Trenchless Pipe Installation

Jacking & Tunneling

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American Concrete Pipe Association

Course Agenda

Why Trenchless?

Pipe Jacking Design

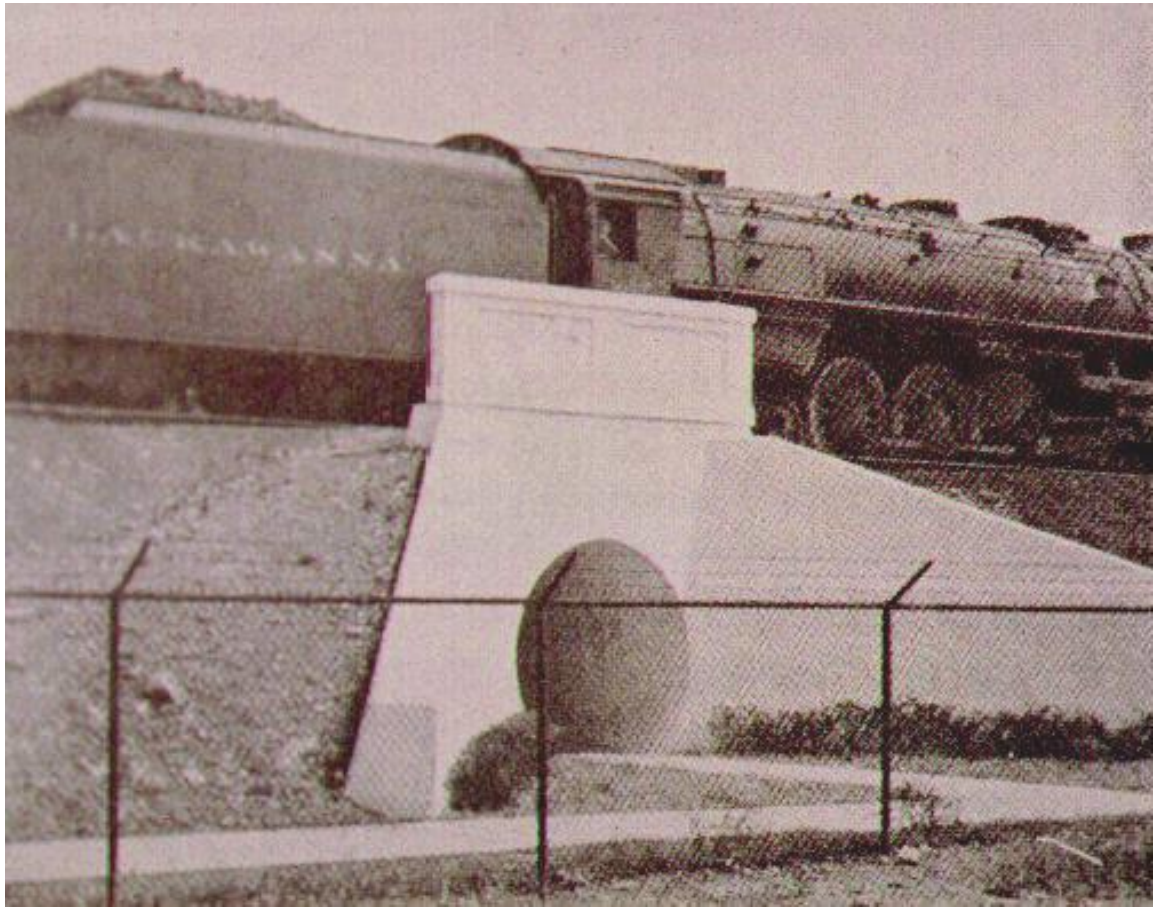
Trenchless Methods

Curved Alignment

Trenchless Replacement

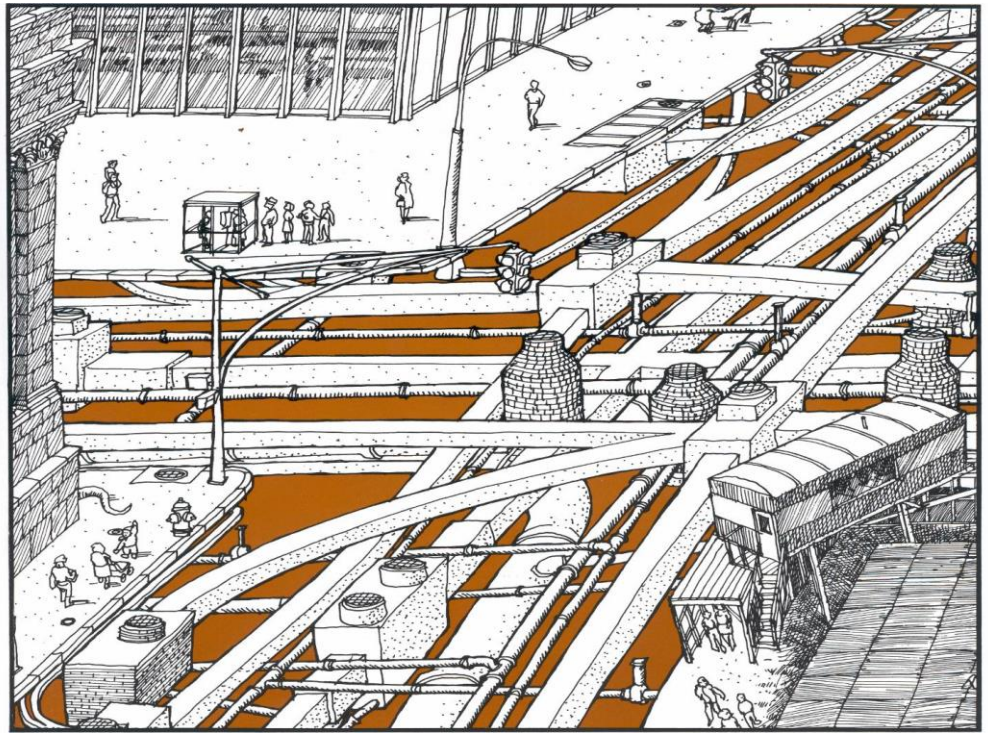
Why Trenchless?

Why Trenchless?



Why Trenchless?

- Less surface disruption
- Low risk of surface settlement
- Lower volume of excavated material
- Reduces or eliminates dewatering
- Special crossings with no other access
  - Highways
  - Railroads
  - Runways
  - Rivers & Streams



Pipe Jacking Association (UK) has sponsored the software that estimates that pipe jacking can reduce carbon emissions on infrastructure projects by up to 75% in comparison to open-cut methods.

- *July 2013 Trenchless International Newsletter*

Trenchless Technology

Environmental Considerations

2a) Comparing the environmental aspects and carbon savings of open trench and pipe jacked sewer construction at two typical sewer diameters

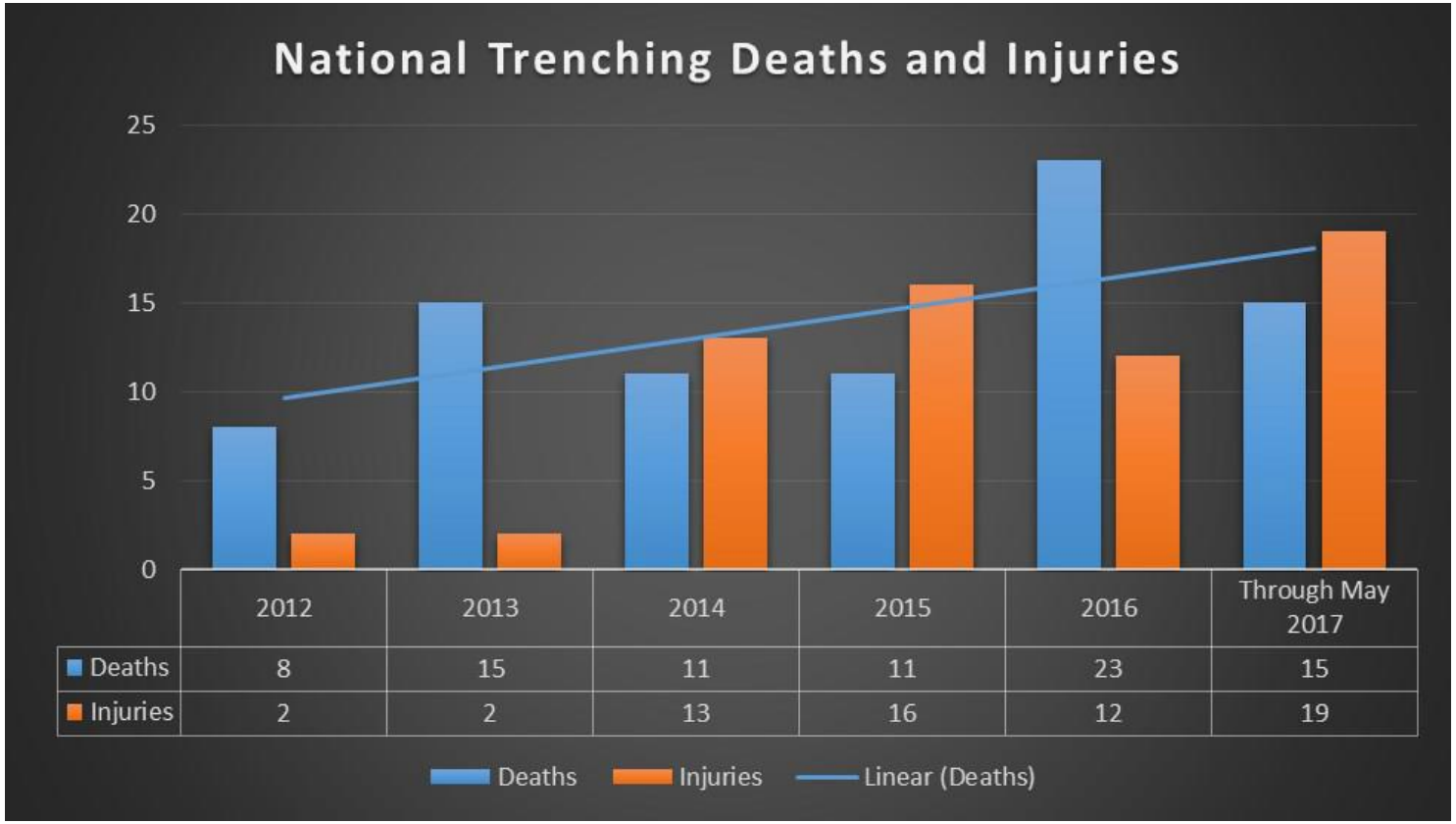
	600mm ID pipeline 4m deep, 100m length		1200mm ID pipeline 4m deep, 100m length	
Aspect	Open trench	Trenchless	Open trench	Trenchless
Excavated width	1400mm (trench width)	760mm (OD of jacking pipe)	2350mm (trench width)	1450mm (OD of jacking pipe)
Reinstatement width	1700mm	None	2650mm	None
Excavated volume per metre of pipeline	6.1m^3	0.5m^3	10.28m^3	1.65m^3
Imported stone fill and coated stone per metre of pipeline	11.9 tonnes	None	18.27 tonnes	None
Number of 20 tonne lorry loads per 100m pipeline (muck away and imported stone)	136	8	220	21
Tonnes CO_2 emissions	66.7	27.1 **60%**	110.6	69.7 **37%**

Trenchless Technology

Safety Considerations

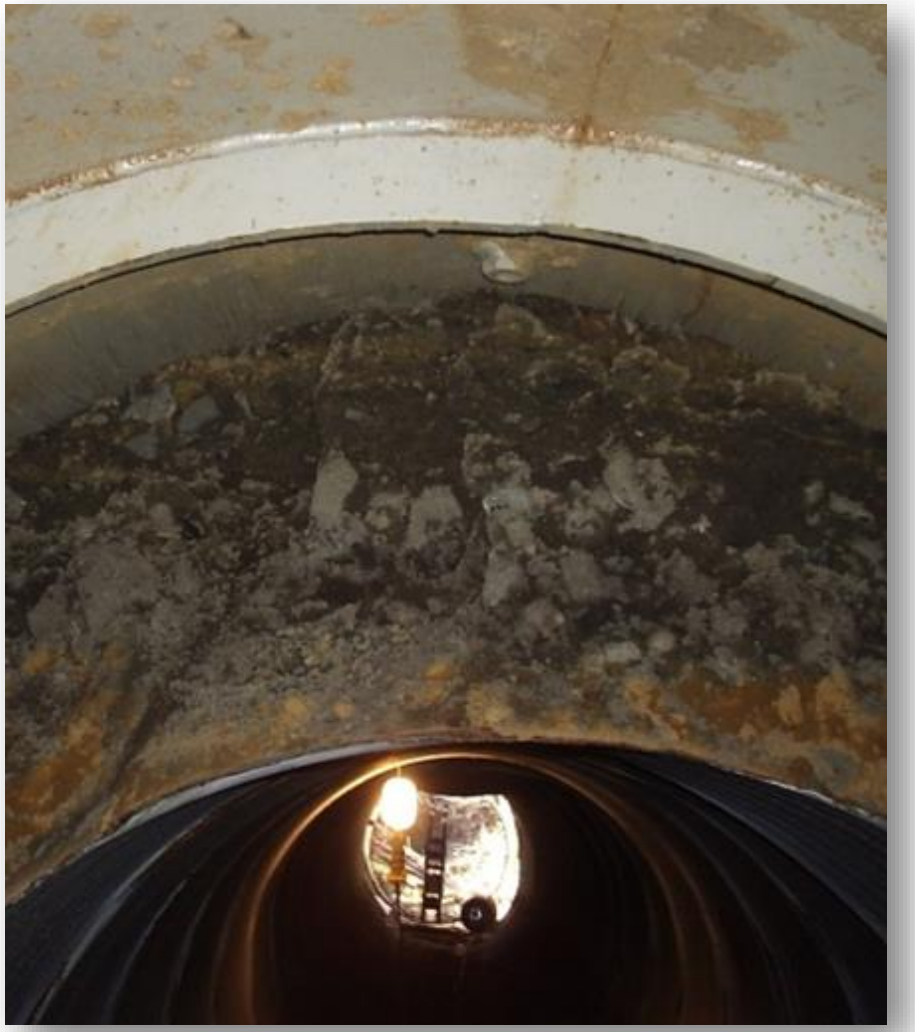
Safety Benefits:

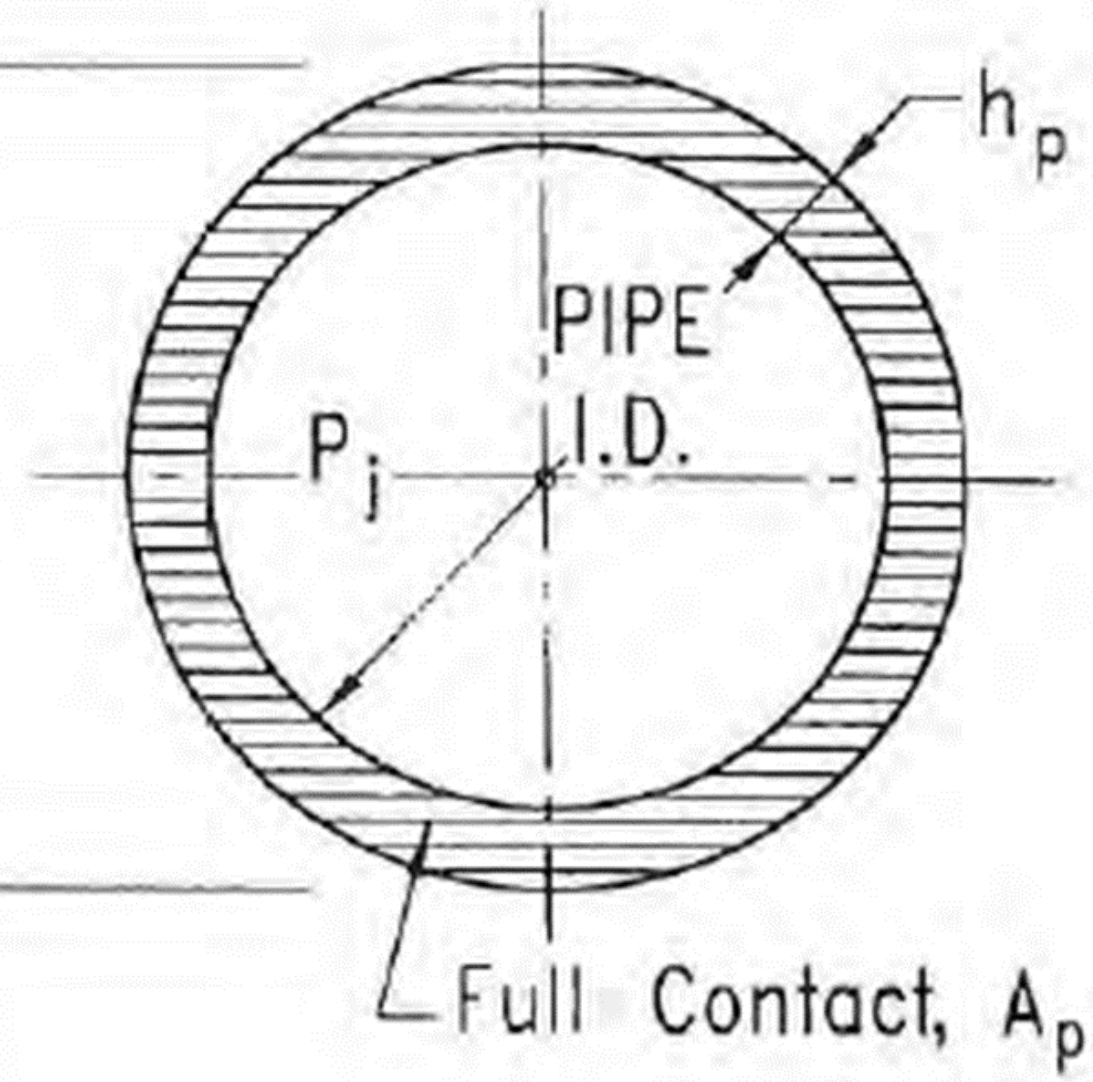
- Inherently safer than open trench
- Reduced labor requirements
- Significant reduction in risk of injury as a result of hitting utilities and danger to the public



OSHA 2017

Why Trenchless?



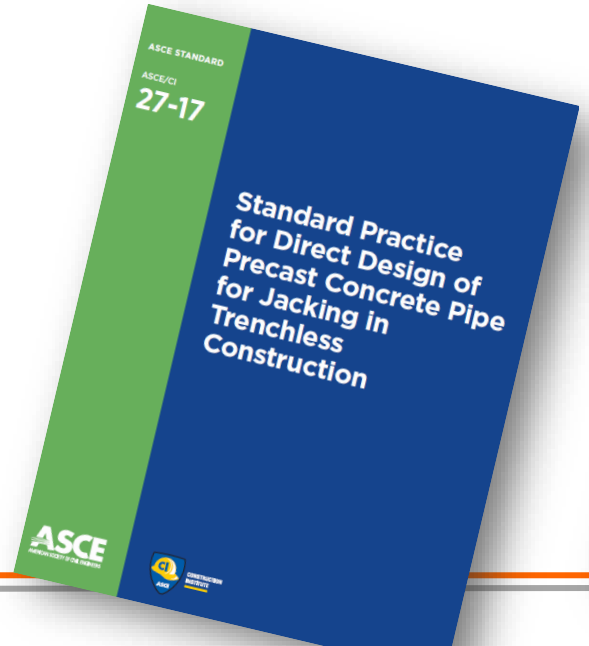


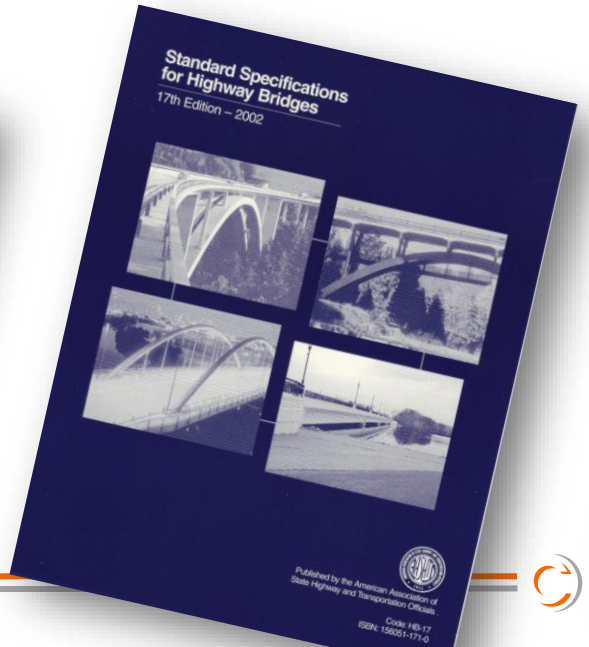
Pipe Jacking Design

Jacking Pipe

Design Guidance

- ASCE 27-17 – Standard Practice for Direct Design of Precast Concrete Pipe for Jacking in Trenchless Construction
- ASCE 36-15 – Standard Construction Guidelines for Microtunneling
- Pipe Jacking Association of UK
- Trenchless Technology (trenchlesstechnology.com)
- ACPA Design Data 4 - Jacking Concrete Pipe (concretepipe.org)





Jacking Pipe

Design Considerations

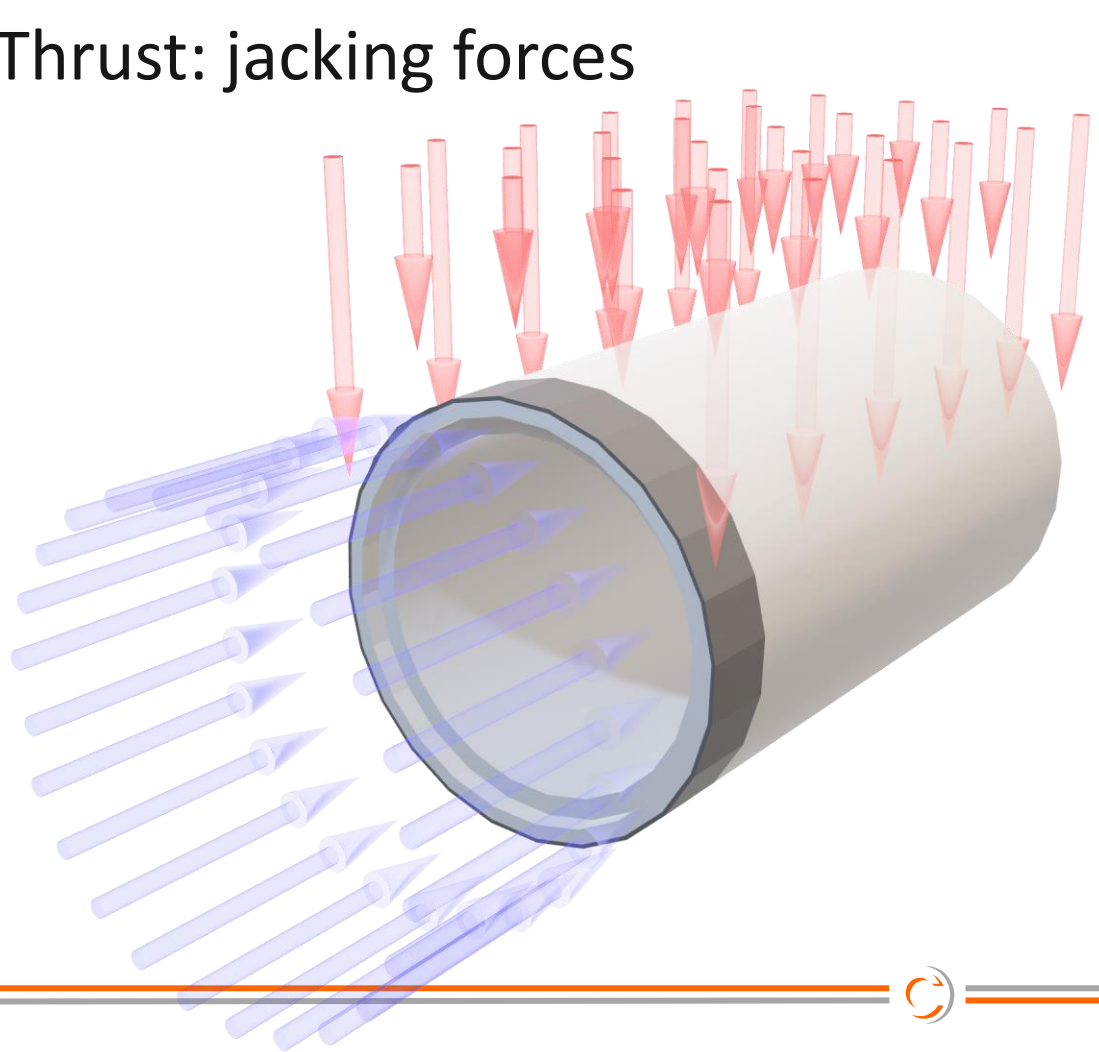
JACKING PIPE

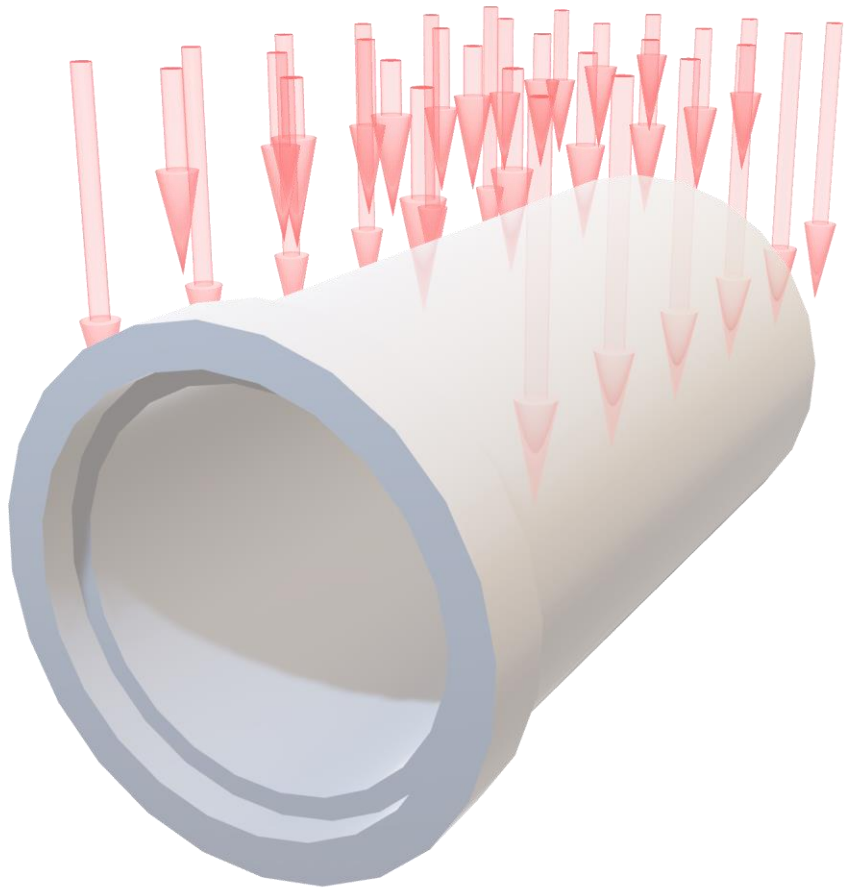
STANDARD PIPE

Jacking Pipe

Design Considerations

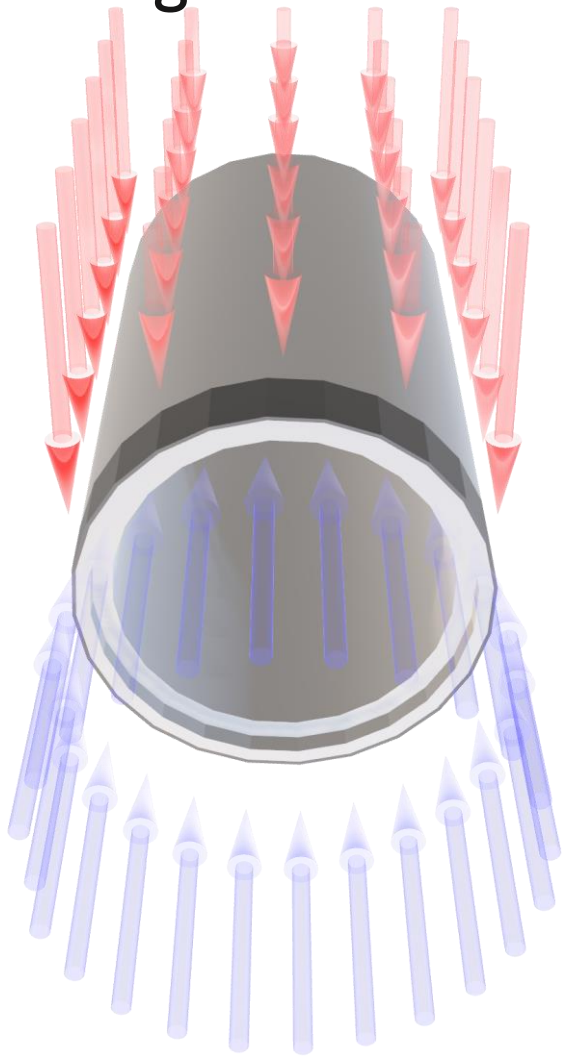
- Vertical loads: earth + live
- Axial Thrust: jacking forces





Jacking Pipe

Design Considerations



Vertical Loads:

- Resisted by circumferential reinforcement
- Significantly smaller for trenchless installations than for open-cut installations

  Example:

  - 48” RCP with 20’ earth cover
  - Load in 8-ft. wide trench = 13,166 lb. / LF
  - Load when jacked = 4,533 lb. / LF

Axial Loads:

- Resisted by compressive strength of longitudinal pipe wall
- Much greater than vertical loads

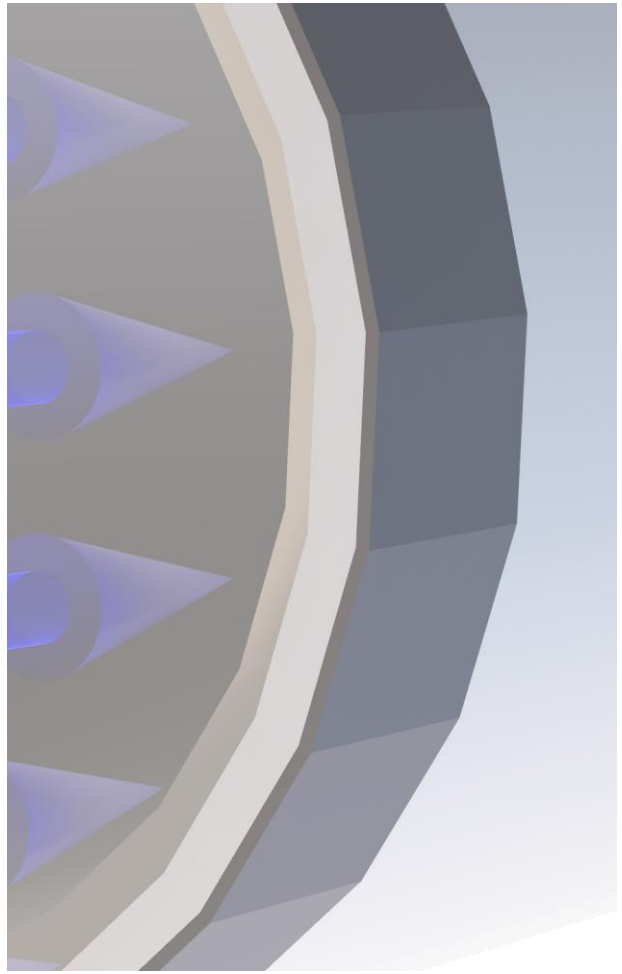
  Example:

  48” RCP with 200’ push

  Axial load when jacked ~ 300,000 lb

Jacking Pipe

Design Considerations

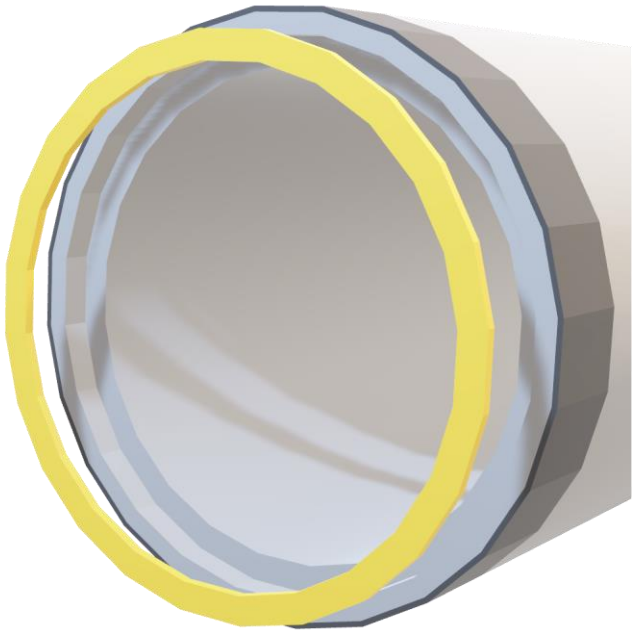


- Transfer of load through the joint
- Angular displacement at the joint

- Axial Jacking Loads
  - Required to overcome friction developed between the pipe wall and the surrounding soil
  - Required to overcome the face pressure on the boring machine.
  - Resisted by the concrete's compressive strength and the area of wall cross section receiving the thrust

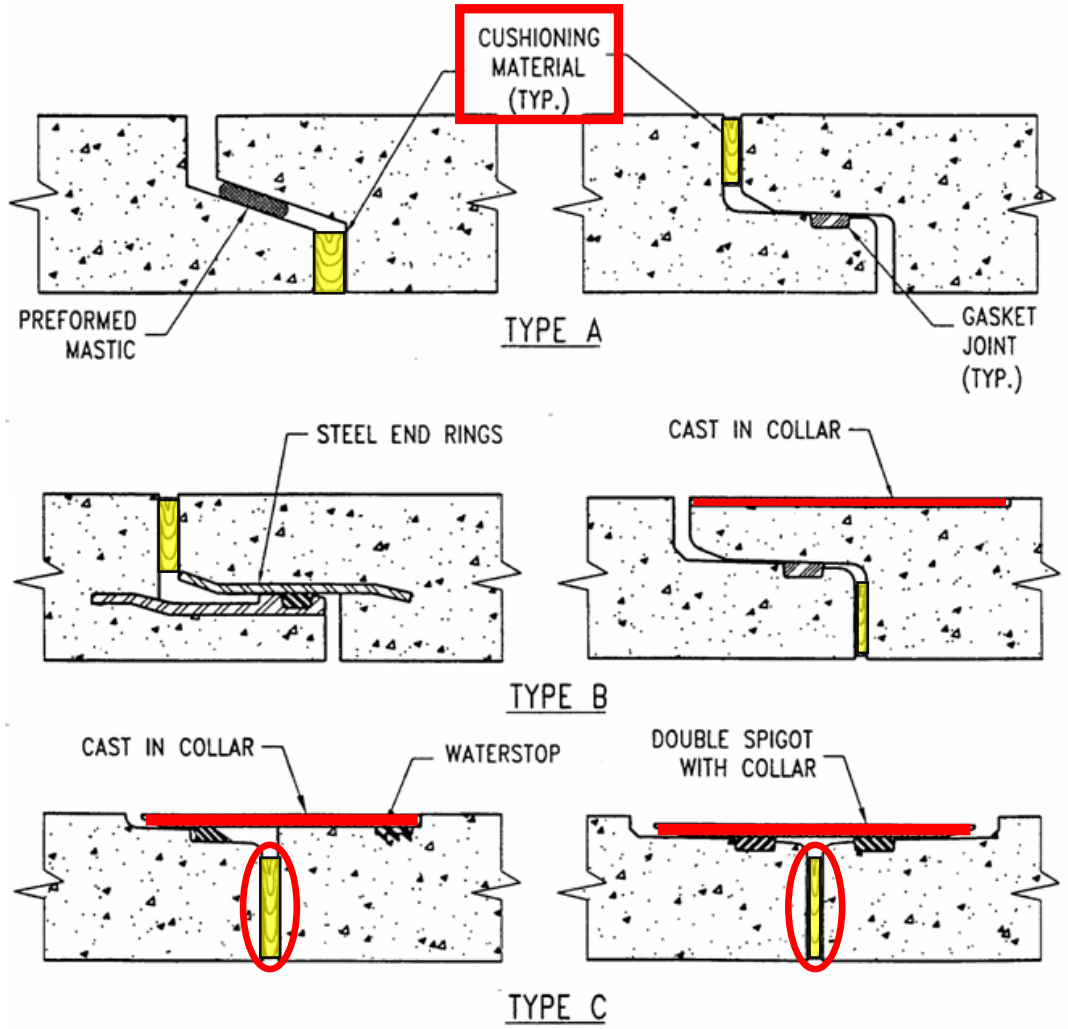
Jacking Pipe

Design Considerations



Cushioning material required to distribute the thrust

OSB or plywood
36" & smaller – ½" thick
42" & larger – ¾" thick



QUIZ

Is lubricant necessary for every jacking/tunneling project?

No, but it is strongly recommended.

Proper lubrication practices can decrease the axial loading by up to 50% simply by applying a bentonite lubricant to the exterior of the pipeline.

Jacking Pipe

Design Considerations

For all Jack Pipe, the keys to a successful project are:

- Lubrication
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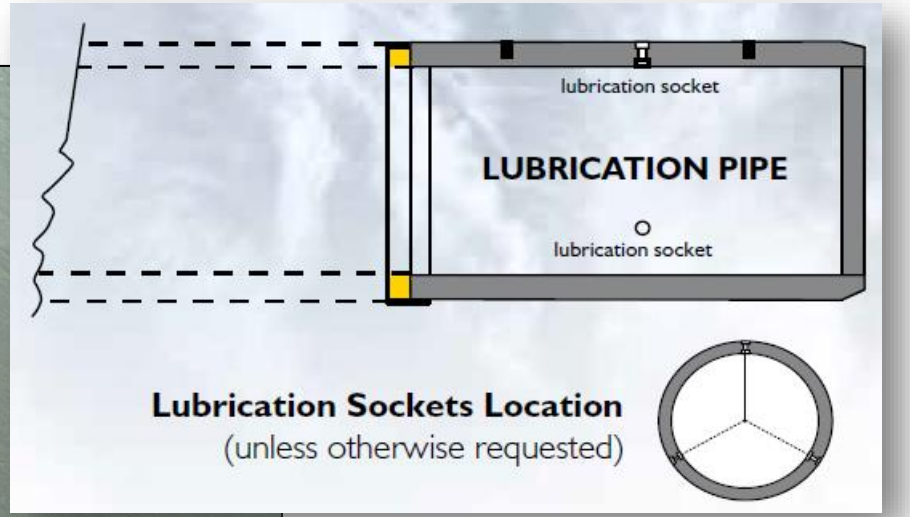
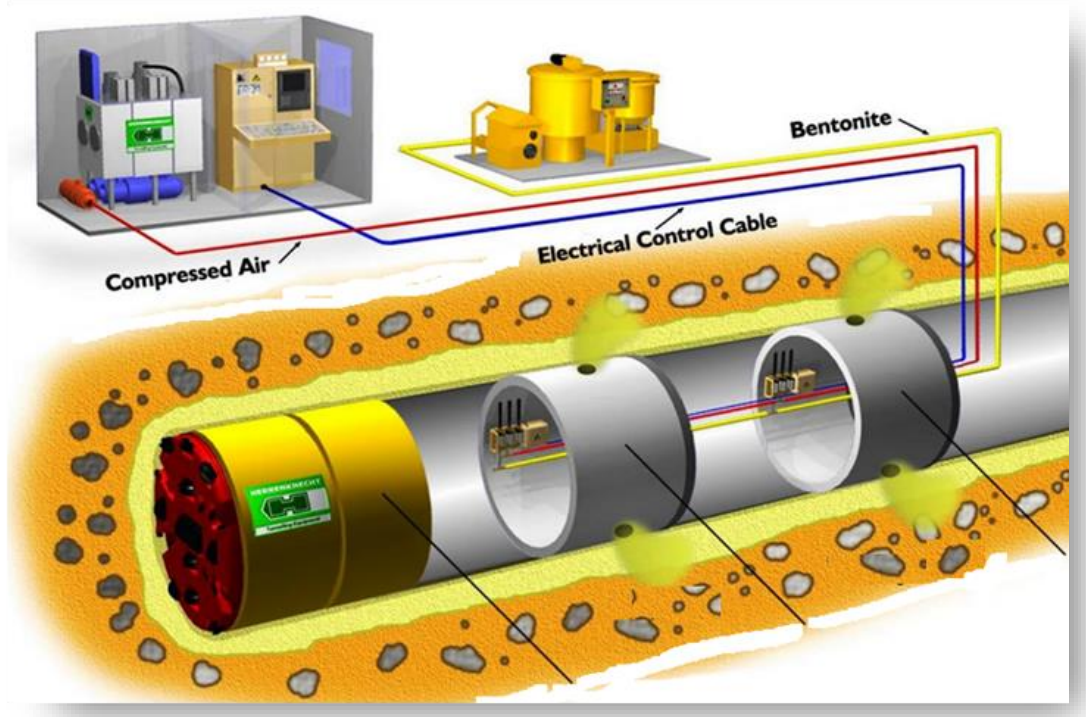


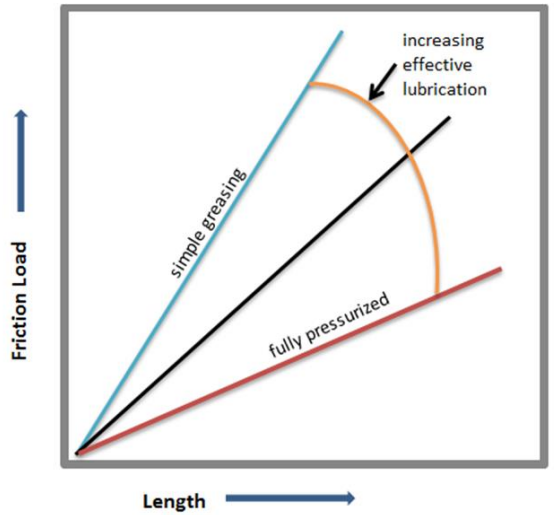
Jacking Pipe

Design Considerations

Factors Effecting Lubricant Use & Selection:

- Soil Type
- Control of Lubricant Loss to Surrounding Soil
- Control of Soil Stability around Pipe
- Environmental Compatibility





<u>Lubrication</u>

Water

Bentonite

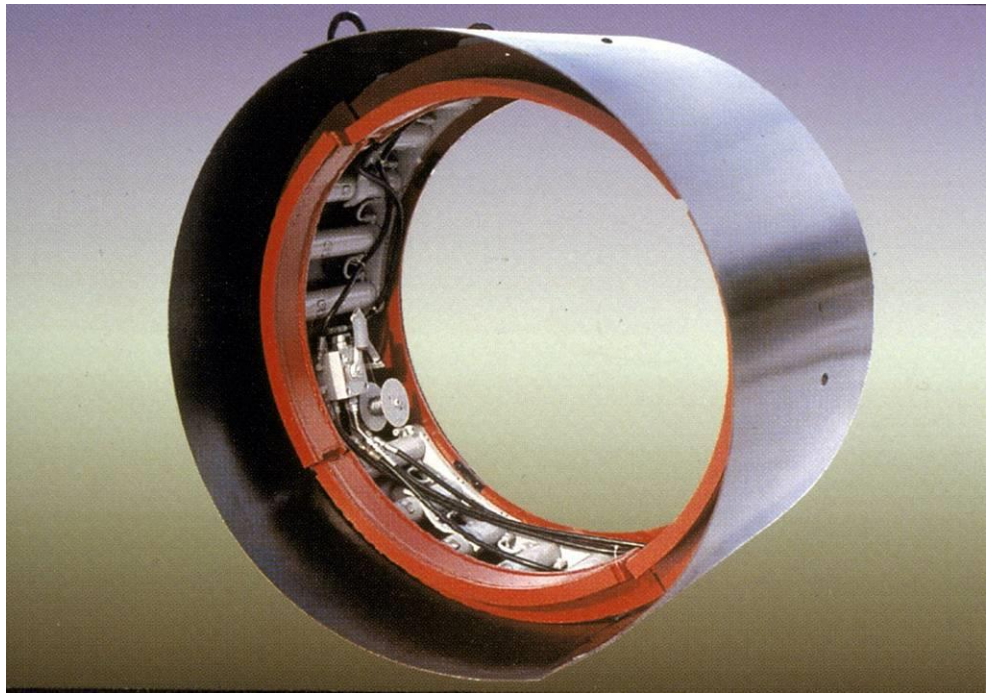
Polymers

Jacking Pipe

Design Considerations

When proper lubrication isn't enough:

- Intermediate Jacking Stations



Jacking Pipe

Intermediate Jacking Stations

Trenchless Methods

Trenchless Methods

- Pipe Jacking
- Microtunneling

Trenchless Methods

Pipe-in-Tunnel

Rib & Lag

Installed Pipe in Tunnel

Trenchless Methods

Jacking Pipe

Closed System

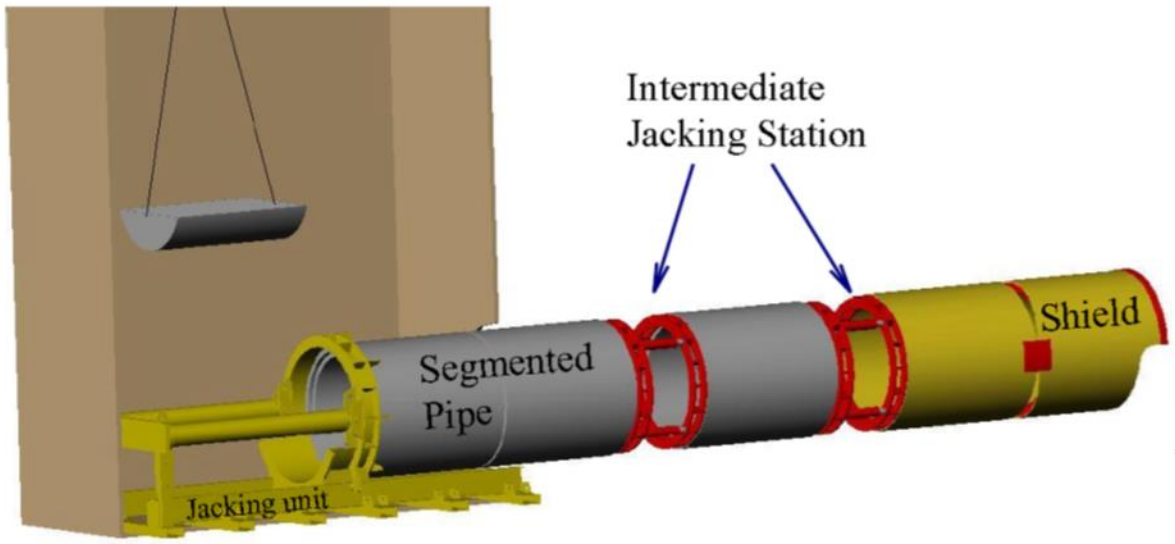
Open System

Trenchless Methods

Jacking Pipe

Jacking Pipe is not Microtunneling

- Hand mined
- Open faced
- Little ability to affect direction



Trenchless Methods

Jacking Pipe

Hydraulic rams jacking pipe through hole as soil is removed at the lead end by manual means, basic mechanical means.

Trenchless Methods

Jacking Pipe

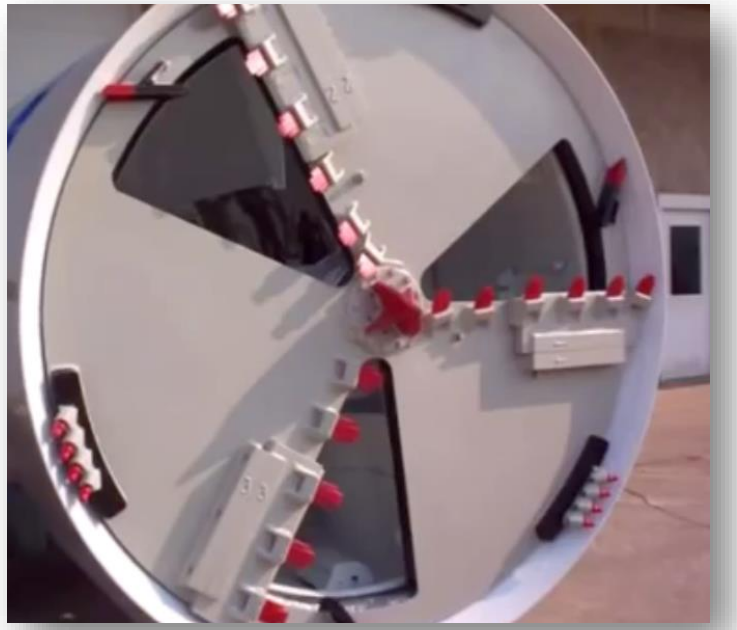
Mechanical and Manual Methods of Excavation

Trenchless Methods

Jacking Pipe

Jacking Shields:

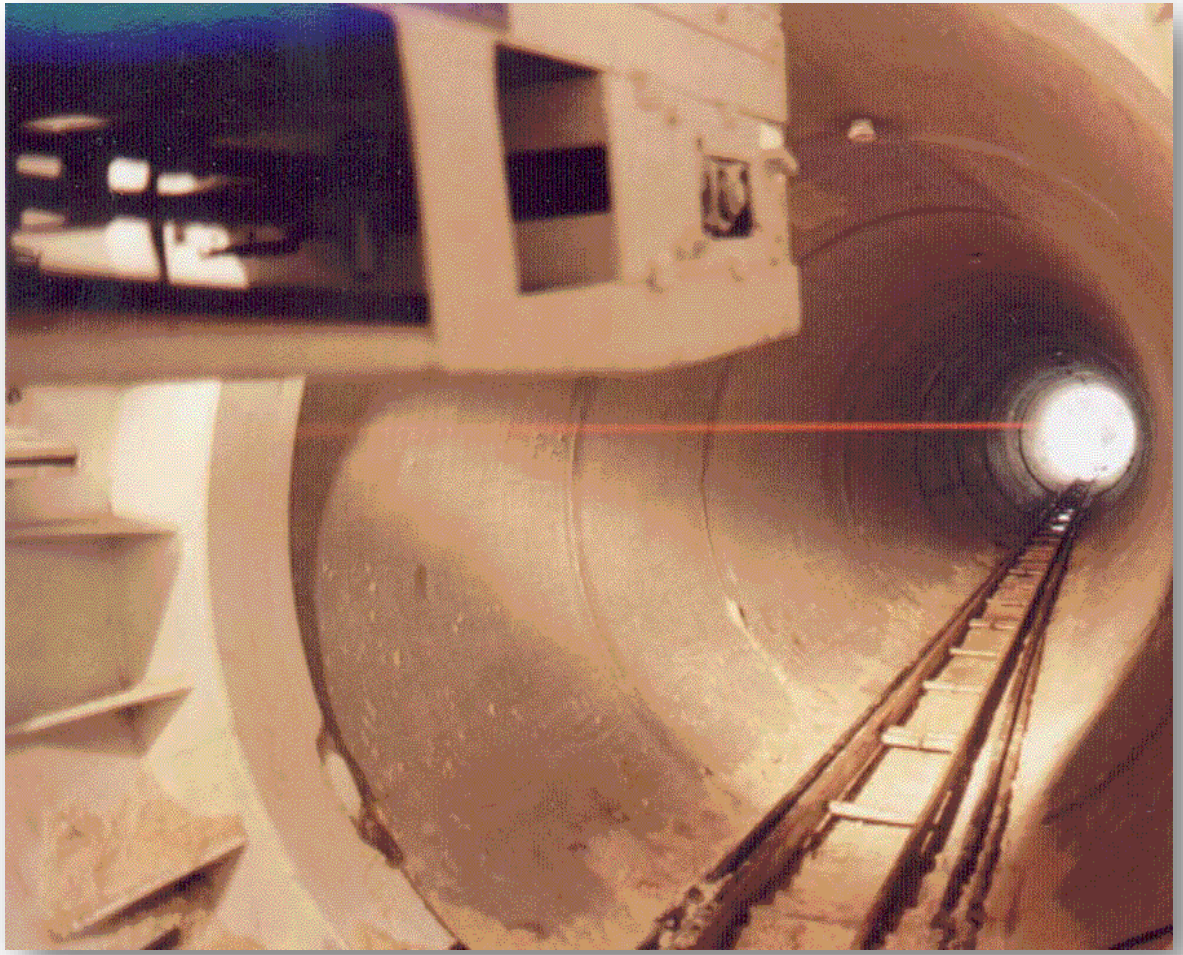
- Loads
- Anchored to Lead Pipe
- Prevent Wobble of Lead Pipe
- Prevent Undue Variation in Grade/Alignment

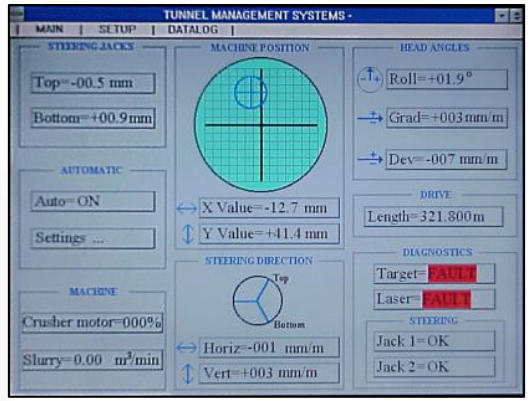


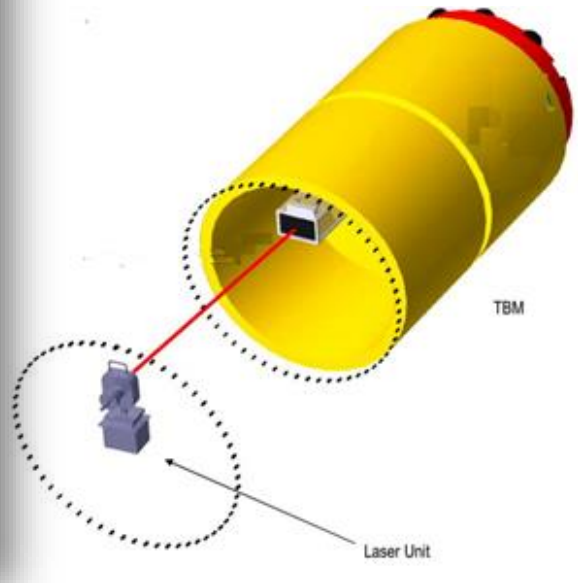
Trenchless Methods

Jacking Pipe

Alignment:







QUIZ

What shapes of pipe/culvert can be jacked?

Any precast product can be installed with trenchless installation technology. For boxes and other non-round products, the excavation is usually achieved by manual removal of spoils.

Trenchless Methods

Jacking Boxes

Jacking Box Culverts is not Microtunneling

- Hand mined
- Open faced
- Little ability to affect direction

Trenchless Methods

Jacking Boxes

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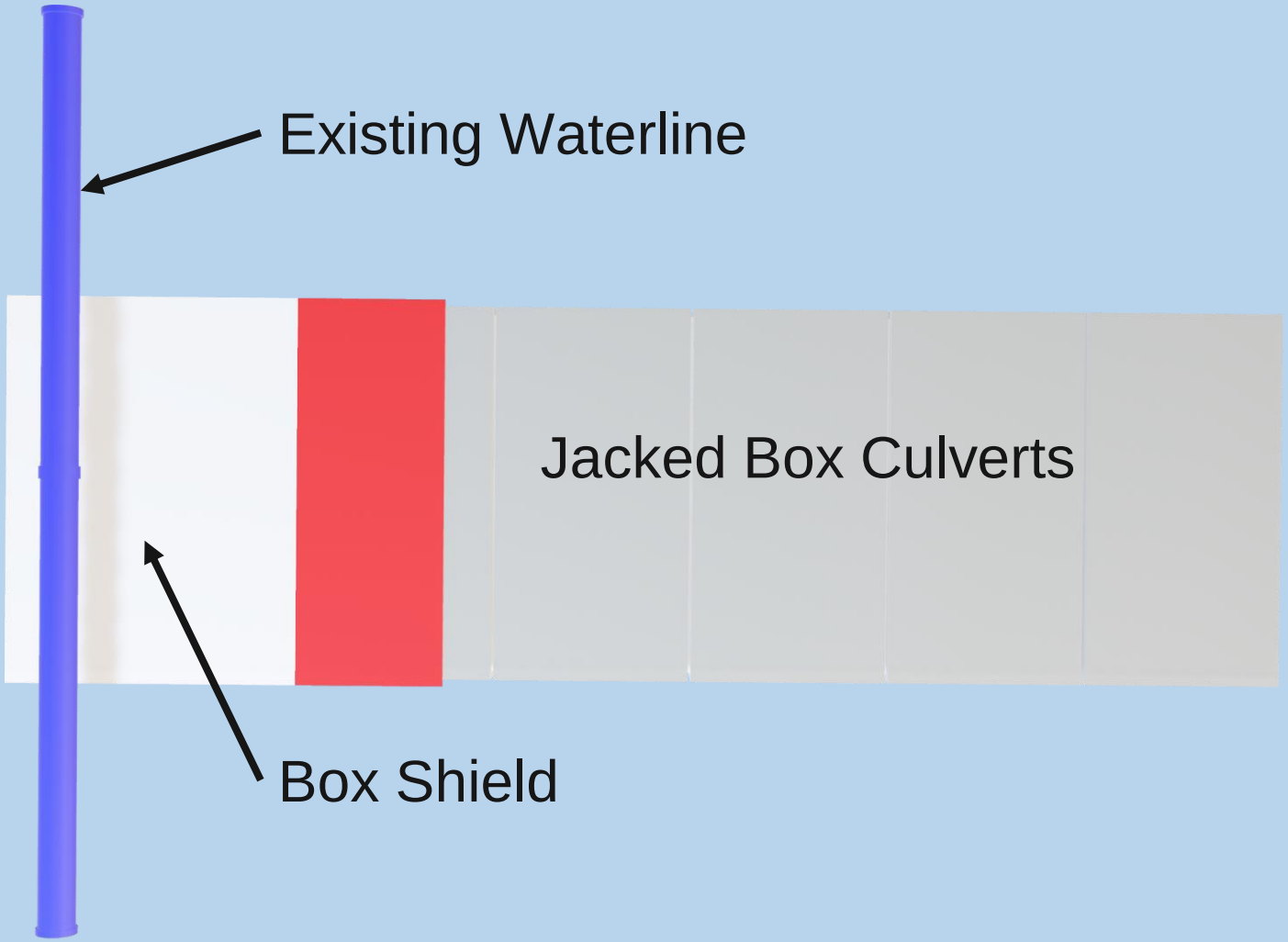
Case Study – Box Jacking

St. Clair St, Dayton, OH

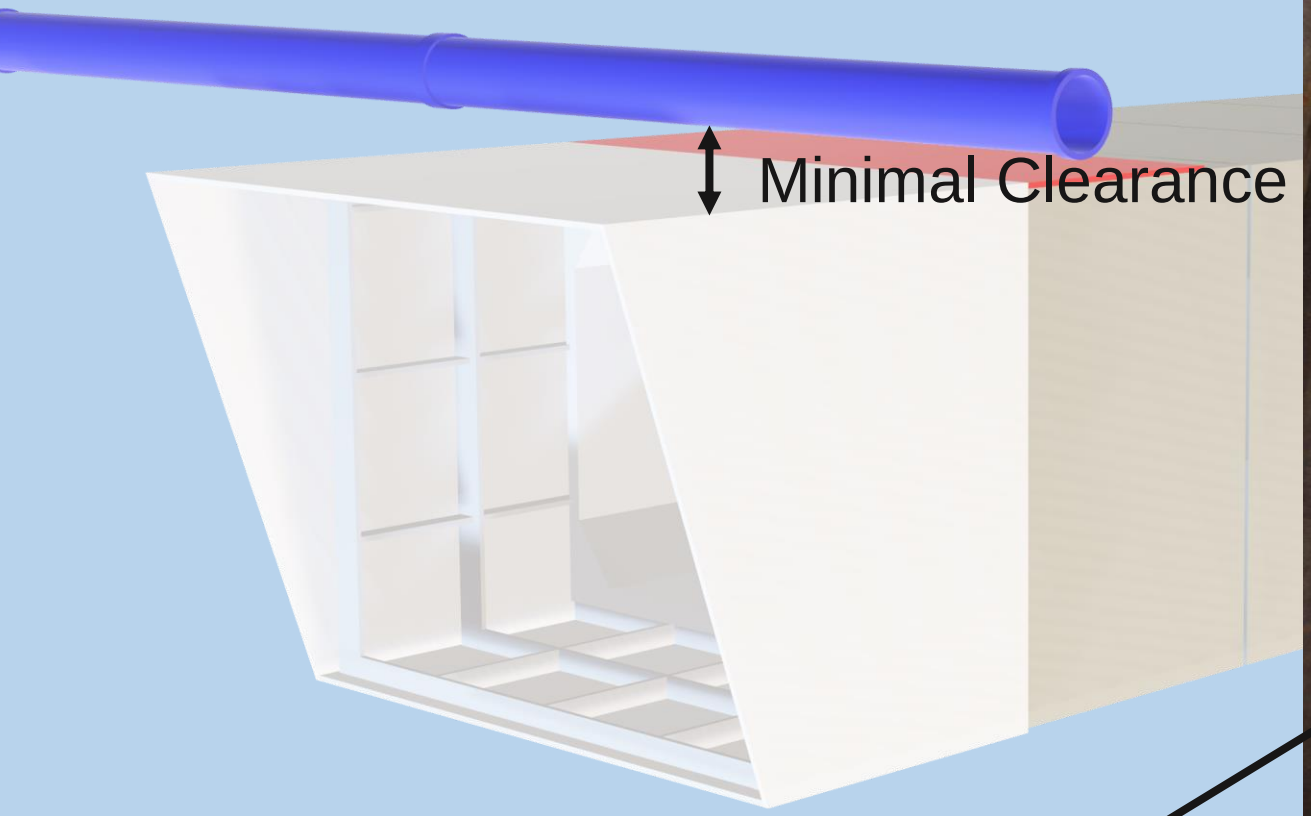
Case Study

Box Jacking – St. Clair, Dayton



Case Study

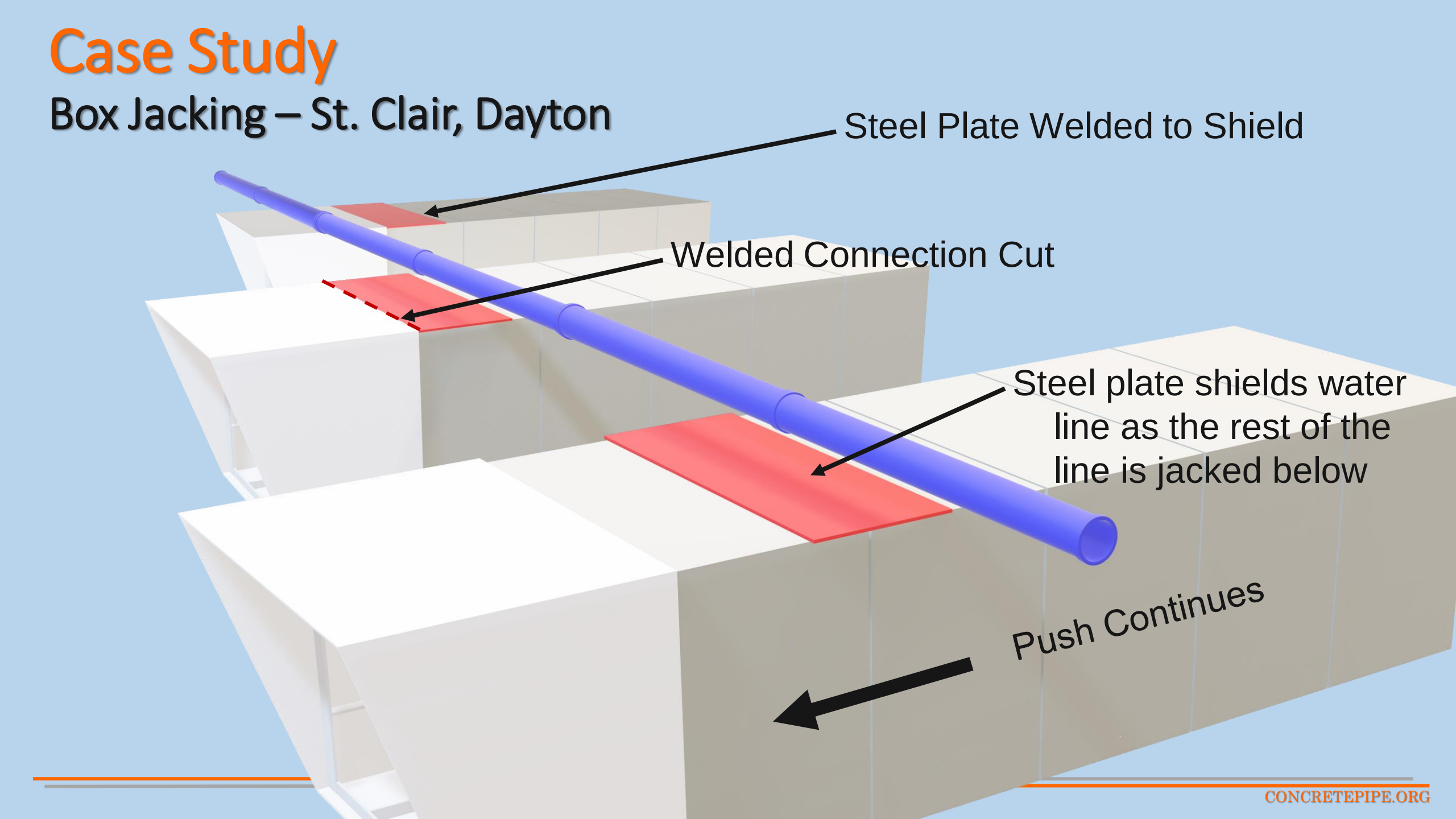
Box Jacking – St. Clair, Dayton



Steel Plate

Case Study

Box Jacking – St. Clair, Dayton



Case Study – Box Jacking

St. Clair St, Dayton, OH

Trenchless Methods

Microtunneling

Remotely Controlled
Active Target Systems
Cutting Head Selection Critical

<u>3 types of microtunnel systems:</u>

Auger – smaller diameters

Slurry – most common

EPB – generally used over 60”

Trenchless Methods

Auger

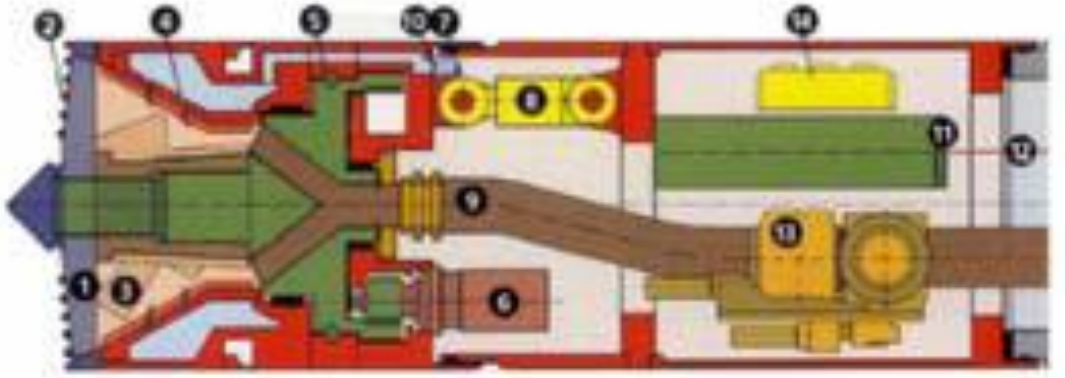
Simultaneously jacking steel casing while auger drilling the hole for the casing

- 8”- 36” pipe
- 40’- 250’ pushes
- medium accuracy

- 2 stages:
  - casing
  - pipe

Trenchless Methods

Slurry



Remotely controlled drilling & pipe jacking process with fully supported soil

- high accuracy
- single pass

Trenchless Methods

Tunnel Boring Machines

EPB Machine:
Provides positive earth pressure during push

QUIZ

Tunnel Boring Machines (TBM's) are unstoppable and can be pushed through any obstacle, right?

Wrong.

Even when using large format drilling equipment, the planning process must take into account the existing soils and obstructions within the planned pathway. An unexpected abandoned 8" CMP drainage pipe was all that was necessary to breakdown and delay "Big Bertha" in Seattle for a period of several months.

Case Study

Big Bertha – Seattle, WA

TBM Big Bertha

- Replace the Alaskan Way Viaduct
- Biggest TBM in history
  - 2 miles long
  - 75’ diameter tunnel
- 500 Cutting Teeth
  - 75 lb each

Case Study

Big Bertha – Seattle, WA

TBM Big Bertha Delays

- Last Half Mile
- $480M Cost Overruns
- 2 Years Delayed (8” steel pipe: 2013-2015)

Trenchless Methods

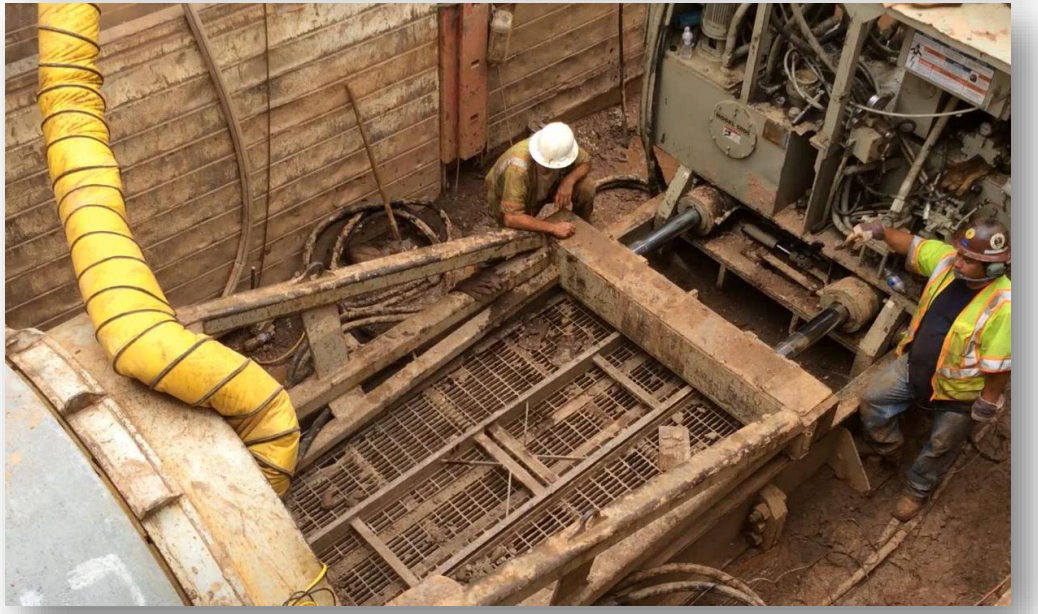
Key Considerations

- Understand Site History
- Conduct Geotechnical Investigation
- Locate Utilities
- Identify Potentials Obstructions
  - Cobbles or Boulders
  - Wood - fibrous
  - Fill materials
  - Hard/soft/mixed zones

Trenchless Methods

Planning Stage

- Offices and accommodation
- Equipment Layout
- Pipe Storage and Handling
- Crane Requirements
- Spoils Handling
- Separation or slurry control
- Fencing and Hoardings
- Traffic Control
- Safety and Security



Trenchless Methods

Jacking Pit

- Location
- Construction Method
- Pipe Size
- Thrust Wall Requirements
- Initial Alignment of Jack –Jack Rails
- Pipe Guide Rails – Accuracy is key

Trenchless Methods

Receiving Pit

- Location
- Size to Retrieve Jacking Head/Shield
- Reception Pit Seal

QUIZ

Is it possible to jack around an obstacle?

Yes.

Jacking and tunneling technology has immensely improved in recent years. The jacking process can be designed to provide a radius pipeline around an obstacle through the use of GPS and laser technology.

Microtunneling

Curved Alignment Risks

Potential for increased risks:

- Increased jacking forces through the curve
- Higher overcut/plowing could lead to increased surface settlement in certain soil conditions
    - Potential for “open” joints through curve
- Potential for jacking “through” the curve, missing alignment
- Reduction of effective drive length due to a modified load transfer

Microtunneling

Curved Alignment Risks

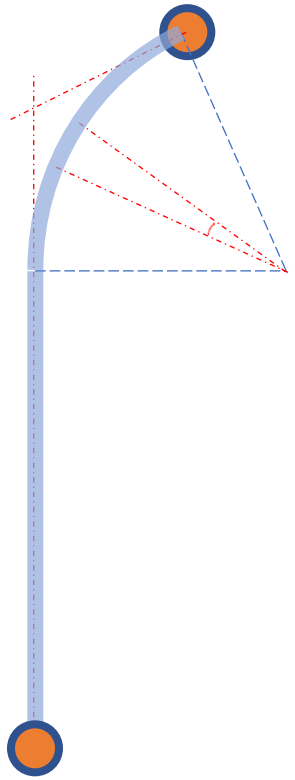
Benefits of curved alignments:

- Avoiding conflicts
- Avoiding buried objects (known)
- Reduced disruption of traffic
- Shaft location flexibility
- Reduction of number of shafts
- Minimize future maintenance costs
- Reduced overall project cost

Microtunneling

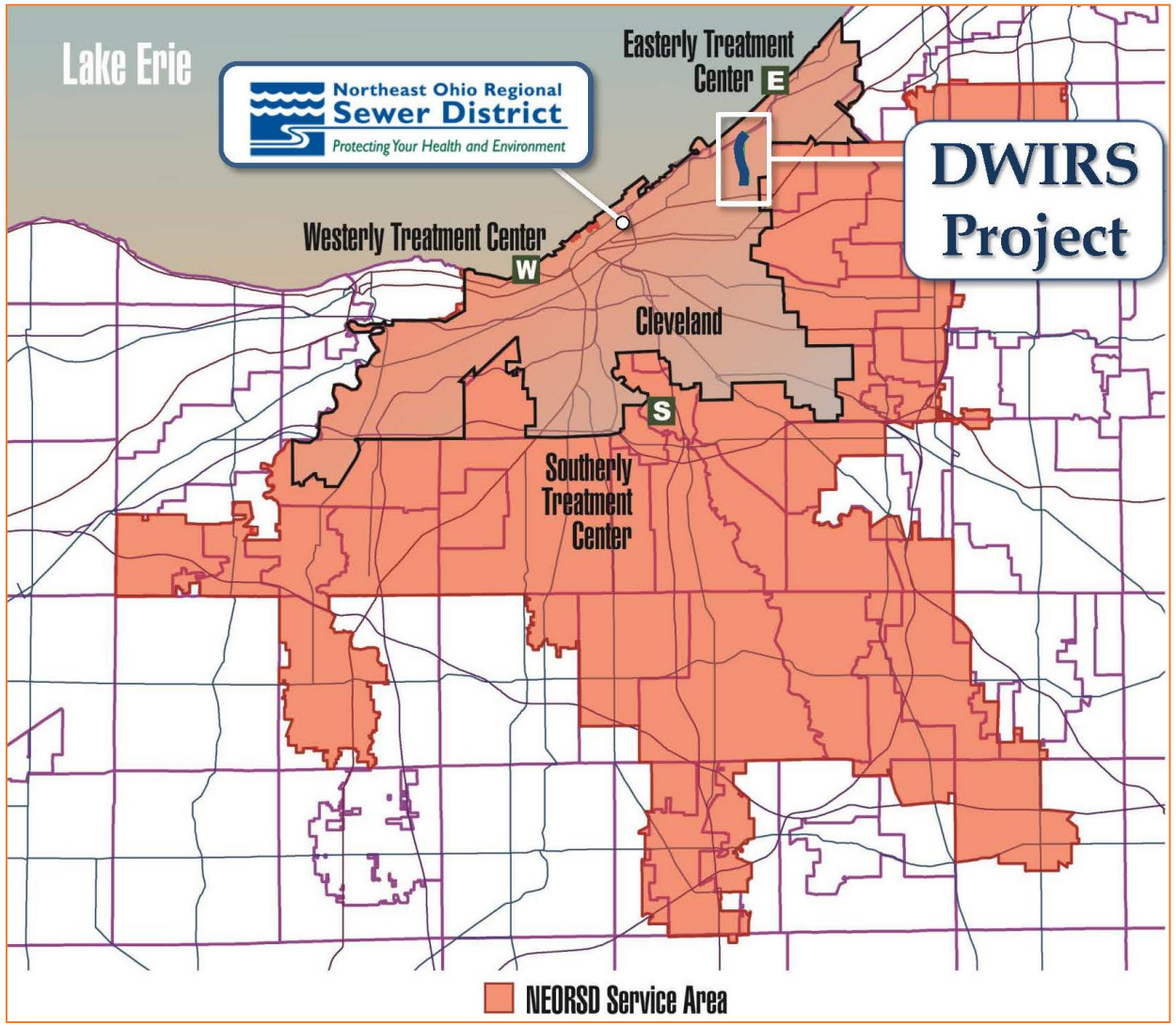
Curved Alignment Designs

- Maintain initial tangent as long as possible before starting curve
- Increase Intermediate jacking stations
- Larger diameters that allow personnel entry for survey checks
- Guidance system is mandatory – and must be capable at radius
- Pipe design should take into account:
  - Allowable joint deflection
  - Individual segment length
  - Joint packing material
  - Radius of the curve



Curved Alignment

DWIRS Project – Cleveland, OH



- 6,631 LF of 72-inch RCP
- 3,069 LF of 48-inch RCP
- Curve – 690 ft of 72-inch RCP
- Contract awarded at $57M

Curved Alignment

DWIRS Project – Cleveland, OH

Geological Data:

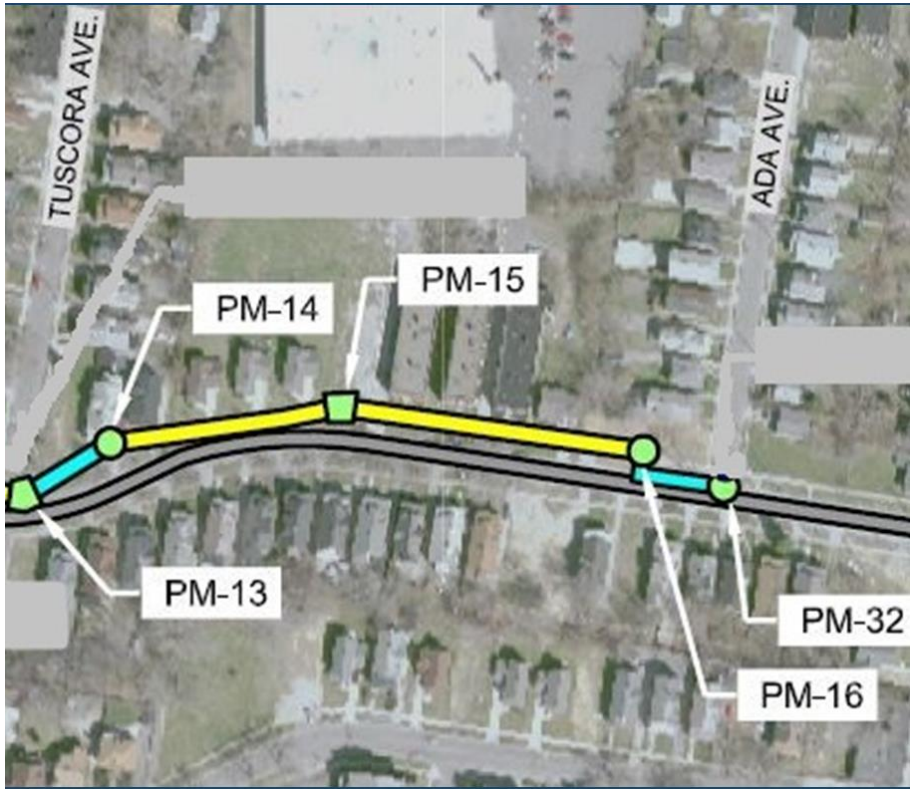
- Primarily lacustrine silt and clay deposits
  - Medium to stiff to very stiff silty clay
  - Medium stiff to hard silty clay with traces of sand and gravel
  - Intermittent alluvial deposits (very loose to medium dense silty fine sand; with fresh wood)
- Water Table: 10 to 20 feet deep
  - Several feet above the tunnel

Curved Alignment

DWIRS Project – Cleveland, OH

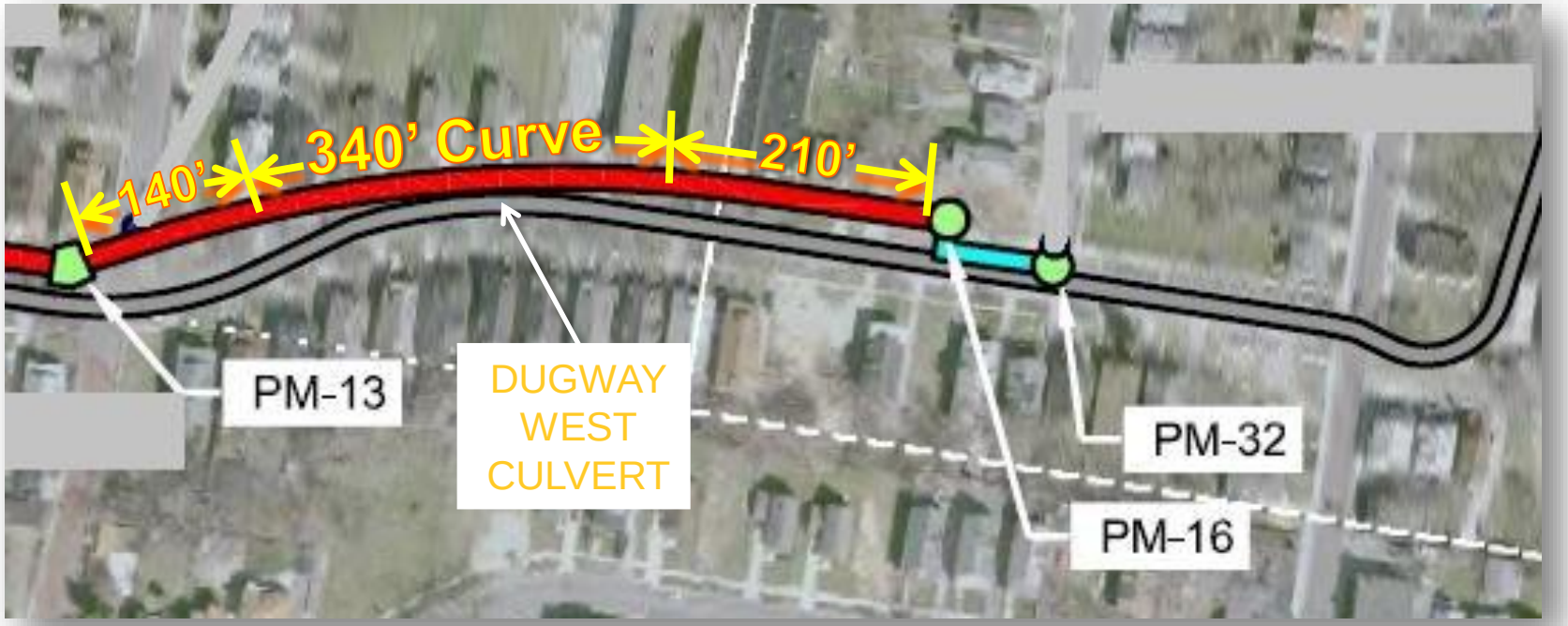
Super Excavators Inc. (SEI) value engineered the idea for a curved microtunnel run

- Proposal Benefits:
  - Accelerated construction schedule
  - 3 tunnels reduced to 1 curved tunnel
  - Reduced construction impact and disturbance to local community



Curved Alignment

DWIRS Project – Cleveland, OH



- 140 LF straight-of-way tunnel with gentle transition into curved section
- 340 LF curve would be constructed at a 915.45 foot radius with 0.2% gradient
- Transition back to a 210 LF straight drive
- Total tunnel run distance of 690 L.F.
- 15-20’ “buffer” between new curved microtunnel, and existing Dugway West Culvert

Curved Alignment

DWIRS Project – Cleveland, OH

<u>Microtunnel Boring Machine:</u>

- Akkerman SL60 for 48” RCP - SL74 for 72” RCP”
  - 2-inch overcut with the gage cutters
- Steering articulation for the MTBM was 0.8˚
  - max articulation of 3.0˚
- Intermediate Jacking Station (IJS) available on site as contingency
- Design calculations estimated that the max jacking forces at the PM-13 thrust block would be 396 tons
  - From PM-13 to terminus of curve

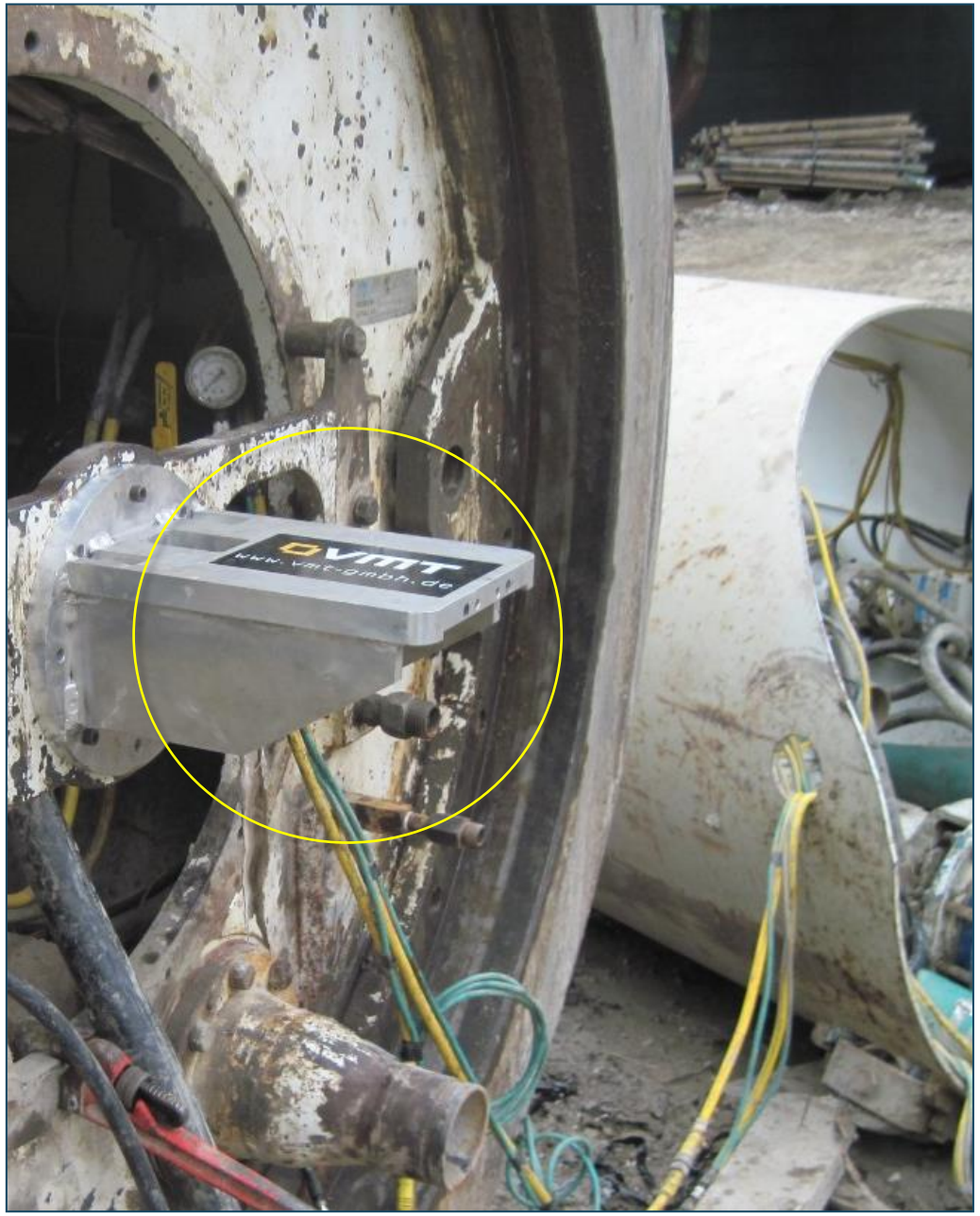

SUPER
GROVE
MID-EXTEND
06/26/2015 10:51

Curved Alignment

DWIRS Project – Cleveland, OH

MTBM Guidance Control:

- SEI used a VMT guidance system paired with the Akkerman MTBM
- VMT laser guidance system provides continuous updates
  - Displaying the MTBM's position independent of drift or refraction
  - Guarantees optimum control in the complex curve areas of the tunnel
- VMT technician was on-site for support



Curved Alignment

DWIRS Project – Cleveland, OH

Pipe Design Modifications:

- 72” Class 3, C Wall RCP w/ special joint
  - 8’ & 10’ lengths
  - Max joint opening = ¾”
- Maximum concrete compression achieved by replacing common bell/spigot design
  - ½” steel corrosion-protected bell band
  - Concrete jacking surface greater than 6.5” wide
- Exterior of each pipe painted with epoxy paint designed by Sherwin Williams (Dura-Plate Multi-Purpose Epoxy) to decrease friction in curve

“European Joint” – Steel Bell Collar

Curved Alignment

DWIRS Project – Cleveland, OH

- Contact grouting to fill potential void areas around the annular space of the 72” RCP
  - Approx (6) cubic yards of grout was utilized for the entire run

Curved Alignment

DWIRS Project – Cleveland, OH

- 9 days were needed to complete the drive once the curve was begun
  - City of Cleveland approved 24-hour operation for the microtunneling
- SEI averaged 39 ft. per shift.
- Max recorded jacking force of 246 tons for the entire curve run
  - overall average was 99 tons
- No downtime encountered. No grade/alignment issues.

Jacking Shaft

Curved Alignment

DWIRS Project – Cleveland, OH

Jacking Shaft

Hole-Out Shaft

Curved Alignment

DWIRS Project – Cleveland, OH

- DWIRS overall microtunneling operation was completed sixty (60) days ahead of schedule
- Curve mitigated construction impacts to the local community and accelerated the tunneling schedule
- Curve reduced the need for 2 manholes which would require future maintenance

QUIZ

Can trenchless installation (jacking/tunneling) be useful when a failing culvert must be replaced?

Yes. The jacking process can be used to jack a new culvert around an existing “host” culvert, allowing minimal Maintenance of Traffic and environmental disruption.

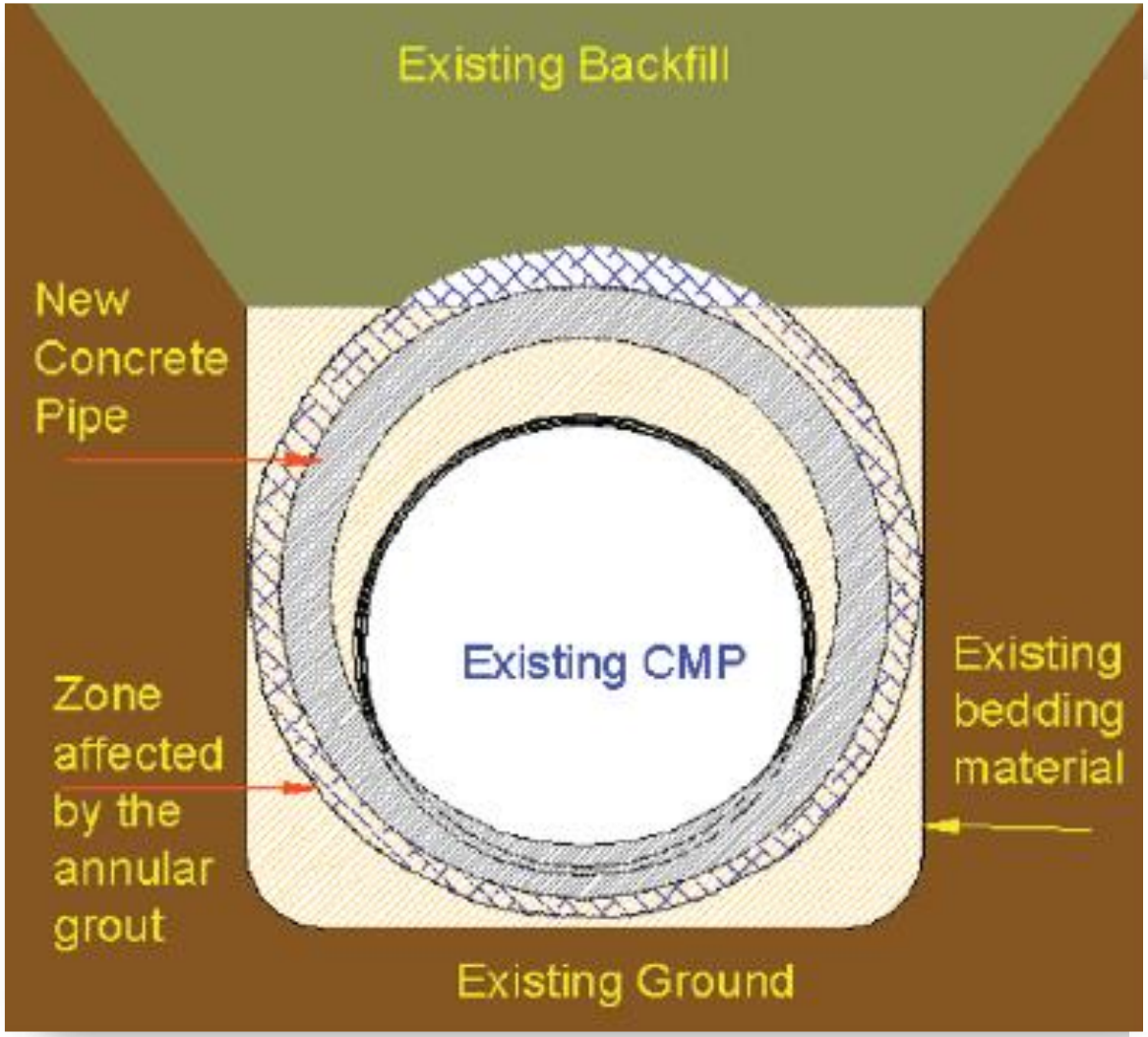
Replace:
Increased Hydraulic Capacity
New Structural Integrity

Rehab:
Reduced Hydraulic Capacity

- Open Cut/Dig & Replace
- Trenchless
  - Tunnel - *Replace*
    - Jacking Pipe
    - Tunnel liner plate
  - Lining - *Rehab*
    - Cured in place
    - Shotcrete
    - Plastic products
  - Sliplining - *Rehab*
    - Plastic liner
    - Tunnel liner plate

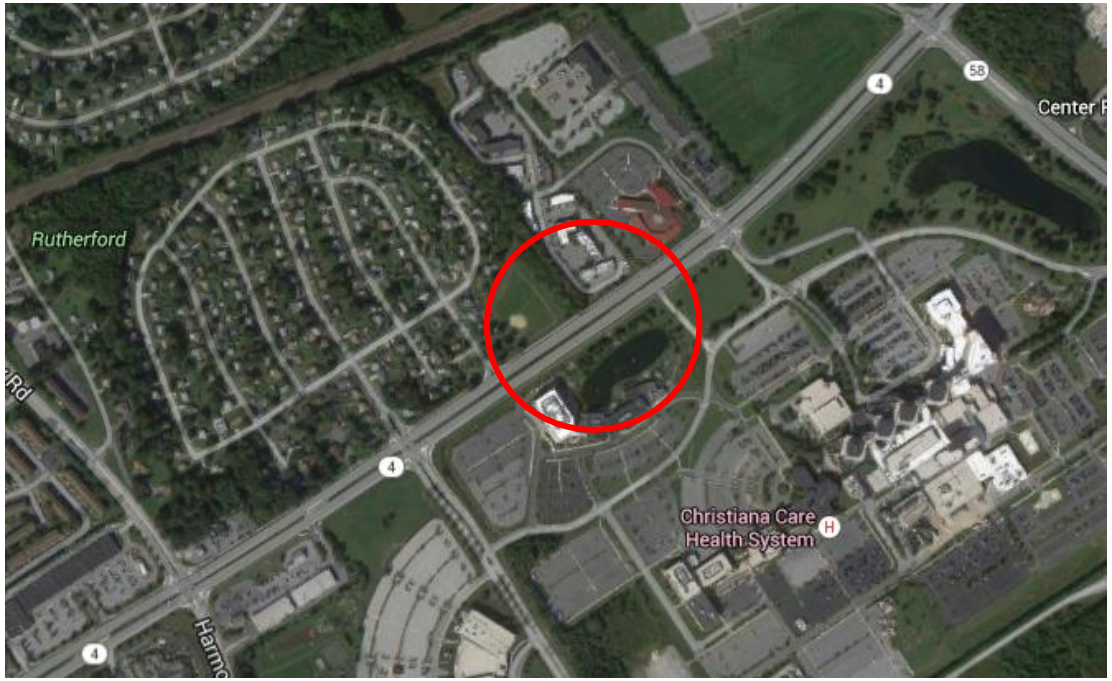
Trenchless Pipe Replacement

Jacking Pipe



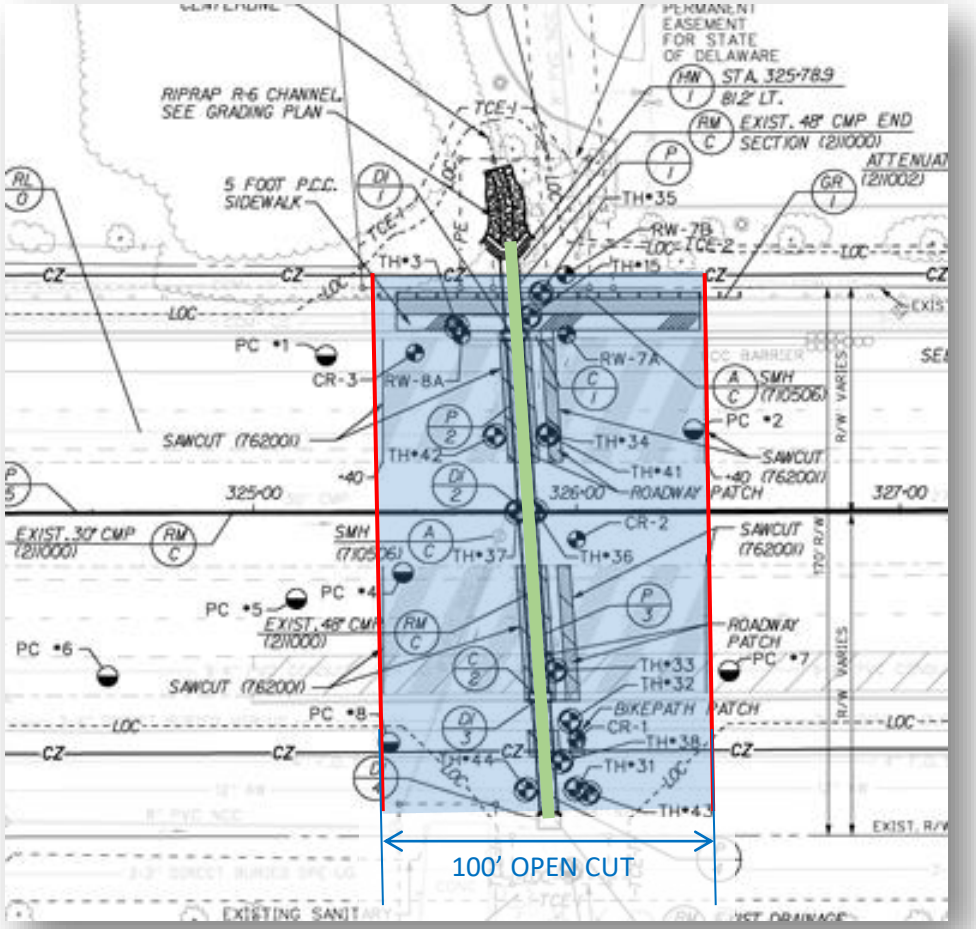
Case Study

DE RT 4 – Trenchless Pipe Replacement



Case Study

DE 4 – Trenchless Pipe Replacement



INITIAL OPEN CUT PLAN

- ~200’ replacement of failed CMP
- 100’ Wide open cut trench
- 75 day project duration
  - MOT Detours
  - Stormwater rerouting
  - Relocation of utilities

Case Study

DE 4 – Trenchless Pipe Replacement

Engineer's Estimate	$975K
Eastern States' low bid	$695K
VE Savings	$126K
Actual Project Total:	$569K

DELAWARE DEPARTMENT OF TRANSPORTATION — DATE : 06/16/08 — PAGE : 001 -1

TABULATION OF BIDS
FINAL

CONTRACT TITLE : SR4, OGLETOWN-STANTON ROAD, 48" CORRUGATED METAL PIPE REPLAC
CALL ORDER : 001 — CONTRACT ID : 25-116-02.01 — COUNTIES : NEW CASTLE
LETTING DATE : 05/20/08 — DISTRICT : N2
STATE/FEDERAL AID NO: 25-116-02 — CONTRACT TIME : 75 CALENDAR DAYS
CONTRACT DESCRIPTION : URBAN (5,000 POPULATION OR MORE) — PROJECT(S) : 25-116-02
THE IMPROVEMENTS CONSIST OF FURNISHING ALL MATERIALS,
INSTALLING DRAINAGE INLETS, DRAINAGE PIPES, HEADWALL,
CONSTRUCTING P.C.C. CURB AND GUTTER, SIDEWALK, INSTALLING
GUARDRAIL AND OTHER INCIDENTAL CONSTRUCTION IN ACCORDANCE
WITH THE LOCATION, NOTES AND DETAILS SHOWN ON THE PLANS AND
AS DIRECTED BY THE ENGINEER.

SET-ASIDE :

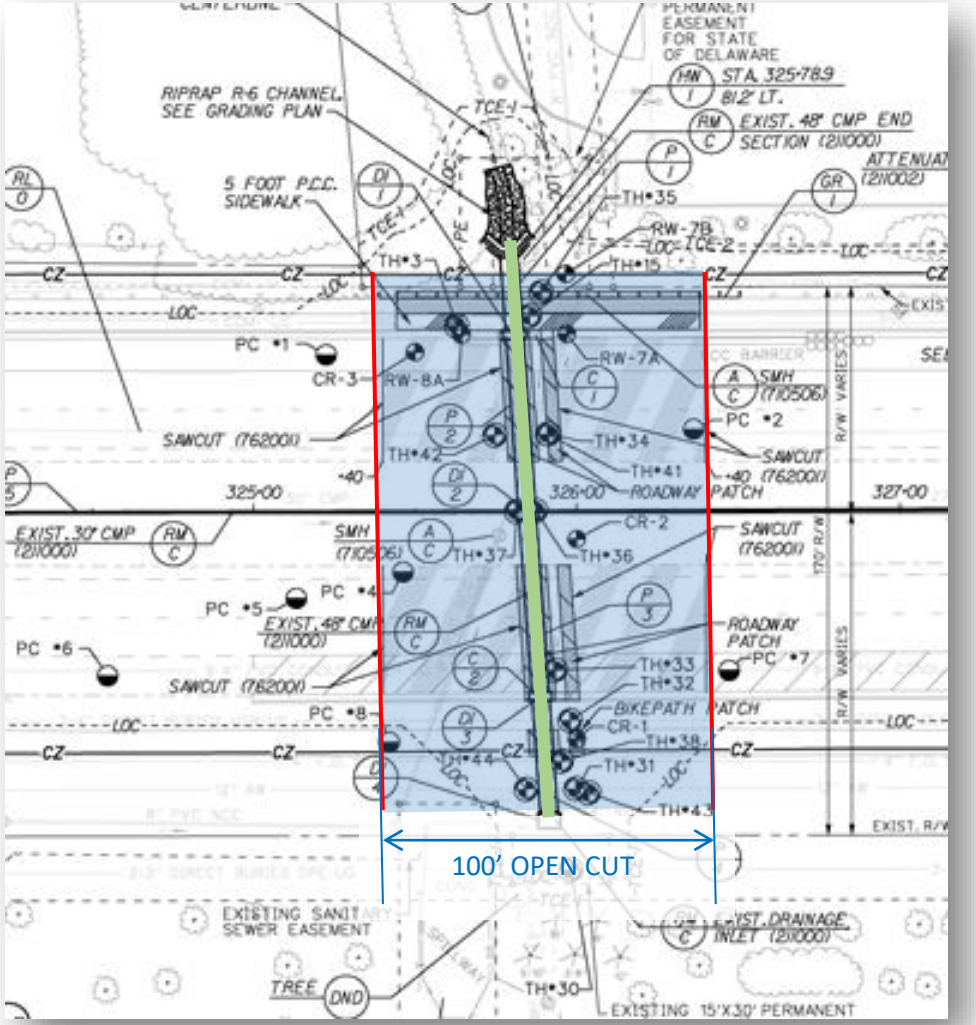
VENDOR RANKING : Contract was awarded on 06/16/08 to vendor EASTERN STATES CONST SERV

RANK	VENDOR NAME	TOTAL BID	% OVER LOW BID	% OVER EST
0	ENGINEER'S ESTIMATE	$ 974,891.26	140.2063%	100.0000%
1	EASTERN STATES CONST SERV, 702 FIRST STATE BLVD, WILMINGTON, DE, 19804	$ 695,326.49	100.0000%	71.3235%
2	JJID INC, 100 JULIAN LANE, BEAR, DE, 19701	$ 776,533.33	111.6790%	79.6533%
3	DAISY CONSTRUCTION COMPANY, 102 ROBINO CT, NEWPORT, DE, 19804	$ 954,881.50	137.3285%	97.9475%
4	SAM'S CONSTRUCTION LLC, 800-A PLANT STREET , WILMINGTON, DE, 19801	$ 1,096,670.91	157.7203%	112.4916%
5	EASTERN HIGHWAY SPEC INC, 920 N CHURCH STREET, WILMINGTON, DE, 19801	$ 1,099,308.05	158.0995%	112.7621%

RICHARD E PIERSON CONST CO INC — IRREGULAR

Trenchless Pipe Replacement

Jacking Pipe



VE: Jack & Tunnel

- Cost Savings - $126,330
  - (split between DelDOT & Contractor)
- Reduced M.O.T. and No Lane Shifts
- Increased Work Zone Safety
- No Supporting of Existing Utilities Required
- Same contract duration (75 days)

Case Study

DE 4 – Trenchless Pipe Replacement

Case Study

DE 4 – Trenchless Pipe Replacement

Before:

Existing 48” CMP Culvert

After:

New 54” RCP

Course Agenda

Why Trenchless?

Pipe Jacking Design

Trenchless Methods

Curved Alignment

Trenchless Replacement

Trenchless Pipe Installation

Jacking & Tunneling

Donald E. McNutt, PE (Don)
Great Lakes Region Engineer
American Concrete Pipe Association
dmcnutt@concretepipe.org / 803-317-3329

Thank You!