

CHAPTER 16
TRENCHLESS TECHNOLOGY

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16.1 Introduction

Trenchless technology consists of a variety of methods, materials, and equipment for inspection, stabilization, rehabilitation, and replacement of existing culverts and installation of new culverts with a minimum of excavation from the ground surface. Some of the methods were available in the early 1900's and with the addition of new techniques are coming into much more widespread use because of their inherent advantages. Trenchless methods minimize damage to the highway, cause little or no disruption to traffic, have less impact on the environment, and occasionally avoid or minimize the handling and disposal of contaminated soils.

Depending on the specific situation trenchless methods can be cost-effective alternatives to the more conventional open excavation. The cost is insensitive to depth of cover meaning that work under high fills will be more economical using trenchless technology. Many times the cost is not the main concern; factors such as safety, inconvenience of the motoring public, and environmental impacts outweigh the initial costs.

ODOT'S main application of this technology is in the rehabilitation, replacement, and installation of culverts and storm sewer lines in areas where open excavation is either more costly, not as environmentally friendly, or creates inconvenience for the motoring public.

16.2 Getting Started

The trenchless technology process starts with the identification of a problem. There is a drainage structure that requires some sort of fix. It may need stabilization, rehabilitation, or replacement. The first question to ask is what has caused this problem. Is the structure at the end of its design life, has it been damaged by mechanical abrasion or chemical erosion, have conditions changed and is it now under capacity, and are undesirable soil conditions causing problems?

It is always necessary to make a site investigation to determine what caused the problems identified. If you are not experienced in dealing with culverts ask for help. If the structure is less than 6.0 feet in diameter call the highway maintenance staff for that area. They are the local experts on what is going on with that structure. Contact the Region Bridge Inspector if the culvert is 6.0 feet in diameter or larger.

16.3 Site Investigation

Before trenchless methods can be considered for installation, replacement, or rehabilitation of culverts or storm sewer lines a thorough site investigation must be made. The existing culvert's condition must be determined. A visual inspection of the culvert's interior can be done if the culvert is at least 4 feet in diameter. If the culvert is less than 4 feet in diameter or other

circumstances prevent human entry, then a CCTV inspection, done by a trained technician must be performed. The resulting video inspection of the culvert can then be viewed by knowledgeable personnel for review and comment. In either case the embankment and surrounding area must also be examined thoroughly for subsidence and/or other anomalies at the time of inspection.

The underlying cause of the culvert's problems must be discovered. The following will provide guidelines on how to answer this most important question. The goal is to determine the underlying problems before a course of action is chosen.

Some of the more common problems found with culverts are:

- Loss of invert, walls, or ceiling due to corrosion and/or abrasion
- Leaking joints
- High debris load causing sedimentation and blockage.
- Settlement.
- Shape deformation.
- Scour and erosion of the streambed and embankments.
- Inadequate flow capacity.
- Joint separation
- Voids in the embankment around and above the culvert.

16.3.1 Roadway

- Look for defects in the roadway and embankment in the vicinity of the culvert. Check for sags, cracks in the pavement, pavement patches, dips in the guardrail, and erosion of the sideslopes. Probe the embankment looking for voids.
- Look for signs of recent high water; roadway overtopping, debris piled above the crown of the culvert, recent riprap placement around the inlet or outlet of culvert, and any other evidence that the culvert may be undersized or partially obstructed.
- Search through maintenance records. Region Bridge Inspectors inspect all culverts 6 feet & larger. District maintenance personnel inspect all of the culverts 6 feet and smaller.

16.3.2 Stream Channel

- In the stream channel look for scour holes at the inlet and outlet of the culvert.
- Examine the stream to determine size of the bed load passing through the culvert.
- Look at horizontal and vertical alignment of the channel for misalignment with the culvert inlet and outlet.

- Look for channel obstructions, such as, debris, slides, and fences. etc.
- Check for excessive embankment erosion, channel aggradation / degradation, and headcutting.
- Look for high water marks and if found above the culvert crown, look for changes in land use or drainage area.
- Examine headwalls, wingwalls, slope protection, and energy dissipators for misalignment and probe for possible voids. Check for scour, undermining of footings, and piping through the embankment.

16.3.3 Within Culvert

Man Entry Possible

- Look at the culvert invert for signs of abrasion and/or corrosion.
- Look for open or misaligned joints. Probe for voids behind open joints *
- Look for settlement
- Look for infiltration
- Look for sedimentation
- Look for blockage by debris.
- Look for cracking and spalling.
- Sound the culvert with a hammer to detect the formation of voids in the embankment surrounding the pipe.
- Look for evidence of fill material inside the culvert that may have migrated through an open joint.
- Look for high water marks within culvert.

**Note: If probing, boring, or any other invasive technique is needed to determine the culvert condition, the Region Bridge Inspector must be contacted first. He will initiate the procedure to obtain the proper permit of entry. Under no circumstances can these procedures be used without obtaining a permit first.*

Man Entry Not Possible

A closed circuit video (CCTV) inspection will need to be made by a qualified video inspection contractor. A video inspection is made with an audio commentary. The complete inspection should be viewed by knowledgeable personnel for comments and recommendations. The culvert inspection form (see [Chapter 6, Appendix D](#)) summarizes the above discussion and is recommended for use during site investigations.

16.4 Design

The critical component in determining what trenchless methods can be used is a thorough geotechnical investigation. The types of soil involved, the groundwater conditions, and the presence of large boulders or debris within the fill are all-important factors in determining method. Success with trenchless methods is very dependent on a more intensive site investigation with appropriate planning, design, and installation methods then would be required with open excavation methods. Field problems occurring during installation often result in much larger impacts to society, cost, and the environment than with open excavation methods. The results of all of the above observations will be factors in determining the best method of replacement or rehabilitation of the culvert and if trenchless technology can be used.

The next question is what other concerns exist? The answer may well change the entire design concept. Contact the Environmental Unit as early on in the project as possible so that environmental concerns can be incorporated into the design. The final design options will have to wait for the geotechnical data as well as the decisions of the environmental agencies before the plans can be approved.

Many ODOT projects that involve trenchless methods are dealing with existing drainage culverts that are nearing the end of their design life and are badly deteriorated. The first question is can the existing culvert be rehabilitated, or must it be replaced? Another alternative to consider is the rehabilitation of the existing culvert and the installation of additional culverts to increase flow capacity or enhance the passage of fish or wildlife.

16.4.1 Culvert Rehabilitation

The following list of conventional maintenance and repair methods is offered to remind that not every project will need trenchless methods to solve the problem:

16.4.1.1 Conventional

- Cleaning
- Root removal
- Internal grouting
- External grouting
- Mechanical seals
- Reinforced shotcrete or concrete placement

16.4.2 Trenchless techniques (pipe not replaced)

- Sliplining with fusion welded continuous pipe.
- Short pipe sections.
- Cured-in-place-pipe.
- Deformed pipe.
- Spiral-wound pipe.
- Coatings.
- Spot repairs.

16.4.2.1 Sliplining with Fusion-Welded Continuous Pipe



Figure 16-1 Sliplining with Fusion-Welded Continuous Pipe

This process refers to a pipe sliplining technique where plastic pipe (HDPE) or PVC sections are joined by fusion welding outside of the pipe to be rehabilitated, and then pulled into place as one solid liner. The installation is quick, but this technique is limited to fusion of circular cross sections only. Any shape of host pipe can be sliplined with fused circular pipe, but since there is a high loss of cross-section area, particularly in smaller sizes, the design must be checked for flow capacity. The liner is generally smoother than the host pipe causing higher outlet velocities, which may require additional design to deal with the increased scour potential.

The outside diameter of the pipe used for sliplining is generally specified to be at least 4 inches smaller than the inside diameter of the host pipe so that a low-density cementitious grout can be injected into the annular space between the two pipes.

The entire annular space is grouted to prevent voids from forming in the pipe bed and embankment. The low-density nature of the grout and the application technique used to apply it

allows it to migrate out into the fill surrounding the host pipe and seal voids that exist. The grout also provides for structural rehabilitation, prevents liner collapse, prevents fatigue failure, stabilizes the pipe, extends the design life from uncertainty to at least 50 years, and resists temperature changes.

16.4.2.2 Sliplining with Short Pipe Sections

Short pipe sections can be made of any material and are primarily used where access is restricted, such as, manhole to manhole installations. Installation is quick with a variety of cross sections to choose from. Some materials are easily damaged and may require special care at joints or when grouting in place.

16.4.2.3 Cured-in-Place Pipe



Figure 16-2 Cured-in-Place Pipe

A felt tube saturated with a thermosetting resin is either pulled into the existing pipe or inverted through as water pressure pushes the tube tightly against the pipe wall. The water in the tube is then heated to the curing temperature of from 160-180 degrees Fahrenheit. The plastic resin on the tube cures to solid pipe inside the existing pipe creating a new lining. Installation goes quickly leaving no annular space to be sealed. Odd cross sections, bends, and minor deformations can be accommodated. This method is particularly useful when flow capacity must be maintained or slightly increased.

16.4.2.4 Deformed pipe



Figure 16-3 Deformed pipe

The fold and form method utilizes PE or PVC pipe whose properties allow for the deformation of the pipe into a “U” shape prior to insertion into the host pipe. Once in place the pipe is heated with steam to expand it back to its original shape. A tight fit is formed against the wall of the original pipe. This process will line pipe up to a 24-inch diameter pipe.

Swagelining also takes advantage of the properties of PE pipe. A liner pipe with a slightly larger diameter than the existing pipe is pulled through a reduction die to temporarily reduce its diameter as it is inserted into the host pipe. After the liner has been pulled through the pipe the pulling force is removed allowing the PE pipe to expand back toward its original diameter. The expansion is stopped by the host pipe creating a tight fitting liner. This process will line pipe up to 48" in diameter.

Rolldown is a process like swagelining except that the pipe diameter is reduced by mechanical rolling instead of use of a reduction die. The liner is then pressurized with water at ambient temperature to revert it to its original size after it has been pulled through the existing pipe. This process will line pipe up to 20-inches in diameter.

16.4.2.5 Spiral-wound pipe



Figure 16-4 Spiral-wound pipe

This method uses a continuous PVC strip, which can be introduced into the existing pipe by hand or by the use of a helical winding machine. It can accommodate variations in cross section and large radius bends. It is mandatory to grout the annular space between the liner and existing pipe in small lifts using structural strength low-density grout. Depending on what must be done structurally to stabilize the pipe, significant loss of capacity can occur if the cross-sectional area is significantly reduced.

Coatings

A wide variety of materials including cement mortar, epoxy resins, and polyurethane, are available to coat the interiors of pipes. These materials are usually sprayed onto the pipe for corrosion protection. Structural spray-on lining is also available made from quick setting epoxy resin or polyurethane material.

Pipe lines may be restored by treating manhole lengths with a chemical solution. The length is first sealed and filled with solution "A" which is then pumped out. The length is refilled with solution "B" which is subsequently pumped out. The chemical reaction between the two components seals joints and cracks in the pipe and stabilizes the surrounding soil.

Spot Repairs

Internal grouting of pipe joints and radial cracks can be accomplished with a packer. The packer is moved into place over the pipe joint or radial crack, then bladders are inflated at each end of the packer and grout is then injected into and around the damaged area. When the repair is completed the bladders are deflated and the packer removed from the system. Cementitious grout, resins, and urethane, are the common grout materials used.

Internal mechanical seals are also available. They are generally made from a special EPDM rubber gasket reinforced with internal stainless steel compression hoops. They form a tight yet flexible pressure seal over the damaged area.

A section of felt tube saturated with a thermosetting resin up to approximately 20 feet can be pulled into the existing pipe at the point of needed repair. This short tube section differs from a conventional cured-in-place liner by the curing process. No heat is required to cure the resin. Ambient temperature cures the pipe in just a few hours.

16.4.3 Trenchless Techniques (Culvert Replacement)

This section will discuss trenchless techniques used in the installation of new culverts. The following list is of popular techniques being used to install new pipe.

- Pipe Jacking
- Auger Boring

- Pipe Ramming
- Microtunneling
- Horizontal Directional Drilling
- Pipe Bursting
- Utility Tunneling

16.4.3.1 Pipe Jacking



Figure 16-5 Pipe Jacking

Pipe Jacking is a method for installing a prefabricated pipe through the ground from a drive shaft to a reception shaft. The pipe is moved by jacks located in the drive shaft. The thrust power of the hydraulic jacks forces the pipe forward through the ground as the face is being excavated. After each pipe segment has been installed, the rams of the jacks are retracted so that another pipe segment can be placed in position for the jacking cycle to begin again.

As the excavation proceeds soil is transported out of the jacked pipe and drive shaft either manually or mechanically. The soil conveyance systems include wheeled carts or skips, belt or chain conveyors, slurry systems, auger systems, and vacuum extraction systems. Both the

excavation and spoil removal processes require workers to be inside the pipe during the jacking operation. For personnel health and safety, a minimum pipe diameter of 42-inches is recommended.

Excavation can be accomplished by hand mining or mechanical excavation within a shield or by a tunnel boring machine (TBM). The excavation method selection is based on soil conditions. If there is any possibility of the excavation face collapsing, soil stabilization techniques must be considered. Dewatering or grouting are both common methods of soil stabilization.

The design of the drive shaft is critical to the success of the project. The shaft floor and thrust reaction structure must be designed to withstand the large jacking forces required to push the pipe through the ground and withstand the weight of heavy pipe segments being placed on them repeatedly. Pipe jacking equipment that has a pipe lubrication system can decrease the jacking forces necessary by 20-30 percent.

The required working space must provide adequate space for storage and handling of the pipe and spoil and space for the shaft. Typically, the working space should be from 4 feet to 10 feet wider than the diameter of the pipe and from 10 feet to 25 feet longer than the length of pipe sections being installed. Shaft size will vary depending on the type of jacking and excavation equipment used.

The primary concern is the prediction of subsurface soil behavior. Unanticipated ground conditions require corrective measures that cause cost overruns and delays. Sandy clay is the most favorable soil condition if the water table is not above the pipe invert. With the use of the proper excavation methods many types of ground conditions can be overcome. Major factors to be considered are the presence of groundwater, unanticipated obstructions such as boulders, and changed soil conditions that would require different equipment to excavate.

Other concerns include proper design of the shaft to withstand the large jacking thrust and that jacking thrust is uniformly transferred through a properly designed joint material. The over-excavation above or ahead of the pipe is to be avoided, if over-excavation occurs or voids develop, external grouting is usually required.

16.4.3.2 Auger Boring



Figure 16-6 Auger Boring

Auger Boring is a method for driving a horizontal bore hole through an embankment from a drive shaft to a reception shaft. A rotating cutting head is attached to the leading end of an auger string. The spoil is transported back to the drive shaft area by the rotation of the helical-wound auger flights within the steel pipe casing being placed. Common practice is to jack the steel casing through the hole as it is being bored. Because of the possible hazards of the unsupported hole collapsing or personnel being hurt from unshielded auger flights, uncased auger boring is discouraged. The boring machine turns the auger string, which rotates the cutter head. A casing is advanced through the bore hole by hydraulic jacks located at the rear of the machine. The jacks push the whole assembly forward as the boring progresses. The soil is excavated, removed, and the casing installed in one continuous operation.

The method is unguided as to line and grade unless a steering head is used. With the steering head and a water-level grade monitoring system an accuracy of 1 percent of the length can be maintained in vertical grade. Horizontal grade is generally not controlled and obstructions such as boulders can cause large deflections. Technology is providing more accurately controlled articulating cutter heads and laser sensing systems which are coming into common use. With the new improvements, auger boring can rival microtunneling accuracy for relatively short drives in stable ground conditions.

A properly designed and constructed drive shaft is critical to the success of the project. The drive shaft provides a stable foundation to maintain the preset grade and to support the jacking process with a properly designed trust block. The boring machine sets on tracks placed on the same line and grade as the desired bore hole. If the foundation settles, the track will also deflect causing inaccuracy in borehole alignment.

The thrust block transmits the horizontal jacking forces from the tracks to the ground at the rear of the drive shaft. The trust block must be designed to distribute the force over a large enough area so that the allowable compressive strength of the soil is not exceeded. If the trust block moves, bore hole accuracy will be lost and binding forces could result.

The casing pipe is typically made of steel to resist damage that can be caused by rotation of the augers. The casing can be lined with any suitable material once it has been installed. Installed sizes typically range from 1 foot to 3 feet with typical bore lengths of 100 feet to 300 feet. Diameters of up to 5 feet and lengths of drive over 800 feet have been made.

Working space is required at both ends of the casing. The drive shaft is the working shaft with its size determined by bore hole diameter and length of casing segments used. Typical casing lengths range from 10 feet to 20 feet. For a casing that is 20 feet in length the shaft size should be from 30 feet to 35 feet in length and from 10 feet to 14 feet wide.

Operator skill is critical as the excavation and spoil removal process can't be seen. Much of the work is done by feel. Changing conditions that are not detected can cause subsidence of the ground by overexcavation. If soil conditions change from cohesive to noncohesive an experienced operator will adjust the location of the cutting head relative to the end of the casing to avoid removing too much soil. Excessive force applied to the excavation face can cause heaving of the ground above the excavation. The operator's skill and experience are the key element of success with this method.

A wide variety of soil conditions can be accommodated from wet sand to firm dry clay. Boulders as large as 1/3 of the casing diameter can be excavated, but deflection from line and grade must be carefully watched. Depending on soil conditions, casing diameter and length a typical advance rate would be from 3 feet to 40 feet per hour. The minimum depth of cover over the excavation should not be less than 2 feet.

16.4.3.3 Pipe Ramming



Figure 16-7 Pipe Ramming

With pipe ramming, the dynamic force and energy transmitted by a percussion hammer attached to the end of a thick-walled steel casing drives it from the drive shaft on one side of the embankment to the reception shaft on the other side of the embankment. The casing can be used without a pipe installed through it or a project pipe can be installed through the casing and grouted in place with low density grout. The casing can also be sprayed with a coating to retard corrosion, or it can be used untreated depending on the local conditions.

The process is simple and similar to pile driving operations. Continuous support is provided during the drive with no over-excavation needed. The spoils stay in the pipe and are mechanically removed when the drive is completed.

The initial setup is the critical factor in the success of any pipe ramming project. The drive shaft must be located on very stable ground or a concrete slab must be placed under the casing. The pipe is unguided so the floor of the drive shaft must be engineered to be on the same line and grade as the pipe to provide the accuracy needed.

Ground conditions encountered also effect the line and grade of the casing making it very important to know what the fill is composed of. There is a possibility of ground heaving and subsidence. Heaving usually is not a problem because there is minimum disturbance outside the pipe. Subsidence can occur in some soils due to the consolidation resulting from the vibratory action of the hammer.

The casing will have the tendency to drift downward slightly as the ramming proceeds due to gravitational forces. When possible it is advantageous to start the drive from the upstream side of the crossing.

Pipe ramming is particularly effective when the fill contains obstructions. Where a boulder or tree stump partially obstructs the pipe, the casing will usually break it up, swallow it into the casing, or push it aside as it continues through the embankment. The line and grade of the pipe can be affected by these obstructions if encountered before enough casing has been driven to give the pipe support. Larger pipe diameters are less likely to be deflected by obstructions. Pipe ramming can be used for a wide range of soil conditions including high groundwater table.

One percent of the length of the drive is the accuracy both vertically and horizontally that can be expected from an unguided ram. The lack of good line and grade control limits the typical length from 100 feet to 200 feet not to exceed 300 feet when pipe ramming is used. Oversize casings are sometimes installed so that a carrier pipe can be adjusted within the casing to correct for line and grade problems.

Recently a steering mechanism has been developed that is attached to the front of the driven pipe that is capable of maintaining accuracies to 0.1 percent of the grade. The largest ramming to date is a 12 feet steel casing, 225 feet long. Larger more powerful machines are now available that have the capability of ramming a 16 feet steel casing over 500 feet.

16.4.3.4 Microtunneling

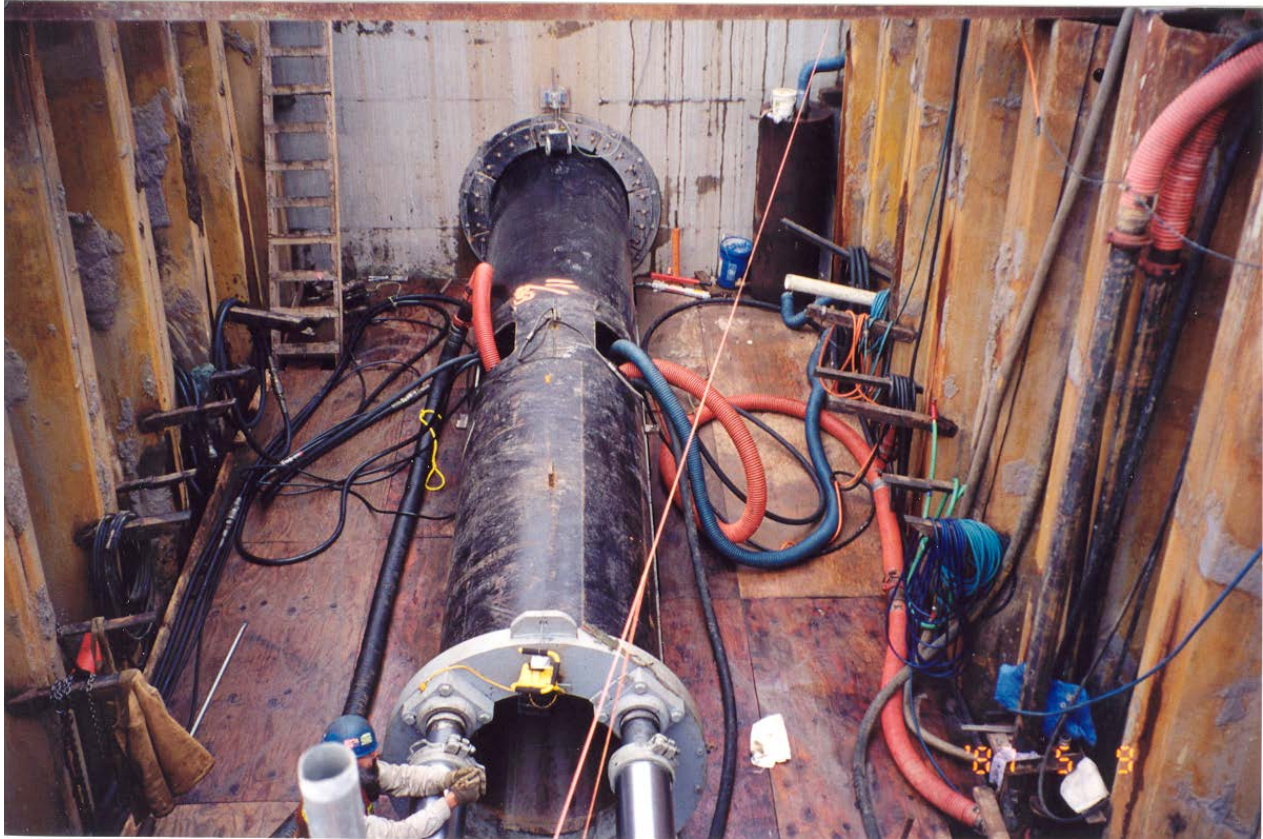


Figure 16-8 Microtunneling

Microtunneling (MT) is a method using a remotely controlled, guided pipe jacking process that provides continuous support to the excavation face. It can be used in a wide range of soil conditions while keeping close tolerances to line and grade. Spoils are removed by either a pumped slurry or by mechanical auger. Five independent systems are incorporated into Microtunneling systems. They are as follows:

- Microtunnel boring machine (MTBM).
- Jacking or propulsion system.
- Spoil removal system.
- Laser guidance and remote control system.
- Pipe lubrication system.

The MT procedure on a typical project is much the same as for Pipe Jacking.

The required working space must provide adequate space for storage and handling of the pipe and spoil and space for the shaft. Typically, the drive shaft would range from 16 feet to 50 feet wide and from 35 feet to 100 feet long depending on pipe diameter, length and equipment dimensions. Working space typically would range from 20 feet to 40 feet wide and 75 feet to 150 feet long.

The primary concern is the prediction of subsurface soil behavior. Unanticipated ground conditions require corrective measures that cause cost overruns and delays. Wet sand for slurry MT and stable sandy clay for auger MT are the most favorable soil conditions for each. A wide variety of MTBM cutter heads are available that provide the capability to handle a range of soil conditions, including boulders and solid rock. Major factors to be considered are the presence of groundwater, unanticipated obstructions such as boulders, and changed soil conditions that would require different equipment to excavate.

Microtunneling is very accurate. Line and grade can be maintained to 0.01 percent of the drive length depending on many factors, the most important being the skill of the machine operator.

16.4.3.5 Horizontal Directional Drilling



Figure 16-9 Horizontal Directional Drilling

Horizontal Directional Drilling is a method that uses steerable soil drilling in a two-stage process. Stage 1 involves drilling a pilot hole approximately 1-inch to 5-inches in diameter along the proposed pipe alignment centerline. Concurrent to drilling the pilot hole, the contractor may elect to run a larger diameter “wash pipe” that will encase the pilot drill string. The wash pipe acts as a conductor casing providing rigidity to the smaller diameter pilot drill string and will also save the drilled hole should it be necessary to retract the drill string for bit changes.

In Stage 2 a backreamer is attached to the end of the drill string and pulled back through the pipe to enlarge the hole to the size necessary to pull back the new pipeline. The pipe can be pulled in behind the backreamer or the hole can be created first then the pipe pulled through. It may require several passes on different diameter backreamers to enlarge the bore to the diameter desired. The bore is drilled oversize approximately 50 percent larger than the diameter of the new pipe so that the pipe can be pulled into place without causing large frictional forces which can lead to binding of the pipe and/or collapse of the bored hole.

The drill rig itself sets on the surface and has an inclined carriage typically adjusted to an angle between 5 to 20 degrees with the ground. The drill string enters the ground at the preset angle and is then guided through the fill in a shallow arc. The drill path is monitored by an electronic package housed in the pilot drill string near the cutting head. Data is transmitted back to the surface where calculations are made as to the location of the cutting head. Installation accuracy depends on which electronic monitoring package is used, but an accuracy of within 1 percent of the bore length is considered acceptable. In actual field operations, such accuracy is not exceeded because of the high drilling speeds preferred by contractors and limitations due to operators’ skill levels and the steering system. Greater accuracy is possible using more powerful sondes in combination with electrically charged surface grids with computer interface.

Large volumes of drilling slurry are used to provide the following:

- Transport of the drilling cuttings to the surface.
- Stabilize the hole against collapse
- Reduction of friction.
- Lubrication of the cutting head.
- Cooling and cleaning of the cutters.
- Providing power to the drill motor.

The slurries most commonly used are bentonite based. Bentonite is naturally occurring clay known for its hydrophilic characteristics. Often polymers and surfactants are also added to enhance certain slurry characteristics. The slurry is pumped downhole and circulates back to the surface and is may be collected in return pits. The slurry is pumped from the return pits to a settling and containment pit. The slurry is then passed through machinery that separates the cuttings from the slurry. This process involves a series of shaking sieves and various size hydroclones and centrifuges.

At the end of the project the slurry can be disposed of by:

- Use at another location.
- Spread onto the surrounding land for water retention improvement.
- Evacuate to a dump site.

A work space of approximately 120 feet x 175 feet should be provided at both the rig side and the outlet side of the project for storage, and required auxiliary equipment.

Directional drilling is best used in clays. Cohesionless fine sand and silt generally stay suspended in the drill fluid for a sufficient amount of time to reach the surface and are also suitable. It is more difficult to use in granular materials such as gravel and rock because the drill fluid may not carry the spoils to the surface causing the cutting head and “wash pipe” to plug. Higher fluid pressure, more powerful jets, and special drill heads can be used to offset the clogging problems, but other problems may occur in spoil removal, hole stabilization, and backreaming operations. Caution must also be used to prevent ground movement and loss of slurry in applications with shallow ground cover.

Directional drilling has the fastest boring rate among all the trenchless methods. In suitable conditions, 500 feet of pipeline can be installed in one day. It can be used under water and a number of different pipe materials can be pulled into place.

16.4.3.6 Pipe Bursting



Figure 16-10 Pipe Bursting

Pipe Bursting technology uses a rod, or cable connected to either a static bullet-shaped bursting head or a dynamic head made from a converted pipe ramming machine. The bursting head is pulled through the existing pipe by a rod or cable, simultaneously shattering the old pipe and pulling a replacement pipe behind it. It is a method developed for use where underground space is at a premium. The subsurface can be so congested with existing services and chambers that the existing hole becomes a valuable route. The existing defective pipe is split and the fragments are displaced into the embankment. A new pipeline of the same diameter, usually of HDPE, is drawn in behind the splitter. If the soil conditions are favorable a larger diameter pipe may be installed. Open trench methods will have to be used to expose any lateral lines coming into the existing pipe before the pipe bursting process begins. The lateral lines are reinstated into the new pipeline after it is installed.

Advantages include rapid installation, replacement with a variety of pipe materials, and the method is not dependent on conditions of existing soil for same size replacement. To reduce the possibility of soil heave above the pipe line, a minimum of 4 feet of cover is needed in most cases.

The host pipes must be brittle to use pipe bursting. Most ductile iron, concrete, reinforced concrete, clay, PVC, Asbestos Cement, and liners can be burst. Corrugated Metal Pipe generally cannot be burst. In some circumstances cuttings blades can be inserted into the pulling head and the CMP can be sliced into longitudinal pieces and pushed into the fill as the replacement pipe is pulled into place.

The length of run is usually from manhole to manhole with longer runs possible. A 500 foot run is common place with the longest run at present being approximately 5000 feet long.

Soil conditions greatly affect the length of run and any potential upsizing of the pipe for replacement. The best to worst soil conditions are original backfill material, expandable clay, loose cobble, beach and running sand, densely compacted clay, with sandstone being the worse.

Upsizing to a larger diameter pipe is dependent on soil conditions, original trench width, and depth. To ensure that the ground surface will not heave there should be at least 4 feet of cover. A rule of thumb is that the burst depth should not be less than ten times the upsize diameter. If the pipe is to upsized by 1 foot then it would require at least 10 feet of cover. This is a rule of thumb only, other conditions such as soil type, groundwater level, and proximity of existing utilities must also be considered.

Areas containing clays and other compressible soils are best suited for upsizing. Sands and gravel are very difficult to burst because the soils tend to collapse in on themselves in the void created by the expander. The collapsed soils cause very large values of skin friction on the pipe being pulled in behind the bursting unit. The friction can stop the bursting head altogether. Rocks in the fill can settle back onto the new liner and collapse it after the expander has passed by. Solid rock outcrops may not expand at all. The need for a thorough geotechnical subsurface investigation before upsizing is attempted cannot be overemphasized. Pipe upsizing from 0 to 25 percent of the diameter is common, 25 percent to 50 percent is challenging, and above 50 percent experimental.

The following should be considered when evaluating a project for proposed pipe bursting:

- Upsizing is harder, whether at depth or shallow.
- The burst length that is possible decreases with depth.
- Pipe frictional drag increases with depth
- Existing utilities can be damaged. Suggest at least 2 feet of clearance between the bursting head and the nearest utility.
- Failures, deep or shallow are more expensive.

- Entry and exit pit construction is affected by depth and soil conditions.
- Lateral connections will have to be disconnected before bursting usually by open trenching.
- Point repairs may be necessary. Bursting does not correct existing sags in host pipe.

Pipe bursting is used extensively in sewer rehabilitation, but has limited use in the replacement of highway cross culverts. Up to 4 foot diameter pipes have been installed using pipe bursting.

16.4.3.7 Utility Tunneling

Utility tunneling is a method of soil excavation similar to pipe jacking. The difference is in the lining used. In Pipe Jacking, the pipe is the lining where in utility tunneling special steel or concrete liner plates, wood box tunnels, steel rib and wood lagging systems are used to provide temporary ground support.

The process involves removing soil from the front cutting face and installing a liner to form a continuous support structure. The tunnel is normally constructed between two access shafts. The procedure consists of four major steps:

- Soil excavation.
- Soil removal.
- Segmental liner installation.
- Line and grade control.

Soil Excavation

Depending on conditions, soil excavation can be accomplished by hand mining, open-face mechanical excavation, or closed-face tunnel boring machines (TBMs).

Hand mining

Hand mining is the simplest form of soil excavation using picks, shovels, or pneumatic hand held tools at the face of the excavation. A protective shield is usually required to provide face stability during soil excavation. In a fixed shield, minor line and grade changes are accomplished by differential excavation in the desired direction. With an articulated shield, line and grade corrections are accomplished by activating hydraulic cylinders internal to the shield.

Hand mining operations are slow, but provide simplicity and the ability to handle difficult and varying soil conditions. Minimal work space is required and linings as small as 30" diameter have been installed. The method is usually limited to short drives where high groundwater table is not a problem.

Open-face mechanical excavation

The soil excavation rate for open-face mechanical excavation is much faster than with hand mining. Special shields can be equipped with power excavation devices such as rotary cutter booms mounted on the front of the shield or modified hydraulic backhoes. Most shields provide personnel with access to the front face for adjustments of cutter heads for varying ground conditions as well as manual handling of unexpected obstructions. In unstable soil conditions or high groundwater table conditions, compressed air is sometimes used, and in some shields, the tunneling operator is not required to work inside the pressurized zone.

Closed-face tunneling shields

Closed face-tunneling shields are called Tunnel Boring Machines (TBMs) when equipped with hydraulically or electrically driven rotary cutter heads or disk cutters. The cut soil is forced inside the shield through slits in the cutter head as the shield advances. Generally, closed-face TBMs provide better face stability during soil excavation and are therefore more suitable for noncohesive soils below the water table. Some TBMs have crushing devices to excavate gravel and boulders. Major drawbacks include relatively high cost, limited face access, and are restricted to circular tunnels. The most sophisticated TBM systems incorporate a pressure chamber that provides a balance between the soil face pressure and external water pressure. At this level of sophistication this method becomes more of a microtunneling process than utility tunneling.

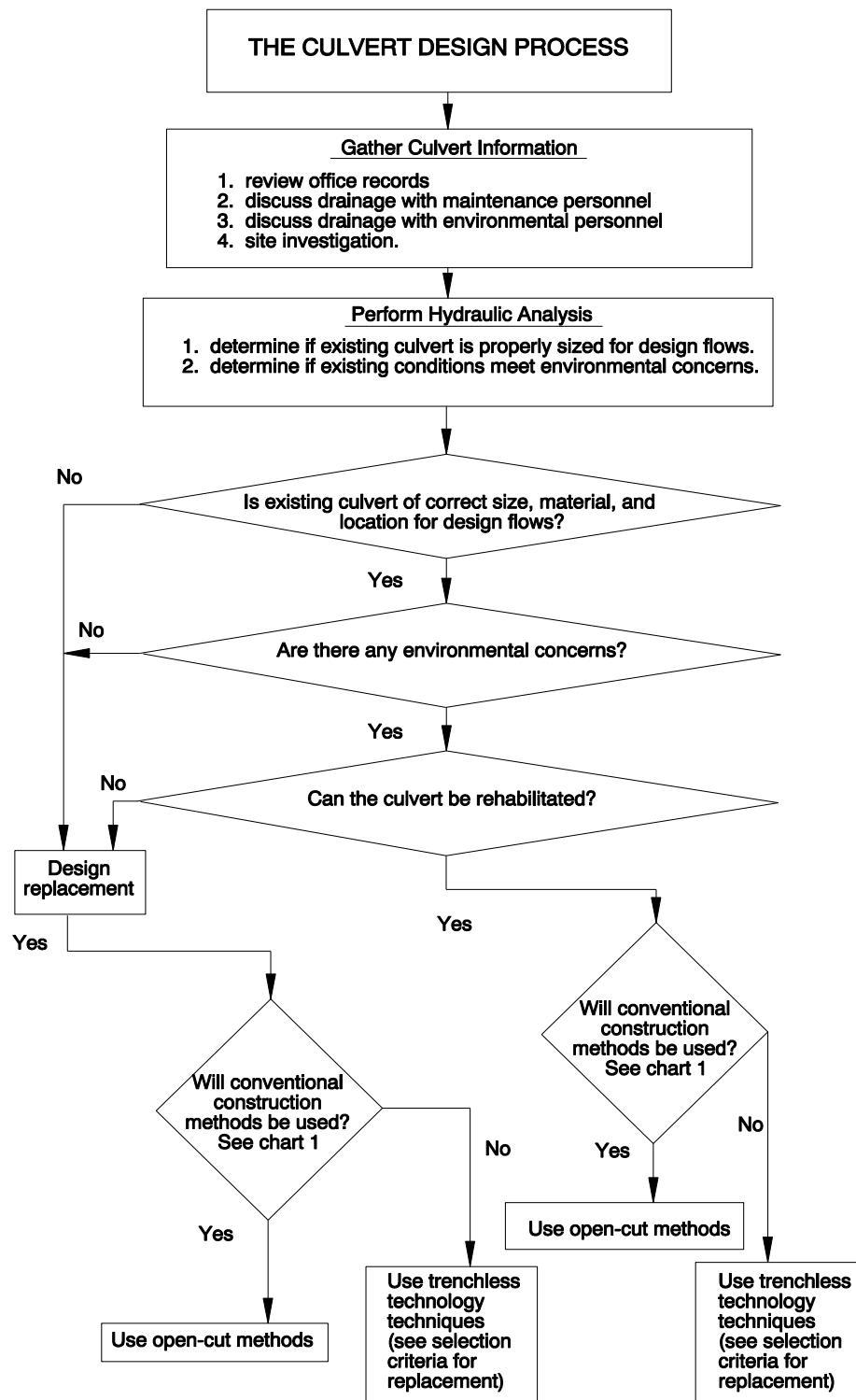
Spoil Removal

Selection of the appropriate spoil removal system is determined by space requirements, method of excavation, the mechanism of face pressure balance, and total tunnel length.

The most common methods of removal are listed below:

- Wheeled carts or skips
- Belt and chain conveyors.
- Positive displacement pumping devices.
- Slurry systems.
- Auger systems.
- Vacuum extraction systems.

Chart 16-1 The Culvert Design Process



Segmental Liner Installation

After the soil face has been excavated and removed or the shield is advanced and the jacking cylinders are retracted, new segmental liner sections are brought through the already erected lining to the face. The new liner sections are assembled and connected to the existing lining. If a tunneling shield is used, the retracted jacking cylinders are extended to make contact with the new lining and then mining continues.

The liner usually requires grouting of the annular space outside the liner/segment. The liner has prefabricated grout application holes installed to facilitate the grout application.

The liner plates are typically made of steel or precast reinforced concrete. The steel liner plates have flanged edges that allow the overlapping and bolting together of successive liner plates to form an integrated lining. Some concrete segments are bolted together through precast holes, and some are unbolted. Steel plates are more widely used than concrete plates because their strength to weight ratio is higher.

Line and Grade Control

The two most common directional measurement controls are the Theodolite and the Laser systems. The theodolite is a surveying instrument that monitors the current position of the tunnel face directly. The laser system also requires a skilled operator as well as a source of light. A laser system allows for any directional variation to be adjusted immediately, but it is sensitive to temperature variations along the line and can be dispersed over a long distance of dusty air. Neither system can be used continuously because they both cause temporary interruption of the mining work. More sophisticated inertia surveying systems, such as the gyroscope, have been adopted for curved tunneling.

During the soil excavation and shield advancing process, directional change is accomplished by applying different forces to the jacking cylinders controlling the advance of the tunneling shield.

Remote control of many elements of the tunneling process have been realized recently, however the installation and grouting of the segmental liners still requires manual operations. Generally, utility tunneling is a slow labor-intensive process, but is well adapted to rapid changes in soil conditions. The actual jacking pressures are low since only the tunneling shield is moving, which, makes possible a tunnel drive of any length.

16.5 Culvert Design Process Guidelines

Chart 1

Site specific considerations for the use of trenchless technology


- Are there environmental concerns to consider?
- Is disruption of traffic an important consideration?
- Does construction have to be completed quickly?
- Is a detour necessary?
- Is a high embankment fill involved?
- Will by-pass flows need to be maintained?
- Will dewatering of the site be necessary?
- Are there extra safety concerns on this project?
- Are utility conflicts a concern?
- Is the existing roadway in good condition?
- Are right of way problems present?
- Is the project not feasible using conventional methods?

If the answer to any of the above is yes, then trenchless technology may offer a solution to the problem.

16.5.1 Trenchless Method Selection Criteria For Replacement

Table 16-1 Method By Pipe Diameter

TRENCHLESS METHOD	DIAMETER RANGE (Inches)						
	12	48	60	72	120	144	168
Horizontal directional drill (HDD)	X	X					
Auger boring (AB)	X	X					
Pipe ramming (PR)*	X	X	X	X	X	X	X
Pipe Jacking (PJ)	X	X	X	X	X	X	X
Microtunneling (MT)	X	X	X	X	X	X	X

 = N.A.

* more than 72 inch diameter use Horizontal pile driving equipment.

Table 16-2 Method By Pipe Length

TRENCHLESS METHOD	LENGTH RANGE (Feet)				
	40	300	500	1000	>1000
Horizontal directional drill (HDD)	X	X	X	X	X
Auger boring (AB)	X	X			
Pipe ramming (PR)	X	X			
Pipe Jacking (PJ)	X	X			
Microtunneling (MT)	X	X	X	X	X

 = N.A.

Table 16-3 Method By Soil Conditions

Soil Conditions	AB	HDD	MT	PJ	PR
Soft clays, silts, and organics	YES	YES	RISKY	RISKY	YES
Medium to very stiff clays and silts	YES	YES	YES	YES	YES
Hard clays and weathered shales	YES	YES	YES	YES	RISKY
Loose sands above water table	RISKY	YES	YES	RISKY	YES
Medium to dense sands above water table	YES	YES	YES	YES	YES
Medium to dense sands below watertable	NO	YES	YES	NO	YES
Gravels and cobbles less than 4"	YES	RISKY	YES	YES	YES
Soils with significant cobbles greater than 4"	RISKY	RISKY	RISKY	RISKY	YES
Firmly cemented soils and weathered rocks	YES	YES	YES	RISKY	RISKY
Solid rock	YES	YES	YES	NO	NO

METHOD BY DEPTH OF COVER

All trenchless replacement techniques require entrance and exit shafts, except HDD. Pipe can be installed at any depth using these methods.

Table 16-4 Method By Pipe Type

Pipe Type*	AB	HDD	MT	PJ	PR
HDPE (high density polyethelene)	NO	YES	YES	NO	NO
STEEL (A-36)	YES	YES	YES	YES	YES
PVC (poly vinyl chloride)	NO	YES	YES	NO	NO
VCP (vitrified clay pipe)	NO	YES	YES	NO	NO
DIP (ductile iron pipe)	NO	YES	YES	NO	NO
FRMP (fiber-reinforced mortar pipe)	NO	YES	YES	YES	NO

*pipe material selected must be designed to meet the project conditions.

16.5.1.1 Cost Guidelines (In 2004 Dollars)

Estimates include cost of installation, mobilization, and planning. Estimates do not include engineering or contingency costs, casing or carrier pipe cost, and cost for preparing entry or exit pits or dewatering costs.

Table 16-5 Costs Per Foot By Method And Pipe Diameter

TRENCHLESS METHOD	DIAMETER RANGE IN INCHES													
	12	18	24	36	48	60	72	84	96	108	120	132	144	168
Horizontal directional drill (HDD)	180	215	250	375	500	NA	NA	NA	NA	NA	NA	NA	NA	NA
Auger boring (AB)	100	150	200	300	400	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pipe ramming (PR)	100	150	200	300	400	600	850	1200	1700	2200	2700	3200	3700	4200
Pipe Jacking (PJ)	140	210	280	425	575	850	1220	1710	2500	3150	3850	4500	5300	6000
Microtunneling (MT)	240	360	480	720	1000	1200	1450	1700	2000	2400	3000	3500	5000	8000

Note: Costs will vary based on location, contractor availability, contractor marketing strategies, time of year, etc. On bores larger than 72-inches in diameter these costs can exceed 50% of the estimate calculated from the following table because costs are totally dependent on soil and site conditions and how effective the contractor's machines are working with the existing conditions.

16.5.2 Trenchless Method Selection Criteria For Rehabilitation

Estimates include cost of installation, mobilization, and planning. It does not include engineering or contingency costs, casing or carrier pipe cost, or cost for preparing entry or exit pits or dewatering costs.

Note: Costs will vary based on location, contractor availability, contractor marketing strategies, time of year, etc


METHOD BY DEPTH OF COVER

Minimum depth of cover for **pipe bursting** is 4 feet + ½ size increase.

Fold and Form Liner is not a structural repair and may fail if used where subjected to high water table. All other methods pipe can be designed to be installed at any depth.

Table 16-6 Method By Pipe Diameter

TRENCHLESS TECHNOLOGY METHOD	DIAMETER RANGE IN INCHES												
	12	18	24	30	36	42	48	60	72	84	96	120	more than 120
SLIPLINING *	X	X	X	X	X	X	X	X	X	X	X	X	X
CURED-IN-PLACE LINER	X	X	X	X	X	X	X	X	X	X	X		
FOLD AND FORM PIPE LINER	X	X	X										
SPIRAL WOUND LINER	X	X	X	X	X	X	X	X	X	X	X	X	X
COATING(INVERT LINING)					X	X	X	X	X	X	X	X	X
PIPE BURSTING	X	X	X	X	X	X							

 = N.A.

*sliplining includes either HPDE or CMP pipe and grouting the annular space.

Table 16-7 Method By Pipe Length

TRENCHLESS TECHNOLOGY METHOD	LENGTH RANGE IN FEET				
	40	300	500	1000	more than 1000
SLIPLINING *	X	X	X	X	X
CURED-IN-PLACE LINER	X	X	X	X	X
FOLD & FORM PIPE LINER	X	X	X	X	X
SPIRAL WOUND LINER	X	X	X	X	X
COATING(INVERT LINING)	X	X	X	X	X
PIPE BURSTING	X	X			


 = N.A.

Table 16-8 Method By Soil Conditions

Soil Conditions	SLIPLINING	CURED- IN- PLACE	FOLD & FORM PIPE	SPIRAL WOUND	INVERT PAVING	PIPE BURSTING
Soft clays, silts, and organics	YES	YES	YES	YES	YES	YES
Medium to very stiff clays and silts	YES	YES	YES	YES	YES	YES
Hard clays and weathered shales	YES	YES	YES	YES	YES	NO
Loose sands above water table	YES	YES	YES	YES	YES	YES
Medium to dense sands above water table	YES	YES	YES	YES	YES	YES
Medium to dense sands below water table	NO	YES	NO	NO	NO	YES
Gravels and cobbles less than 4 inches	YES	YES	YES	YES	YES	YES
Soils with significant cob inches	YES	YES	YES	YES	YES	YES
Firmly cemented soils and weathered rocks	YES	YES	YES	YES	YES	NO
Solid rock	YES	YES	YES	YES	YES	NO

Table 16-9 Method By Pipe Type *

PIPE TYPE*	SLIPLINING	CURED- IN- PLACE	FOLD & FORM PIPE	SPIRAL WOUND	INVERT PAVING	PIPE BURSTING
HDPE (high density polyethylene)	YES	NA	NA	NA	NA	YES
STEEL (A-36)	YES	NA	NA	NA	NA	YES
PVC(poly vinyl chloride)	YES	NA	NA	NA	NA	YES
VCP (vitrified clay pipe)	YES	NA	NA	NA	NA	NO
DIP (ductile iron pipe)	YES	NA	NA	NA	NA	NO
FRMP (fiber-reinforced mortar pipe)	YES	NA	NA	NA	NA	NO

* Pipe material selected for liner must be designed to meet project conditions.

16.5.2.1 Cost Guidelines (In 2004 Dollars)

Estimates include cost of installation, mobilization, and planning. Estimates do not include engineering or contingency costs, casing or carrier pipe cost, cost for preparing entry or exit pits or dewatering costs.

Note: Costs will vary based on location, contractor availability, contractor marketing strategies, time of year, etc.

Table 16-10 Costs Per Foot By Method And Pipe Diameter

TRENCHLESS TECHNOLOGY METHOD	PIPE DIAMETER IN INCHES											
	12	18	24	30	36	42	48	60	72	84	96	120
SLIPLINING *	100	150	180	200	225	250	300	350	400	460	560	700
CURED-IN- PLACE LINER	100	180	250	300	400	510	680	910	1200	1600	2200	NA
FOLD AND FORM PIPE LINER	165	205	250									
SPIRAL WOUND LINER	80	130	160	170	200	220	250	315	380	440	500	630
COATING (INVERT LINING)	NA	NA	NA	NA	80	85	95	110	130	140	145	150
PIPE BURSTING	200	300	400	480	600	800						

*sliplining cost includes pipe and grouting the annular space.