ADMINISTRATIVE INFORMATION:
• This Engineering Instruction (EI) is effective beginning with projects submitted for the letting of January 10, 2008.
• This EI supersedes EI 04-014.
• The information transmitted by this issuance will be included in a future revision to the Highway Design Manual, Chapter 9.

PURPOSE: The purpose of this EI is to issue design guidance for the revised standard specification for the trenchless installation of casing.

TECHNICAL INFORMATION:
• The Standard Specification Section 650 is being issued concurrently via EI 07-016.

TRANSMITTED MATERIALS:
Attached is the design guidance for trenchless installation of casing.

BACKGROUND: The specification was created to provide flexibility to a Contractor, given a situation where the traditional open-cut-trench method is not permitted or where the trenchless installation of casing is more efficient, less disruptive, etc. The generic specification requires the Contractor to submit the method of trenchless installation, which may include Auger Boring, Slurry Boring, Pipe Jacking, Microtunneling, Horizontal Directional Drilling, or Utility Tunneling Method.

REFERENCES: The definitions for the trenchless installation methods were taken from, and described further in, the following:
Trenchless Installation of Conduits Beneath Roadways, A Synthesis of Highway Practice.
Transportation Research Board, National Research Council.

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TRENCHLESS INSTALLATION OF CASING

GENERAL
The intent of the specification is to pay the Contractor for opening a cased hole from one point to another, as indicated in the contract documents. For instances where a utility is to be installed, the item may be used to open a hole/pathway for the placement of the utility carrier pipe.

The specification is organized by casing size (XX denotes casing diameter size).

Definitions. The following are definitions of acceptable trenchless installation methods.1

A. Auger Boring (AB). A technique that forms a bore hole from a drive shaft to a reception shaft by means of a rotating cutting head. Spoil is transported back to the drive shaft by helical-wound auger flights rotating inside a steel casing that is being jacked in place simultaneously. AB may provide limited tracking and steering capability. It does not provide continuous support to the excavation face. AB is typically a 2-stage process (i.e., casing installation and product pipe installation).

B. Slurry Boring (SB). A technique that forms a bore hole from a drive shaft to a reception shaft by means of a drill bit and drill tubing (stem). A drilling fluid (i.e., bentonite slurry, water, or air pressure) is used to facilitate the drilling process by keeping the drill bit clean and aiding with spoil removal. It is a 2-stage process. Typically, an unsupported horizontal hole is produced in the first stage. The pipe is installed in the second stage.
C. **Pipe Jacking (PJ).** A technique for installing a prefabricated pipe through the ground from a drive shaft to a reception shaft. The pipe is propelled by jacks located in the drive shaft. The jacking force is transmitted through the pipe to the face of the PJ excavation. The excavation is accomplished, and the spoil is transported out of the jacking pipe and shaft manually or mechanically. Both the excavation and spoil removal processes require workers to be inside the pipe during the jacking operation.

D. **Microtunneling (MT).** A remotely controlled, guided pipe-jacking process that provides continuous support to the excavation face. The guidance system usually consists of a laser mounted in the drive shaft communicating a reference line to a target mounted inside the MT machine’s articulated steering head. The MT process provides ability to control excavation face stability by applying mechanical or fluid pressure to counterbalance the earth and hydrostatic pressures.

E. **Horizontal Directional Drilling (HDD).** A 2-stage process that consists of drilling a small diameter pilot directional hole along a predetermined path and then developing the pilot hole into a suitable bore hole that will accommodate the desired utility and then pulling the utility into place. The HDD process provides the ability to track the location of the drill bit and steer it during the drilling process. The vertical profile of the bore hole is typically in the shape of an arc entrapping drilling fluid to form a slurry pathway rather than an open hole. This entrapped slurry provides continuous support to the bore hole.
F. Utility Tunneling (UT). A 2-stage process in which a temporary ground support system is constructed to permit the installation of a utility. The temporary tunnel liner is installed as the tunnel is constructed. Workers are required inside the tunnel to perform the excavation and/or spoil removal. The excavation can be accomplished manually or mechanically.

Because trenchless installations are typically specified to minimize/eliminate disturbance to the surrounding area, the specification dictates monitoring tasks for the Contractor to perform. A survey of the existing ground surface along the proposed path of casing installation, prior to the start of work, will establish baseline data. The trenchless installation process will be closely monitored during its operation to minimize/eliminate ground movements. The designer should ensure that the project contains Item 625.01 Survey and Stakeout.

If Pipe Jacking or Utility Tunneling is determined to be the method of installation during construction (both the excavation and spoil removal processes require workers to be inside the pipe during the jacking operation), work will proceed in accordance with §107-05 R. Confined Spaces and a written confined space plan (addresses prevention of unauthorized entry, type of hazard, work practices, monitoring, provision for attendant, duties of employees, rescue and emergency medical services, multi-employer operations, and provisions for review procedures).
Figure 1 Classification Systems for Trenchless Methods

CASING LENGTH, TYPE, AND SIZE
The proposed casing length, type, and size shall be indicated in the contract documents.

A. Auger Boring (AB). The auger boring method forms a bore hole from a drive shaft to a reception shaft by means of a rotating cutting head. Since augers rotate inside the casing, the casing and its coating material must resist potential damage from the augers. The typical casing pipe is made of steel. If required, the utility carrier pipe may be made of any material suitable for the utility being carried.

- Steel pipe shall be bare steel casing pipe meeting the requirement of ASTM A53, Grade B, Types E or S, or approved equal. The ends shall be prepared for butt welding and beveled at 37 ½ degrees.

B. Slurry Boring (SB). The slurry boring method forms a bore hole from a drive shaft to a reception shaft by means of a drill bit and drill tubing (stem). A pilot hole is drilled and checked for accuracy. Once confirmed, the pilot hole is reamed to the desired bore-hole diameter and a casing is inserted. Any type of casing can be installed. The casing may be installed by tension forces, compressive forces or both.
C. Pipe Jacking (PJ). The pipe jacking method installs a prefabricated pipe through the ground from a drive shaft to a reception shaft by propelling it by jacks located in the drive shaft. The jacking force is transmitted through the pipe to the face of the PJ excavation. Therefore, the type of casing must be capable of transmitting the required jacking forces from the thrust plate to the jacking shield. Steel casing, reinforced concrete pipe (RCP), or glass-fiber reinforced plastic pipe (GFRP) are the most common types of casing used.

- Steel pipe shall be bare steel casing pipe meeting the requirement of ASTM A53, Grade B, Types E or S, or approved equal. The ends shall be prepared for butt welding and beveled at 37 ½ degrees.
- Reinforced concrete pipe shall meet the requirements of §706-02 Reinforced Concrete Pipe for Class V, except that the exterior barrier shall be smooth.

D. Microtunneling (MT). The microtunneling method is a remotely controlled, guided pipe-jacking process. Since the microtunneling process is cyclic pipe jacking process, the discussion on the pipe jacking method applies. Steel casing, reinforced concrete pipe (RCP), or glass-fiber reinforced plastic pipe (GFRP) are the most common types of casing used.

- Steel pipe shall be bare steel casing pipe meeting the requirement of ASTM A53, Grade B, Types E or S, or approved equal. The ends shall be prepared for butt welding and beveled at 37 ½ degrees.
- Reinforced concrete pipe shall meet the requirements of §706-02 Reinforced Concrete Pipe for Class V, except that the exterior barrier shall be smooth.

E. Horizontal Directional Drilling (HDD). The horizontal directional drilling method consists of drilling a small diameter pilot directional hole along a predetermined path and then developing the pilot hole into a suitable bore hole that will accommodate the desired utility and then pulling the utility into place. The type of casing is limited to one which can be joined together continuously, while maintaining sufficient strength to resist the high tensile stresses imposed during the pullback operation. Steel casing or butt-fused, high density polyethylene pipe (HDPE) are the most common types of casing used.

- Steel pipe shall be bare steel casing pipe meeting the requirements of ASTM A53, Grade B, Types E or S, or approved equal. The ends shall be prepared for butt welding and beveled at 37 ½ degrees.
- High Density Polyethylene (HDPE) pipe shall be SDR-9 or SDR-11 and shall meet the requirements of AWWA C906, PPI PE 3408 and ASTM D3350 B PE 345444C.

F. Utility Tunneling (UT). The utility tunneling method consists of temporarily supporting the bore with tunnel liner plates to permit the installation of a utility. When a shield is used, the tunnel liner plates shall be designed to withstand the thrust from jacking the shield against the full front edge of the newly installed tunnel lining. Tunnel liner plates may be manufactured from steel or designed as precast concrete.

DESIGN DEVELOPMENT
Table 1 provides the designer with an assumption on the potential method of installation based upon the identified subsurface conditions.

Some trenchless installation methods are unsuitable for some diameters. Table 2 provides the designer with guidance on the potential method of installation for the desired length of casing to be installed.

Table 3 provides the designer with an assumption on some productivity rates, limitations and cost estimates to develop an overall cost and schedule for their project.
### TABLE 1 Ground Conditions and Suitability of Trenchless Methods

<table>
<thead>
<tr>
<th>Ground Conditions</th>
<th>Auger Boring</th>
<th>Slurry Microtunneling</th>
<th>Auger Microtunneling</th>
<th>Slurry Boring</th>
<th>HDD</th>
<th>Mini-HDD</th>
<th>Pipe Jacking</th>
<th>Utility Tunneling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft to very soft clays, silts &amp; organic deposits</td>
<td>Y</td>
<td>Y</td>
<td>M</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>M</td>
<td>Y</td>
</tr>
<tr>
<td>Medium to very stiff clays and silts</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>Hard clays and highly weathered shales</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Very loose to loose sands above watertable</td>
<td>M</td>
<td>Y</td>
<td>Y</td>
<td>M</td>
<td>Y</td>
<td>Y</td>
<td>M</td>
<td>Y</td>
</tr>
<tr>
<td>Medium to dense sands below the watertable</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Medium to dense sands above the watertable</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>M</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<td>Gravel &amp; cobbles less than 50-100 mm diameter</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>M</td>
<td>M</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>Soils with significant cobbles, boulders and obstructions larger than 100-150 mm diameter</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>N</td>
<td>M</td>
<td>N</td>
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<td>M</td>
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<tr>
<td>Weathered rocks, marls, chalks and firmly cemented soils</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>M</td>
<td>Y</td>
</tr>
<tr>
<td>Slightly weathered to unweathered rocks</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>M</td>
<td>M</td>
<td>N</td>
<td>Y</td>
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<tr>
<td><strong>Yes</strong></td>
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<td>Generally suitable by experienced contractor with suitable equipment.</td>
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<tr>
<td><strong>Marginal</strong></td>
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<tr>
<td>Difficulties* may occur, some modifications of equipment or procedure may be required.</td>
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<tr>
<td><strong>No</strong></td>
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<td>Substantial problems, generally unsuitable or unintended for these conditions.</td>
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</tbody>
</table>

* Difficulties in certain trenchless installation operations may require corrective solutions which, if not comprehensively detailed in the contract documents, can add significantly to the projects overall cost through delays and claims. For example, a low density soil with numerous, loose boulders may result in failure of many of the trenchless installation methods. A corrective solution may necessitate a soil grouting operation, which will increase costs dramatically if not originally outlined in the contract documents. These situations should be thoroughly examined with the Regional Geotechnical Engineer to determine if trenchless installation is the appropriate mechanism for the installation of the casing.
<table>
<thead>
<tr>
<th>Installation Method</th>
<th>Typical Installation Diameters</th>
<th>Typical Installation Lengths</th>
<th>Work Space Requirements</th>
<th>Compatible Soil Types</th>
</tr>
</thead>
</table>
| Auger Boring (AB)    | Achievable Dia. Range: 100 mm to 1500 mm  
Common Dia. Range: 200 mm to 900 mm | Typical project lengths range from 30 m to 91.5 m. | Entry & Exit bore pits (8 m to 11 m by 2.5 m to 3.5 m).  
Working area: 9 m by 25 m, includes room for storing augers, casing, etc. | Variety of soil conditions. |
| Slurry Boring (SB)   | Achievable Dia. Range: 50 mm to 1200 mm  
Common Dia. Range: 50 mm to 300 mm | Typically, SB is a non-directionally controlled process; therefore, the risk of obtaining an unacceptable pilot hole increases greatly with distance. Although the common bore hole spans are approx. 15 m, bore holes longer than 100 m have been installed by SB. | Entry & Exit bore pits/shafts.  
Working area: 5 m to 10 m by 15 m to 20 m, includes room for laydown space for drill tube, casing, lifting equip., pumps, drill fluid, etc. | Firm, stable cohesive material. Wet, noncohesive material can be accommodated provided that special precautions are exercised. |
| Pipe Jacking (PJ)    | Achievable Dia. Range: 1060 mm to No theoretical limit.  
Common Dia. Range: 1200 mm to 1830 mm | The length of the PJ drive is determined by the amount of available jacking thrust and the compressive strength of the pipe. The most common range for drive lengths is from 150 m to 305 m. No theoretical limit. | Jacking pit is a function of the pipe size. Pit sizes vary from 3 m to 9 m.  
Confined space entry for hand mining. | Stable granular and cohesive soils are best. Unstable sand is least favorable. Large boulders cause frequent work stoppage. Method can be executed with any ground condition with adequate precautions. |
| MicroTunneling (MT)  | Achievable Dia. Range: 250 mm to 3500 mm  
Common Dia. Range: 600 mm to 1200 mm | The most common range for drive lengths is from 150 m to 305 m for slurry MT and 61 m to 122 m for auger MT. | Primary Jacking Pit: 4 m long, 3 m wide, smaller retrieval pit, room for slurry tanks, pipe storage. | Variety of soil conditions, including full face rock and high groundwater head. |
<p>| Horizontal Directional Drilling (HDD) | Achievable Dia. Range: 75 mm to 1200 mm | Bore lengths can range from 120 m to 1800 m depending on the site conditions. | Entry &amp; Exit pits not required. Space for set up of rig and drilling fluid tank: 120 m x 60 m. | Clay is ideal. Cohesionless sand and silt require bentonite. Gravel and cobbles are unsuitable. |
| Utility Tunneling (UT) | Achievable Dia. Range: Person-entry and hand mining requires a min. 1060 mm dia. tunnel. No theoretical limit. | No theoretical limit. | Smaller surface area compared to PJ (compactness of liner system). Confined space entry for hand mining and liner installation. | Variety of soil conditions. |</p>
<table>
<thead>
<tr>
<th>Installation Method</th>
<th>Productivity Rates*</th>
<th>Limitations</th>
<th>Cost**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auger Boring (AB)</td>
<td>It will take a four-person crew 3-4 hr. to set up the AB equipment for a steel casing project 600 mm in diameter utilizing segments 6m in length. A typical production rate for this size project is 30 m in an 8-hr shift.</td>
<td>Cannot be used in wet, running sands or soils with large boulders.</td>
<td>$0.4-$0.5 per mm of casing diameter per linear meter of casing.</td>
</tr>
<tr>
<td>Slurry Boring (SB)</td>
<td>SB typically is used for small-diameter, short bore lengths. For example, a common size conduit is 100 mm with a bore length of 15 m. A two-to three-person crew can be expected to accomplish three or four of these drives in a workday.</td>
<td>A major concern with using any type of drilling fluid under a roadway is the potential for overexcavation.</td>
<td>$0.13-$0.4 per mm of casing diameter per linear meter of casing.</td>
</tr>
<tr>
<td>Pipe Jacking (PJ)</td>
<td>A reasonable productivity range for PJ projects is 9 m to 30 m per shift with a four- or five-person crew. Factors that can affect productivity include the presence of groundwater, unanticipated obstructions such as boulders or other utilities, and changed conditions such as encountering wet, silty sand after selecting equipment for stable sandy clay.</td>
<td>Large boulders cause frequent work stoppage.</td>
<td>Hand Mining: $0.77-$1.9 per mm of casing diameter per linear meter of casing.</td>
</tr>
<tr>
<td>MicroTunneling (MT)</td>
<td>A four- to eight-person MT crew can obtain a production rate of 9 m to 18 m per shift.</td>
<td>Obstructions are an issue. A special concern that is critical to the success of an MT project is the ability to predict and control jacking forces.</td>
<td>$1.7-$2.6 per mm of casing diameter per linear meter of casing.</td>
</tr>
<tr>
<td>Horizontal Directional Drilling (HDD)</td>
<td>A three-person HDD crew, in suitable ground conditions, can install a pipeline as long as 180 m in a workday.</td>
<td>Not suitable for high degree of accuracy such as gravity sewer application. An HDD operation allows curved bores on casing diameters under 600 mm but the radius of curvature is generally not less than 100 times the diameter of the casing pipe.</td>
<td>50-250 mm: $16-$160 per linear meter. 250-600 mm: $160-$650 per linear meter. 600-1200 mm: $650-$1650 per linear meter.</td>
</tr>
<tr>
<td>Utility Tunneling (UT)</td>
<td>The installation of segmental liners almost always requires manual operations. The actual tunnel advance is determined by soil conditions encountered, the method of soil excavation and removal, liner materials, and the field coordination and skill level of the Contractor. Carrier pipe is required to be installed to carry the utility and the annular space between the tunnel liner plates and carrier pipe need to be grouted.</td>
<td>Hand Mining: $0.9-$2.1 per mm of casing diameter per linear meter of casing.</td>
<td></td>
</tr>
</tbody>
</table>

* Productivity estimate does not include the excavation and shoring of the entrance and exit pits.  
** Cost estimates given in reference, based on Midwest Cost indices, 1996. Recent bid prices should be reviewed and compared.
SUBMITTAL PROCESS

The trenchless installation of casing specification was created to provide flexibility to a Contractor given a situation where the traditional open-cut-trench method is not permitted or where the trenchless installation of casing is more efficient, less disruptive, etc. This generic specification requires the Contractor to submit the method of trenchless installation, which may include the previously defined methods. By accepting various types of trenchless installation methods, we allow the Contractor to utilize their experience and expertise to decide on the appropriate method to progress through the anticipated subsurface conditions. This places a responsibility on the Department to define the subsurface conditions. The subsurface explorations must provide enough information to define the engineering characteristics of the soil and rock. See “Designer Guidance – Geotechnical Review”.

To ensure the designed drill path is in compliance with the contract documents during installation, the Contractor is required to submit their proposed steering (e.g. articulated steering head, offset jets incorporated into a direction sensing and steering head, etc.) and tracking equipment (e.g. sonde transmitter & receiver, electromagnetic down-hole navigational system, water level line, laser & survey tools, etc.), procedures, and proposed locations requiring surface or subsurface access.

Figure 9-4a Slurry Boring Tracking Equipment: Electromagnetic Down-Hole Navigational System: Tracer Wire Splice.

Figure 9-4b Slurry Boring Tracking: Electromagnetic Down-Hole Navigational System: Surface Cables.
A review of the Contractors submittal of their proposed steering and tracking equipment procedures should note that walk-over monitoring systems will require a depth measurement at least every 1.5 m to 9 m directly over the cutting head, depending on the pipe tolerances required. The maximum depth of walk-over monitoring is often limited to 4.5 m or less. Electromagnetic down-hole navigational systems can be used for deeper depths but is often not as accurate as walk-over monitoring. Overhead wires, concrete rebar and adjacent CMP culverts can interfere with the accuracy of the readings.

**DESIGNER GUIDANCE**

**Geotechnical Review.** The designer should consult with the Regional Geotechnical Engineer (RGE) to ensure adequate subsurface explorations are progressed to verify the feasibility of installing the proposed casing via trenchless methods. The designer and the RGE should discuss the subsurface conditions (type of soil, groundwater elevation, obstructions, existing utilities, etc.), length of bore, sensitivity of existing aboveground structures, etc., with respect to the proposed casing type and diameter, to determine the appropriateness of utilizing the specification.

The importance of adequate subsurface explorations cannot be overstated. Since there is no separate payment for obstructions, the Department must adequately define the subsurface conditions if we are to avoid contract disputes.
Subsurface explorations must provide enough information to define the engineering characteristics of the soil and rock. This is important for the Contractor to know what kind of conditions will be encountered while installing the casing so appropriate methods and equipment can be selected and a reasonable bid submitted.

A majority of the trenchless installation methods are potential techniques for progressing through full-face bedrock. However, if bedrock is encountered in the subsurface explorations at an elevation in the vicinity of the proposed drill path, revisions may be necessary. A minimum separation of 1.2 m should be allowed between bedrock and the bottom of the proposed casing. The designer should investigate installing the casing completely within rock. If this separation cannot be achieved, the Regional Geotechnical Engineer should investigate the subsurface conditions further with close interval subsurface explorations to identify the rock surface.

Utility Review. The specification will pay for the trenchless installation of casing which may be used to install a utility. The designer should consult with the Regional Utilities Engineer (RUE) to discuss the location and type of casing with consideration to the type of utility to be installed.

Rails Review. For an installation under a railroad, the designer shall consult with the Rail Agreements Section of the Design Services Bureau to identify the appropriate additional items for the track support system:

- Item 675.77--23 M – Furnishing and Removing Temporary Track Support System.
- Item 675.7701--23 M – Furnishing, Installing, and Removing Temporary Track Support System.

The Railroad (or the Department depending on the site specific subsurface conditions) may require an uninterrupted trenchless installation within the railroad/roadbed influence zone. Railroad's typically require this operation to progress on a 24-hr basis, without stoppage (except for adding lengths of casing), until the leading edge of the casing has reached the exit pit.

Environmental Review. The designer should identify potential impacts the trenchless installation may have on existing environmental and cultural resources and identify watercourses, wetlands, etc., which may require protection from the cuttings and pit spoil handling areas and final placement areas of the trenchless installation method.

Right-Of-Way Review. The designer should identify potential impacts the trenchless installation may have on existing right-of-way restrictions with respect to the location of the entrance and exit pits. It should be noted that all trenchless installation methods may be pit launched. However, some techniques may be surface launched, which may extend the required work space requirements.

Health and Safety Review. The designer should consult with the Regional Health and Safety Representative (if appropriate) to discuss potential use of Pipe Jacking or Utility Tunneling and the applicable safety standards for work in confined spaces. Regional Health and Safety Representative will work with the Regional Construction Safety Coordinator and EIC as a technical advisor during construction.
REFERENCES


4. Trenchless Construction Methods and Implementation Support University of Missouri-Columbia and Missouri Department of Transportation Organizational Results Research Report, R102.003, October 2005 http://168.166.124.22/RDT/reports/Ri02003/or06007.pdf

5. Pipe Jacking and Microtunnelling J. Thomson, Chairman, Jason Consultancy Group Blackie Academic & Professional, 1993