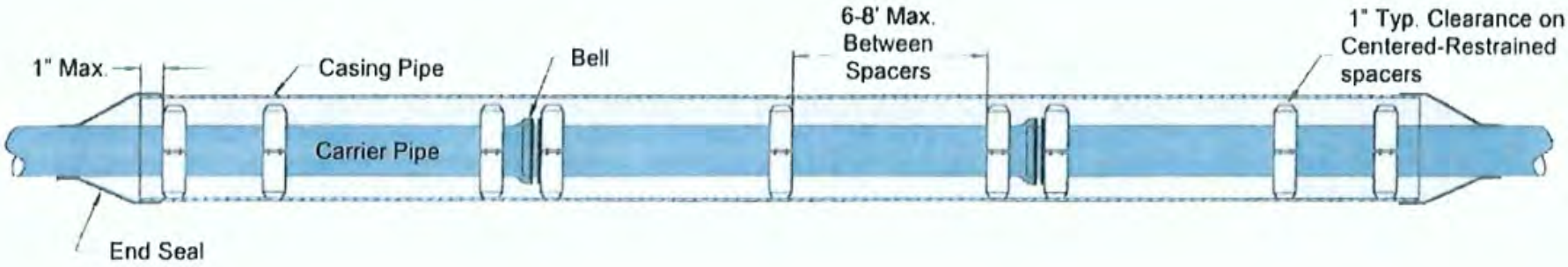
RUNNER
2" WIDE X I 112" X 11" MOLDED POLYMER
4 TOP, 4 BOTTOM
Attached using (3) 3/8" welded steel studs/ locknuts recessed ½" below wearing surface of runner
Recess shall be filled with corrosion inhibiting filler.

RISERS
10 GA. (.134) HOT ROLLED PICKLED STEEL
MIG WELDED TO BAND
RISER 'A'= 1.00" TALL
RISER 'B' = J.3125"TALL

LINER
PVC LINER
HARDNESS "A.' 85-90
OPERATING TEMP, 140 F
DIELECTRIC STRENGTH - 60.000 VPM

BAND
12" WIDE
12 GA. (.105") HOT ROLLED PICKLED STEEL 1 0-16 M!L THICK OF HEAT FUSED FLUIDIZED BED THER."10 SET CROSS LINKED " EPOXY COATING" RIBBED FLANGES

Recommended Placement (For typical 20' joint)



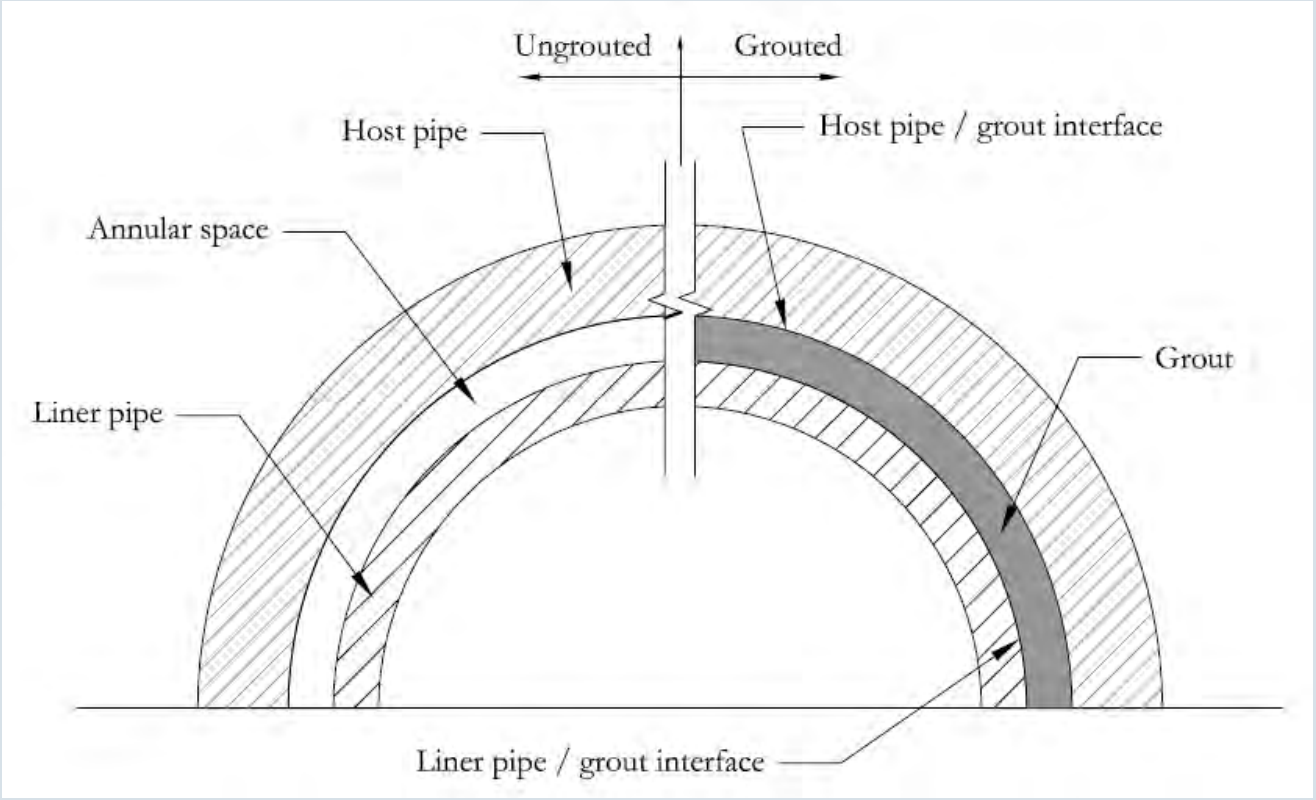
A. General Carrier: One spacer shall be placed not more than one foot from each end of the casing and pipe joint. Subsequent spacers shall be a maximum of 7' intervals within the casing.

B. PVC Carrier: One spacer shall be placed on the spigot end of each segment at the line marking the limit of insertion into the bell. When the joint is complete, the spacer shall be in contact with the bells of the joint so that the spacer pushes the joint and relieves compression within the joint.

Grouting of Annular Space

Key Attributes Necessary to Grout Annular Space

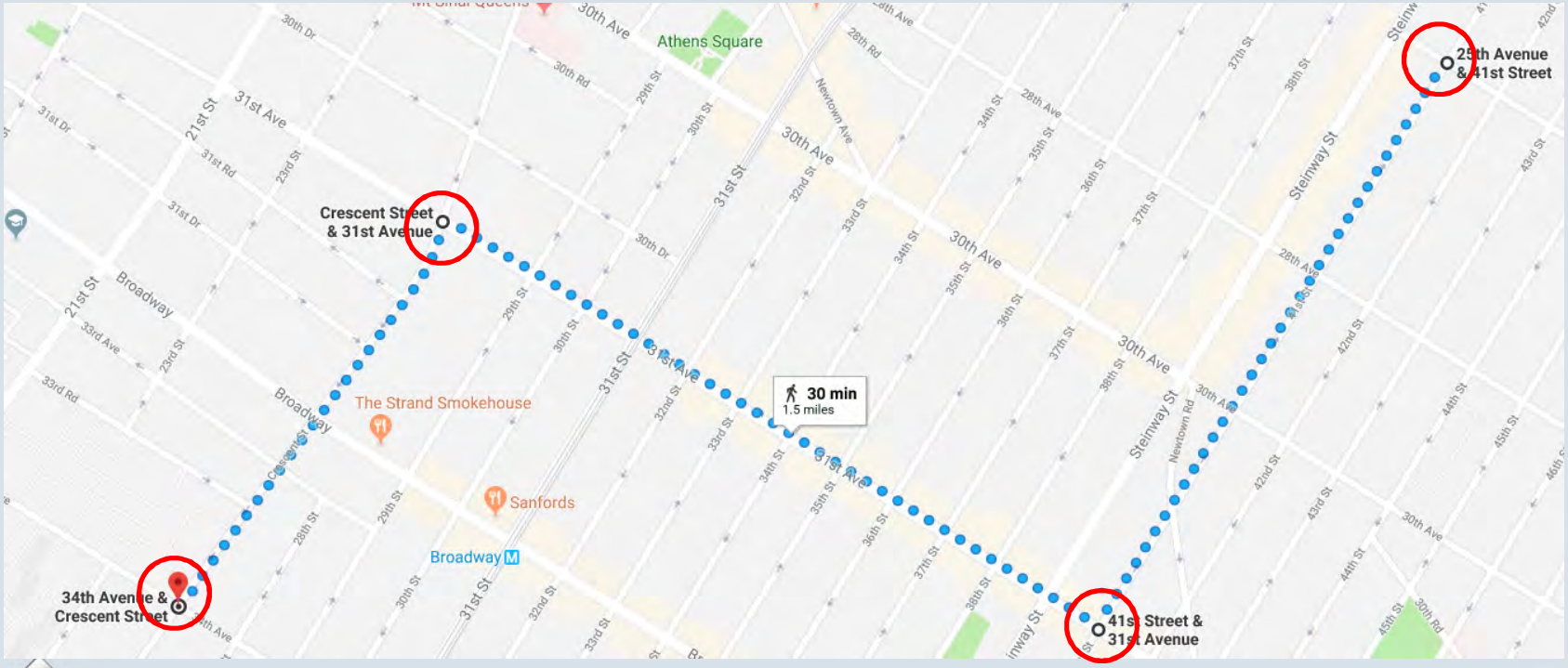
- High Flow Rate
- Lightweight
- 350-psi strength



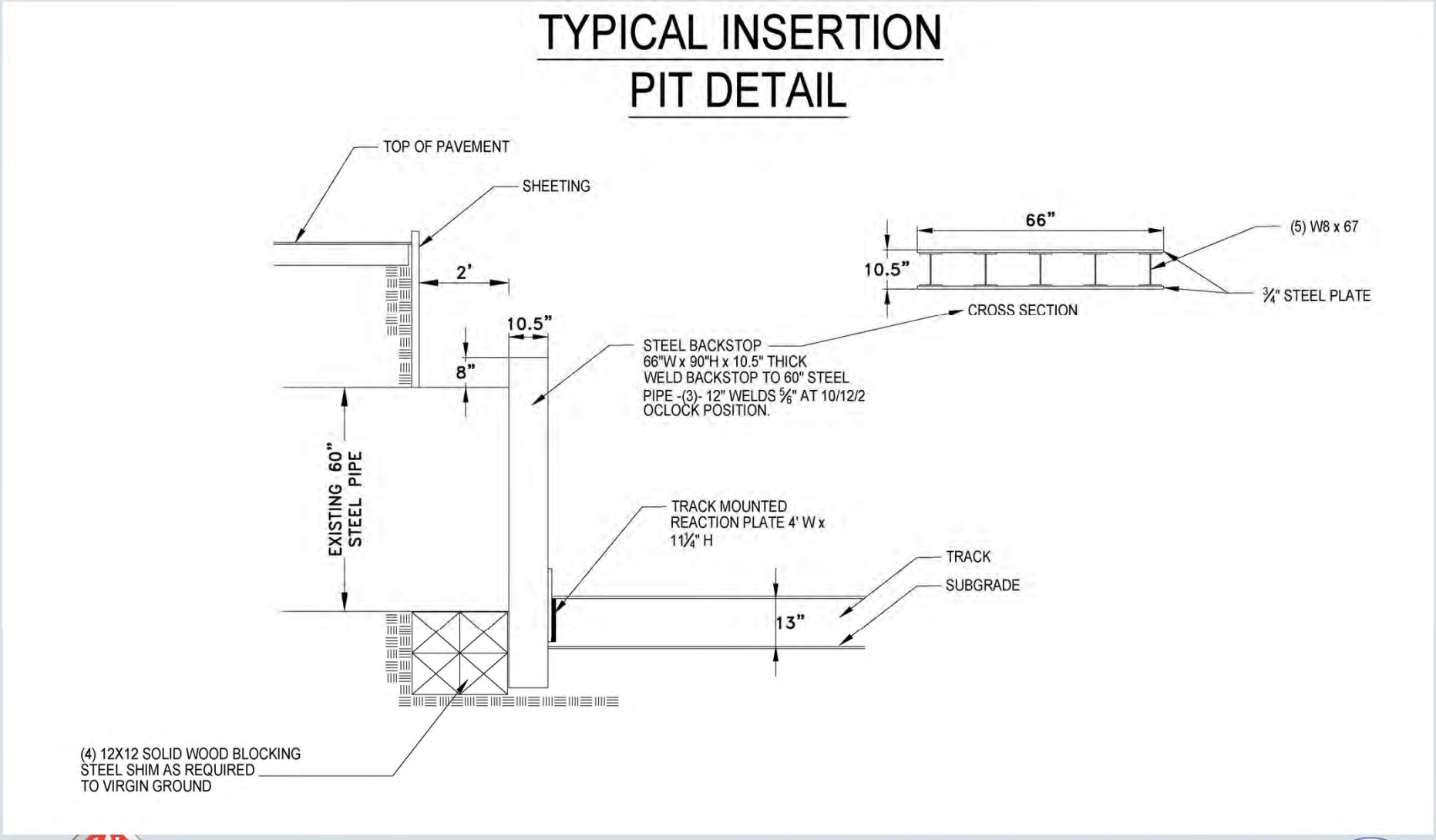
Jacking & Receiving Pits

Open-cut Trench necessary only for:

- Negotiating bends
- Connections to Butterfly Valves
- Result = Over 80% Reduction of Open-Cut!



Jacking & Receiving Pits



Constructability – Push Force Requirements I

To establish the insertion push force requirements, the following factors were taken into consideration:

- Maximum Allowable Push Force
  - **66.75 tons** may be exerted on the 52" liner pipe
- Longest Slip Lining Run Length
  - **773'**
- Weight of 52" Liner Pipe & Spacers
  - **376.81 PLF.**
- Coefficient of Friction between Casing Spacers and Existing 60" host pipe. Extensive testing resulted in the following:
  - 60" Host Pipe/ APS Runners, no lubrication - .54
  - 60" Host Pipe/ APS Runners with water lubrication - .52
  - 60" Host Pipe/ APS Runners with lubricant gel - .45
  - **60" Host Pipe/ APS Runners with lubricant soap - .32**
  - 60" Host Pipe/ APS Roller Spacers, no lubrication - .35

Push Force Requirements II

Maximum expected push force for slip line insertion is as follows:

Coefficient of Friction - .32
Length of longest Slip Lining Run – 773’
Weight of Pipe with Spacers - 376.8 PLF

F max = (Coefficient of Friction) x (Weight)
F max = (.32) X (773’ X 376.8 PLF)

F max = 93,205 LB = 46.60 Tons

Jacking Unit JU-60 SL

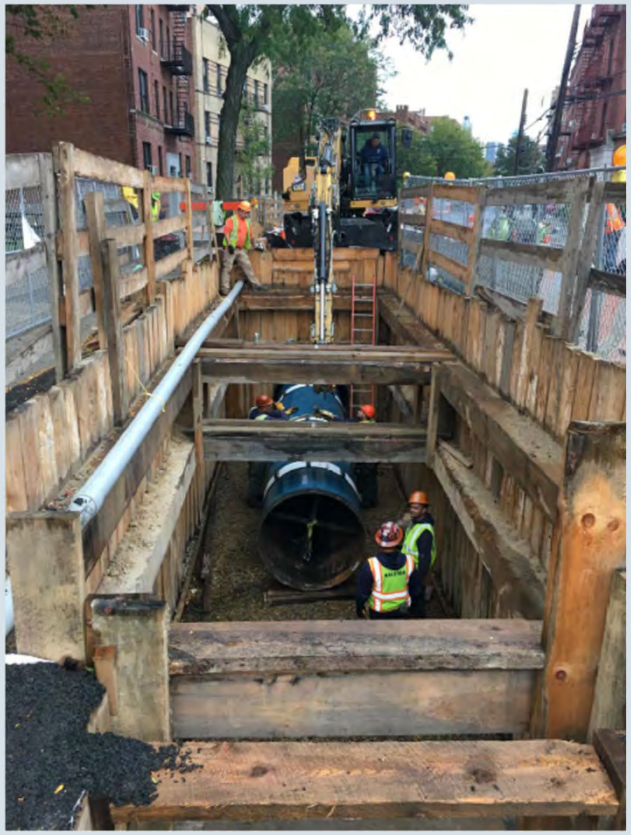
- Designed to push a 52" steel pipe into an existing 60" steel pipe.
- The front plate of the sled is removable.
- Can be used for other sizes and pipe materials by simply changing the adapter plate.

- This machine has a sled that moves down the track, which is equipped with a winch that is connected to an anchor in the backstop.

Test Pull Demonstration

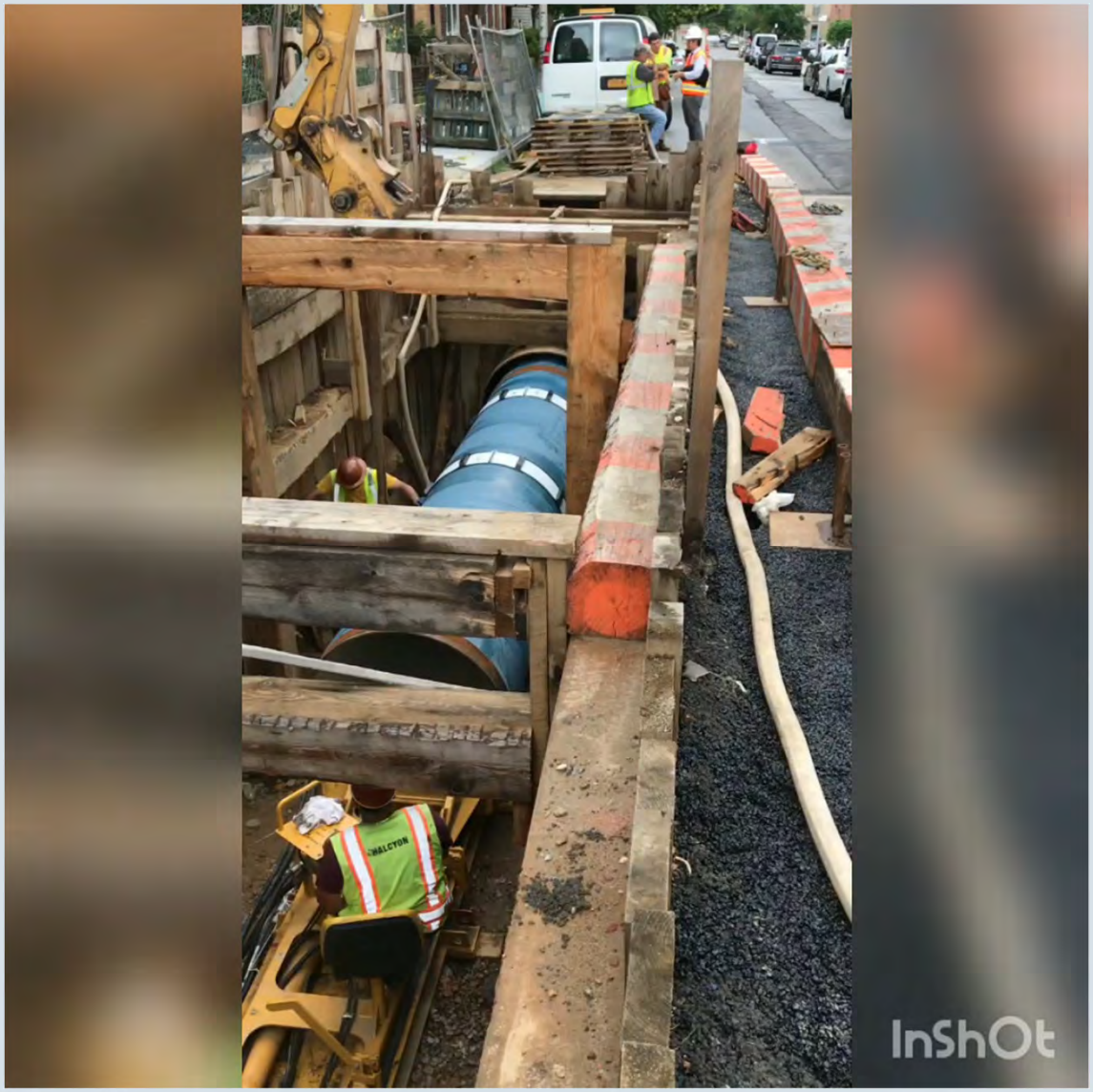
Location: South side of 31st Avenue between 38th Street and Steinway Street
Operation: Test Run using 20.0 L.F. test pipe with runners.

In this test run, the pipe is pulled using a winch instead of pushed with the maximum allowable pushing force of 66.75 tons. The purpose of this test run was to test the friction of the runners and their performance against sliding.



Location: South side of 31st Avenue between 35th Street and 36th Street
Operation: Test Run using 20.0 L.F. test pipe with runners.

Construction Video



Schedule

Crescent Street

Starting date: June 26, 2017 — Duration

Completion date: February 01, 2019 — 585 CCDs

31st Avenue — Overlapping 529 CCDs

Starting date: August 21, 2017 — Duration

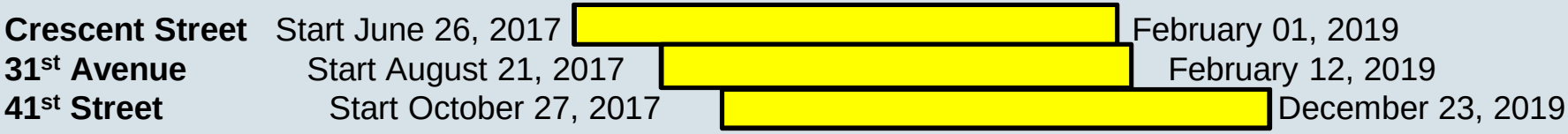
Completion date: February 12, 2019 — 541 CCDs

41st Street — Overlapping 473 CCDs

Starting date: October 27, 2017 — Duration

Completion date: June 24, 2019 (Original contract) — 606 CCDs

Final Completion date: December 23, 2019 — 787 CCDs



Conclusion

Slip Lining of 52” Pipe into the 60” Trunk Main projected to:

- Provide fully structural solution with full design life
- Reduce open-cut trenching by at least **80**%
- Minimize environmental and socio-economic impacts
- Reduce construction duration by at least **50%**
- One-third the cost compared to Carbon Fiber Wrap
- One-half the cost compared to Open-Cut.

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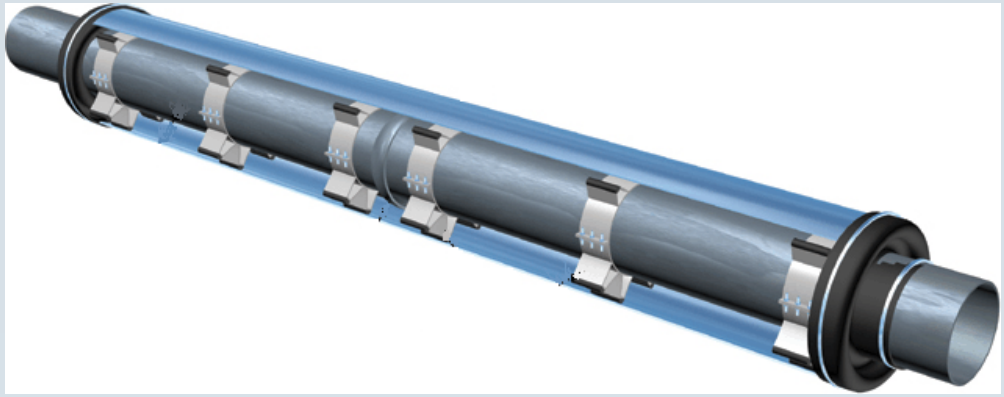
OF NEW YORK CITY'S TRUNK WATER MAIN SYSTEM

ANY QUESTIONS?



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