# Australasian Society for Trenchless Technology

# Guidelines for Horizontal Directional Drilling, Pipe Bursting, Microtunnelling and Pipe Jacking

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# 1.0 BACKGROUND

This Guideline has been developed by the Australasian Society for Trenchless Technology for assisting users of Trenchless Technology in Australia and New Zealand in selecting and utilising the most suitable Trenchless Technology method available.

General information on current methods in Horizontal Directional Drilling, Pipe Bursting, and Microtunnelling and Pipe Jacking as a Trenchless Technology methodology for installing pipe are provided, as well as means of determining which Trenchless Technology methods is most appropriate.

This document is intended as a guide to be used for information only and it does not replace any existing manuals or standards. It is the user's responsibility to ensure that all relevant laws, standards and specifications are adhered to during the course of any Works which use Trenchless Technology.

Additional information on each of the Trenchless Technology mentioned in this Guideline can be obtained from the Australasian Society for Trenchless Technology website (www.astt.com.au):

- Standards for Horizontal Direction Drilling, Pipe Bursting, Microtunnelling & Pipe Jacking;
- Specifications for Horizontal Direction Drilling, Pipe Bursting, Microtunnelling & Pipe Jacking;
- National Utility Contractors Association Trenchless Assessment Guide, a web-based tool that can be used for identifying trenchless construction methods suitable for a particular set of project attributes (i.e.: diameter, length, depth, geological conditions and so on).

# 2.0 DEFINITIONS

A number of abbreviations and technical terms have been used in this guideline:

**ASTT** - Australasian Society for Trenchless Technology.

**Auger -** A method of moving material by use of rotating helical flighting, a screw conveyor. The auger drill can also be used to excavate or drill through material.

**CCTV** - Closed Circuit Television - The use of video cameras to visually inspect the installation. Often used where manual entry is not feasible or possible.

**CIPP** - Cured-in-place pipe. The process involves the insertion, pulling in and inflation of a resin-impregnated fabric tube into an existing pipe by the use of water or air inversion.

**Client** - Person or company requiring the Works to be undertaken.

**Contractor** - Person, establishment, or company undertaking the Works required.

**Cutter Head** - The part of the MTBM that is responsible for excavation. Contains the cutter face, which is responsible for breaking, cutting and other wise removing earth from the desired bore path.

**Entry Chamber** - Also called insertion, thrust, drive or launching pit. A point in the ground where the all TT machine is setup to start the TT process.

**EPBM -** Earth Pressure Balance Machine. Mechanized excavating equipment similar to the MTBM which uses excavated spoil to pressurise the machine and balance the forces experienced upon it during excavation.

**Exit Chamber** - Also called reception pit. An area where the TT machine complete it TT process.

**Feasibility Study** - Preliminary design and study to ascertain whether commencing the works would prove logical.

**GBR** - Geotechnical Baseline Report for all anticipated conditions.

**Guideline** - General information about an item, process, method, material, system or service.

**HDD** - Horizontal Directional Drilling. A steerable trenchless method of installing underground pipes, along a prescribed path by using a surface launched drilling rig.

**HDPE** - High Density Polyethylene. A strong, relatively opaque form of polyethylene thermoplastic made from petroleum.

**IPBA** - International Pipe Bursting Association.

**ISTT** - International Society for Trenchless Technology.

**Intermediate Jacking Stations -** A fabricated steel cylinder fitted with hydraulic jacks that is incorporated into a pipeline between two pipe segments. Its function is to distribute the jacking load over the pipe string on long drives.

**MT** - Microtunnelling. Method for installing an underground service conduit to a high accuracy using a Microtunnelling machine. Generally guided by a laser. Most often used for the installation of gravity flow systems- i.e. sewer and stormwater or for other services where high accuracy is required.

**MTBM** - Microtunnelling Boring Machine. Mechanized excavating equipment that is remotely operated, steerable, connected to and thrust forward by the jacking system. The common range of pipe diameter are from 600mm to 1200mm.

**NUCA TAG** - National Utility Contractors Association Trenchless Assessment Guide.

**Operator** - Suitably trained or qualified person who operates machinery, an instrument, or other equipment.

**PB** - Pipe Bursting. It is ann In-Line pipe replacement technology that is used to replace utilities. A cone-shape tool is inserted into the existing pipe and forced through, fracturing the pipe and pushing its fragments into the surrounding soil.

**Pipe Jacking –** Is a method of installing pipe utilizing a thrust system at the entry shaft. The thrust system is normally powered by hydraulic cylinders. Pipe jacking is use for a number of different pipe formats including concrete sewers.

**PTMT** - Pilot Tube Microtunneling. A MT method that involves drilling a pilot bore prior to tunnel excavation.

**Risk Management Assessment** - The overall process of identifying all the risks to and from an activity and assessing the potential impact of each risk.

**Shield** - Often comprised of circular lining and the cutter head, protects the internal workings of the MTBM from ground water, spoil and debris. Sometimes referred to as part of the MTBM, the shield is pushed forward through the intended bore path by the jacked pipe.

**Shield** – the shield is a cylindrical lining user to protect the internal components of the MTBM. The front face of the shield can either be open or be equipped with a closed cutter head. The shield is thrust forward by the action of the pipe jacking machine, in the case of the MTBM. In the case of TBM, the shield is thrust forward by the TBM itself.

**Specification** - A document that specifies, in a complete, precise, verifiable manner, the requirements, design, behaviour, or other characteristics of a system, component, product, result, or service and, often, the procedures for determining whether these provisions have been satisfied.

**Spoil -** Material removed in the course of an excavation or drilling process.

**Standard -** A document that provides uniform technical criteria, methods and processes to establishes a norm.

**TT - Trenchless Technology**. Technology for installing pipelines or creating bores without the need of full surface excavation.

**Vacuum Extraction -** The use of high flow, high pressure air produced by a vacuum power unit to transport cuttings from the excavation face to the ground surface.

**Work -** The project or task to be completed by the Contractor on behalf of the Client.

## 3.0 INTRODUCTION

This Guideline has integrated the necessary background information on three types of Trenchless Technology methods to assist industry users to gain the knowledge in the following fields:

- Horizontal Directional Drilling,
- Pipe Bursting,
- Microtunnelling and Pipe Jacking.

The objective of this Guideline is to assist Trenchless Technology users to understand the possible benefits of selecting the applicable method for their project.

There are four sections in this Guideline. The first three sections provide comprehensive information outlining, the background of Trenchless Technology (HDD, PB, MT&PJ), process, methods of available application, its capabilities and limitations. The last section outlines the importance of some front-end engineering considerations encountered by users in the field of Trenchless Technology.

A decision matrix is summarised in figure 3.1 to assist users through this Guideline. The decision matrix details a step by step process that assists the users which Trenchless Technology could benefit their project.

This decision matrix establishes the starting point for each selection process and prompts the user to review the Standards and Specification applicable to the referral Trenchless Technology method selected. Using these processes, the user will be able to determine which method, or combination of Trenchless Technology methods that are suitable.

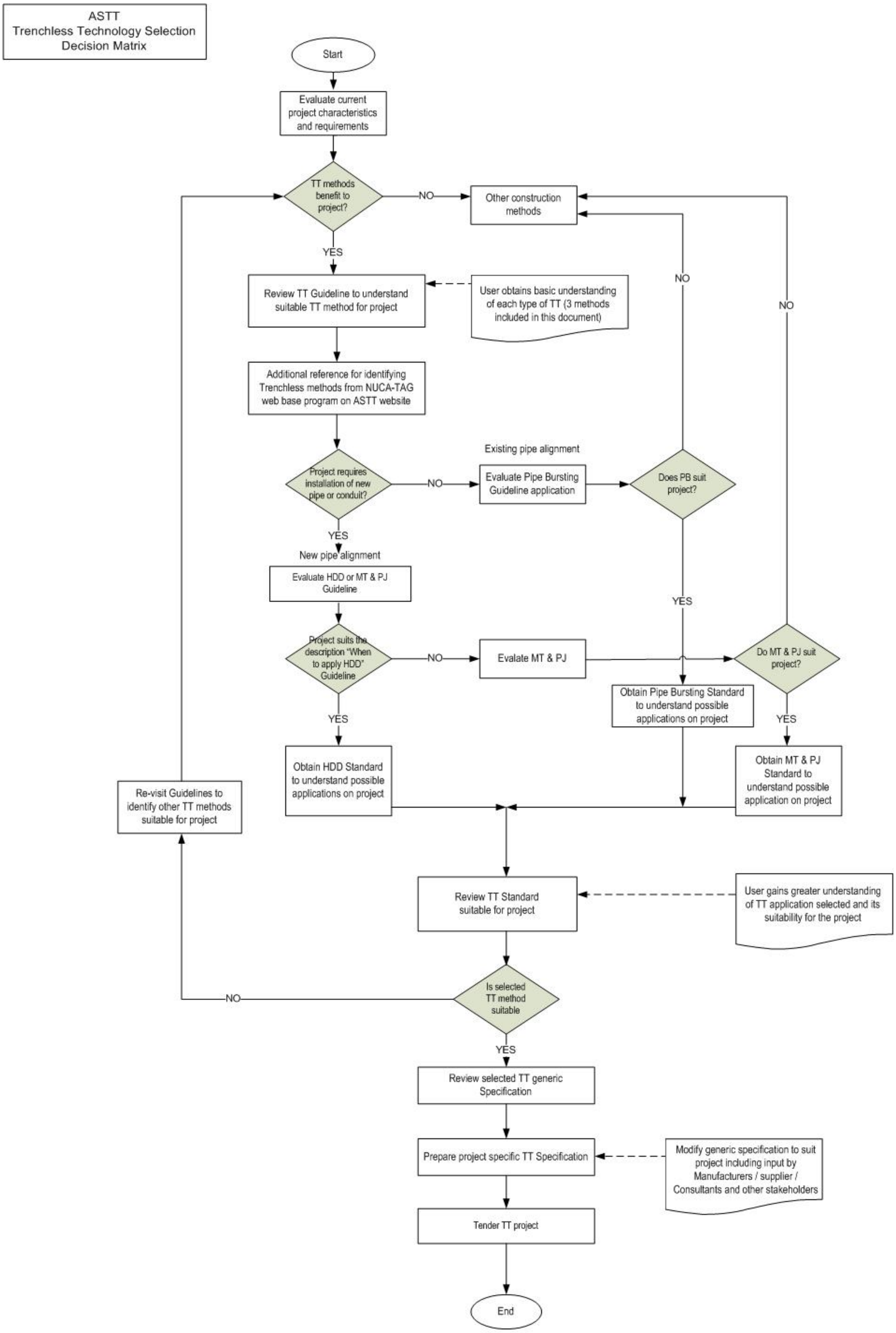



FIGURE 3.1: Trenchelss Technology Decision Matrix

# 4.0 HORIZONTIAL DIRECTIONAL DRILLING GUIDELINE

Horizontal Directional Drilling (HDD) is a trenchless excavation method originated in the late 1960's by merging technologies prominent in the water wells and utilities industry. It is use to install new pipeline such as sewer, water and other utilities in ground. It has minimum working area and is very effective in areas where trenching is faced with difficulties.

HDD involves drilling along a desired pathway while simultaneously inserting a pipe into the new borehole. The HDD process is completed in three parts, the first is the drilling of a pilot hole along the proposed centreline and the second is the enlarging of the hole with a reamer. The third step is where the new pipe is installed behind the reamer during the last pass of the reaming process.

In any HDD works, a major component of the drilling activities is the drilling fluid. In many instances and particularly in cases where the new pipe diameter is much larger than the pilot hole, it is vitally important that the correct amount and mixtures of drilling fluid is used. The use of drilling fluid helps to prevent the collapse of the bore path, assists in the removal of cutting material produced by the drilling process, and reduces friction during the process of pullback of the new pipe.

Ensuring the correct diameter of the borehole to install the proposed new pipe may require more than one ream. The number of required reaming passes may also be affected by geographical conditions. On the final pass with the reamer, the new pipe is attached to the reamer and pulled back through the borehole from the exit point to the drill rig.

HDD operations are performed using a drill rig situated on the surface (Figure 4.1). They do not require a huge entry pit. Generally only a small slurry containment pit is require in order to commence the HDD process. The self-contained rig usually consists of a powered rack which provides the thrust force to push the drill string into the ground and acts as a storage area for the additional drill rod require during the drilling process. Once the drill rod is added onto the drill string, it pushes the drill into the ground, and a motor and drive system to provide the rotation of the drill string. To provide the reaction force, the drill rig is securely fastened to the ground before drilling commences. The desired directional path is followed and tracked using a guiding or tracking system. The most common guiding and tracking systems are the walkover, and the hard wire steering system. Both of these systems are discussed in Section 4.3.

**FIGURE 4.1: DRILL RIG (Picture Courtesy of UAE)**

HDD is an attractive option for installing pipelines under bodies of water, access restricted, protected areas, or urban spaces where the social and environmental costs of construction (and destruction) of surface are too high. High initial HDD capital costs due to the purchase of the drill rig, mud recycle system, and other possible require equipment for the HDD project will be offset by lower labour costs and faster completion of works when compared to conventional open trenching methods.

## 4.1 HDD Process

The HDD process requires the use of a drill rig, drilling head, drilling fluid, a reaming head, drill rods and a range of ancillary equipment, including pulling heads, swivel connectors, and a pipe roller. Although implementation of HDD does not require an entry pit at the entry point when the HDD machine penetrates into the ground, setting up a small containment area within the area where the drill penetrate the ground would be ideal to contain the drilling fluid during the drilling process. An exit pit is requires to contain drill slurry for collection prior to recycling or removal. From the drill rig, the drilling head navigates through the ground along the desired bore path and past any obstructions. The cuttings are removed during the drilling process with a drilling fluid comprised of Bentonite and sometimes a composition of water and polymer. This drilling fluid stabilises and lubricates the borehole as well as acting as a cooling agent for the drill head and embedded location transmitter.

Although the drilling fluid is the method in the HDD process that help keeps the borehole open and prevent collapse in the drilling process it could harden or cure like grout or cement and equalise with the natural ground conditions to seal the borehole if the drilling process stop over a period of over 24 hours.

A commonly used HDD guidance system utilises a transmitter, located in the drill head, receiver, and remote monitor to transmit and receive signals along the designated drill path, from the surface entry point to the final exit point. This is called the “walk-over” system. This monitoring process allows the drill head's position, depth and orientation to be determined at all times. This ensures that the drill string will not collide with any existing utilities while drilling.

Where there is a risk of damage to existing utilities from ground heave, small potholes may be required to be excavated in the vicinity of where HDD bore path and the existing utilities crosses. This effectively relieves the pressure forces on the utilities caused by any ground movement.

## 4.2 HDD Methods

### 4.2.1 Pilot Bore

The HDD process requires the use of a drill rig to drill the pilot borehole from the surface through to an exit pit at the far end. The position of the drill head is monitored by a guidance system, via a transmitter fitted in the drill head. The pilot bore usually ranges from 75mm to 150 mm in diameter. Figure 4.2 below is an illustrated example of a typical pilot bore.

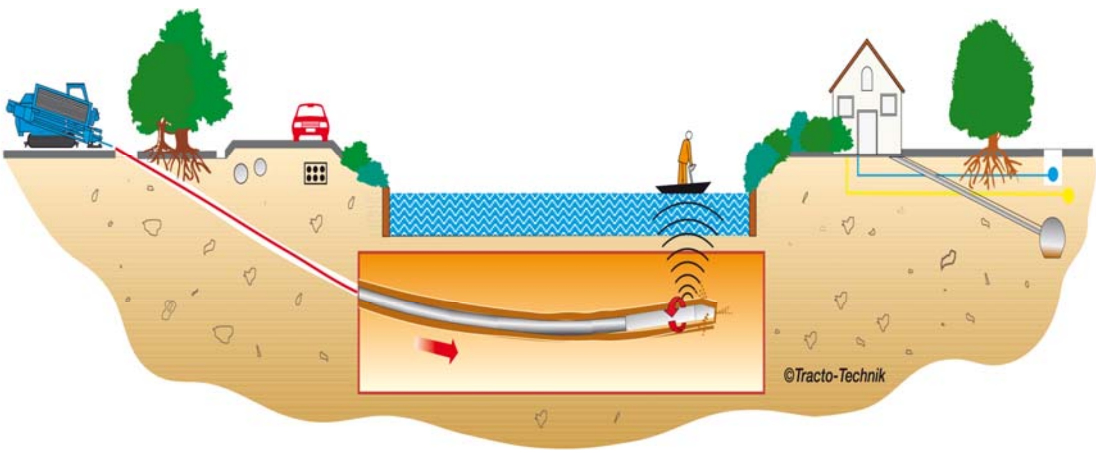



**FIGURE 4.2: GENERAL EXAMPLE OF A PILOT BORE (Graphic Courtesy of TT)**

### 4.2.2 Reaming

After the completion of the pilot borehole, a reaming head is attached to the drill pipe at the exit pit. The reamer is pulled back whilst being rotated through the pilot bore to enlarge the borehole. Due to the thrust and rotational forces required to drive the reaming head it may be impossible to enlarge the borehole to final size in on pass. The forces absorbed by the reaming action are generated by the drill rig and transmitted along the drill string. Excessive forces at the reaming head could result in permanent damage or destruction of the drill string. It may take a number of passes of the reamer before the borehole diameter is sufficient to accommodate the new pipe. Figure 4.3 illustrates an example of a reaming process.

During reaming, drilling fluid is use to remove cutting and reduce friction. Generally, a final reamed borehole of 1.5 times that of the new pipe outer diameter is required.

This allows for the "return" of the drilling fluids, spoils from the new pipe surrounding, and provides room to achieve a safe bending radius of the pipeline.

### 4.2.3 Pullback

The pullback process is carried out once the reaming process has been completed. The new pipe is attached to the rear of the reaming head when the head is in the exit pit.

As the drill string and reamer head is pulled backwards through the borehole it is rotated, as during the reaming process. To avoid rotating the new pipe, the reaming head is connected to the pipe by means of a pulling head and swivel assembly.

The reaming head is used in the borehole during pullback to remove any loose debris in the hole which may prevent the pipe from being successfully pulled back.

This also facilitates the use of drilling fluid which lubricates the process, assisting the pullback of the pipe. The pullback process is continued until the new pipe reaches the drill rig. Figure 4.3 illustrates a typical reaming and pull-back process.

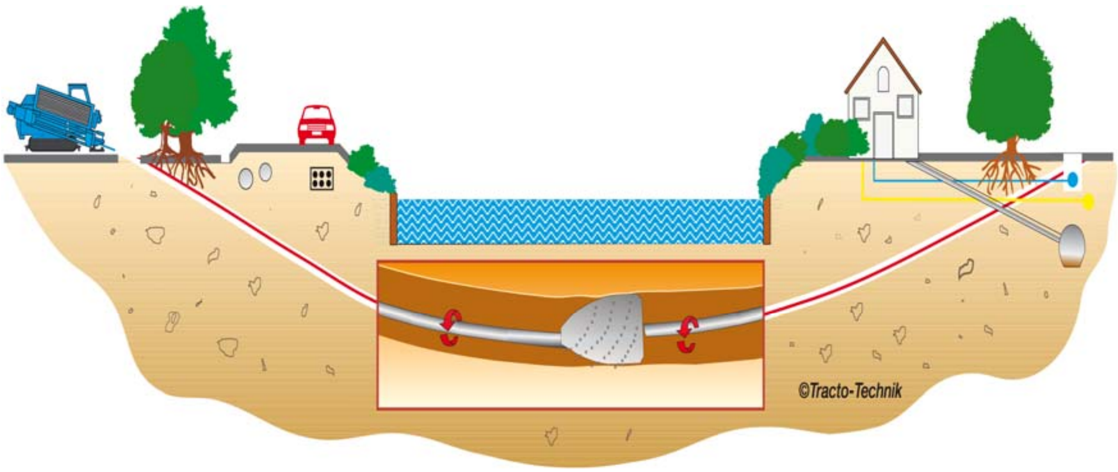



**FIGURE 4.3: GENERAL EXAMPLE OF A REAMING AND PULLBACK SYSTEM (Graphic Courtesy of TT)**

## 4.3 HDD Guidance Systems

Most HDD systems require an accurate guidance system. The most common guidance systems are known as 'walkover' and 'hardwire' systems. Figure 4.4 below is an illustrated example of a typical 'walkover' guidance system.

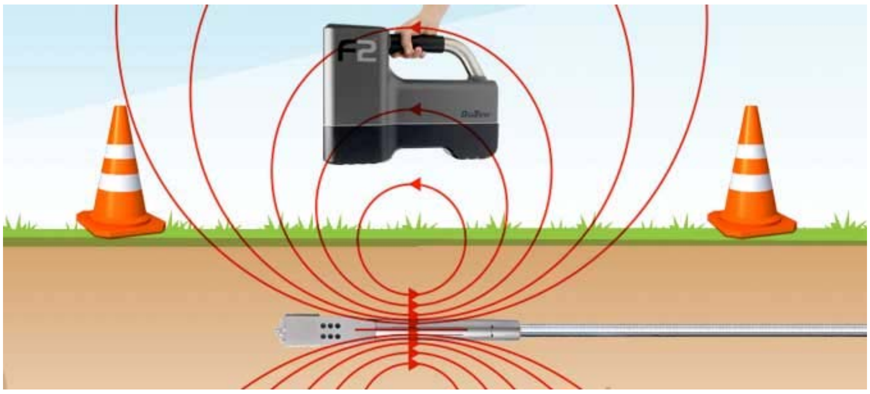


**FIGURE 4.4: GENERAL EXAMPLE OF A WALKOVER GUIDANCE SYSTEM**
**(Graphic Courtesy of Digital Control Incorporated)**

### 4.3.1 Walkover Guidance System

A Walkover system operates with the use of a radio transmitter placed within the drill-pipe (Figure 4.5). The surface walkover receiver picks up the signal transmitted from the drill head in the borehole. Transmitted information, includes drill head location and orientation, beacon battery status and beacon temperature. The system allows the distance between transmitter and receiver to be up to 40m away.

The main limitations of walkover systems is the requirement for the receiver operator to be positioned directly above of the bore. This cannot always be achieved e.g. drilling under a body of water. In circumstances where the route cannot be traversed or the depth exceeds 40m, the hardwire guidance system option should be considered.

**FIGURE 4.5: GENERAL EXAMPLE OF A TRANSMITTER PLACED IN DRILLING PIPE**
**(Picture Courtesy Of Digital Control Incorporated)**

### 4.3.2 Hard Wire Guidance System

The Hardwire guidance system (also called "Wire-line" guidance system) utilises a cable running through the drill string to transmit data from the drill head beacon to the control console in the cab of the drill rig. As such, it overcomes the depth limitation of the walkover system. It also has a higher degree of accuracy as the information sent to the control console is not interrupted by the different ground conditions or the depth of the bore. This system can be used in any environment, providing the beacon is durable and shock and vibration resistant. The disadvantages of the hard-wire system are:

i. Initial capital cost
ii. Reduction in drilling productivity due to signal connections being required at each drill rod change.

## 4.4 When to Apply HDD

HDD is most suitable for the installation of pipelines such as water, sewer, gas and utilities conduits up to 1.2m internal pipe diameter. The HDD drilling process performs well in a range of ground conditions including silt, sand, clay and many solid rock formations. It will face challenges when the ground conditions changes several times during one drilling bore path.

Calculation of the correct pressure and amount of drilling fluid to utilise is another major consideration for HDD projects. The correct amount of drilling fluid can prevent a number of potential risks, including collapse of the bore hole – problems such as loss of slurry and improper slurry. Other potential risks such as , water ingress, and surface heaving (caused by excessive drilling fluid pressure), incorrect surface depth (too shallow), or pulling the reamer through faster than the recommend machine pulling rate. Those can which can be minimised with an effective drilling and drilling fluids plan.

### 4.4.1 Capabilities

As indicated HDD is limited to a maximum reaming of pipeline with internal diameter of 1.2m. Alternative TT methods have been developed that normally provide a better success rate in installing larger pipe diameters, in differing and deeper ground conditions, e.g. MT & PJ. TT methods are the drive length that HDD can achieve is the longest of any unmanned trenchless method.

Excellent steering capabilities give HDD a major advantage over other TT methods. When obstacles are encountered in the drilling process, the drill head can be retracted and re-routed around the obstacle.

Since a HDD process can be launched from the ground surface and requires a relatively shallow containment chamber, the set up time and project costs can be considerably reduced. Additionally, unlike other TT processes, HDD is a continuous drill method, which facilitates further reductions of time and costs. Figure 4.6 illustrate a 477m bore distance under a harbour canal in Germany.

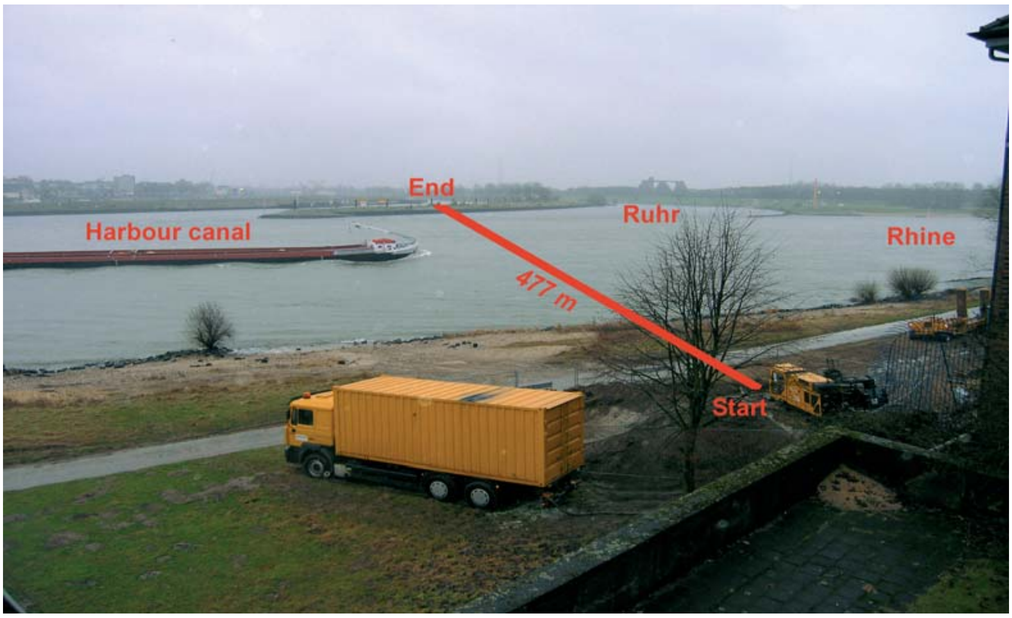



**FIGURE 4.6: HDD UNDER CANAL**

### 4.4.2 Limitations

HDD does not perform well in locations with gravel soils, boulders, and compact stone layers. The changing ground formations and mixed soils create difficulty in controlling the drill direction (e.g. Sandy soil or limestone layers), due to voids within the soil mixture. There is also the possibility of loss of drilling fluid pressure.

Coarse-grained soils, or soils that contain boulders or cobbles, encountered during the HDD process, can result in an increase in the overall project duration and cost. When these type of situations are encountered, the HDD machine might not be able to drill through the ground. This could result in delays due to requiring additional ground investigation to further clarify the type of drill head required. Another potential delay that could be experienced is frac-out in between these cobbles or boulders due to loss of drilling fluids.

A specific HDD limitation that has been encountered is installing gravity sewer line because HDD has challenges on gradient control during the process. Thorough site investigation of the proposed drill path has proved to be a major reason for, and key to, successful HDD projects.

# 5.0 MICROTUNNELLING AND PIPE JACKING GUIDELINE

Microtunnelling (MT) and Pipe Jacking (PJ) are Trenchless Technologies normally utilised to install below ground pipes such as ducts and culverts under protected sites and busy urban areas. It is a very popular option for installing pipelines in a wide range of soil conditions.. It is used in areas where open excavation would prove too costly, socially unacceptable (traffic diversions and route blockages), economically damaging to local business, and or environmentally unacceptable (surface damage causing distress to flora and fauna). It can also be considered when installing under railroad and highways. MT and PJ also require less labour than conventional open trenching methods and therefore can be a very cost effective solution. It achieves tolerances of +/- 25mm in line and grade.

## Microtunnelling

MT is defined as a remotely controlled technique that provides continuous support to the excavation face that does not require personnel entry into the tunnel[1]. The tunnel boring machine, must be accessed from an access shaft if required, e.g. for changing cutter and facilitate maintenance.

Microtunnelling requires that a tunnel is bored. This is normally done by a MTBM. Pipes are jacked to an exit shaft by means of a jacking frame. At the same time, ground displacement or full-face excavation of the tunnel face is carried out. The minimum depth of cover to the pipe being installed using the MT process is normally 2 times the outer diameter of the new pipe being installed. Figure 5.1 show an example of an MTBM.


**FIGURE 5.1: MICROTUNNEL BORING MACHINE (Courtesy of Akkerman)**

Five independent systems are incorporated into a Microtunnelling system. They are as follows:

(1) Microtunnelling Boring Machine (MTBM)

(2) Jacking and intermediate Jacking system

(3) Spoil removal system

(4) Laser guidance and remote control system

(5) Pipe lubrication system

Three types of spoil removal will be discussed in this guideline, they are the Auger system, Slurry system with Vacuum extraction, and Pilot Tube MT system (PTMT).

**Pipe Jacking**

Pipe Jacking is a reference to using powerful hydraulic jacks to push specifically designed pipes through the ground behind a shield at the same time as excavation is taking place within the shield. MT and PJ is achieved with the use of a remotely controlled MTBM. These methods provide a flexible, structural, watertight, finished pipeline as the tunnel is excavated.

Shields are open to the face where mechanical excavation is applied. Manual excavation is done in an open hand shield, whilst mechanical excavation is done using either a cutter boom shield (cutter installed in an open face shield) or a backacter shield (backacter installed in an open face shield).

Due to operator conditions and occupational health and safety regulations, open hand shields are limited to a minimum diameter of 1.2m and can only be used on fairly short drive lengths. Suitable equipment, work methods and practices must be instigated to limit exposure of workers to noise and vibration, and other hazards. These must be identified in a Risk Assessment, and mitigated prior to commencement of any Works.

## 5.1 MT& PJ Process

### 5.1.1 Microtunnelling Process

All MT processes utilizes a Microtunnelling Boring Machine (MTBM), which is essentially a combination of, a rotating cutting head and shield. It also includes a entry and exit shaft, jacking system, automated spoil transportation system, guidance and direction control systems and pipes to be jacked into position (jacking pipes). Microtunnelling is considered as a cyclic jacking process.

MT applications range in diameter from 250mm to 3500mm, with the most common applications being in the range of 600mm to 1200mm.

The Microtunnelling process and spoil removing system are discussed as follows.

- Auger system: an auger chain installed within the jacked pipe transports the spoils to a muck skip under the jacking frame. When the mud skip is full, the operation is paused to allow the skip to be hoisted to the surface and emptied. This is normally done between pipe changes.
- Slurry System: In situations where difficult ground conditions are encountered, or when there are high groundwater heads, recirculating slurry systems may be utilised to remove the spoil. The slurry is a mix of Bentonite and water sometimes including for a polymer, in which the excavated spoil is suspended. It is then pumped out via a system of pipes in the jacked pipe to a solids separation system, at which point the spoil is filtered and separated from the slurry. The filtered slurry is subsequently recirculated and reused within the slurry system.[2]
- Vacuum: Vacuum extraction can be used in ground conditions ranging from clayey sands to rock. It cannot be used in soft soils such as non-cohesive silts and sands below the water table.
- Pilot tube Microtunnelling (PTMT) utilises the same steering head used for Horizontal Directional Drilling (HDD). Using a 360° rotatable shoe-shaped drill head to provide the resultant force from the soil makes the pipe string highly steerable and accurate. The drill pipe is used as an alignment guide for the product pipe after the drilling of the pilot tube has been completed. The displaced soil is excavated through the product pipe using simple auger systems.[3]

  PTMT has relatively lower capital costs than other MT methods. This method can work from very small access shafts, e.g. the existing access chambers as the entry and exit chambers. Accurate alignments of +/- 25 mm are a achievable by the drill pipe. PTMT systems can be used for installing pipe diameters from 150mm to 600mm over lengths of up to 150m.[3]

Pipelines installed using MT achieve a high degree of accuracy by the utilisation of laser and CCTV guidance systems.

Most guidance systems provide data regarding the exact position of the MTBM, the deviations from the designed tunnel axis, as well as the predicted movement tendency of the MTBM. A typical MT guidance system is shown in Figure 5.2. Steering is achieved with the use of steering rams mounted in an articulated joint, normally at the mid point of the MTBM.

A lubrication system reduces the risk of pipe damage on most Microtunnelling works, and is particularly useful for longer pipe drives. The lubricant is applied manually to the exterior of the pipeline during installation to minimize pipe friction and to ensure that the pipe can be installed from the drive shaft to the exit shaft within the safe working load rating of the pipe.

### 5.1.2 Pipe Jacking Process

Pipe Jacking requires similar process to MT. Different types of PJ methods are discussed further in next section of this guideline. The hydraulic/mechanical excavation methods employed are similar to those used in MT.

A thrust wall is constructed at the entry shaft to provide a reaction against the jacking force. Thrust wall design should consider the ground conditions encountered, to provide sufficient reaction to the jacking force. A thrust ring is used to transfer the jacking forces from the cylinders to the pipe to prevent damage to the pipe due to point loading. The thrust force is developed by a pair of hydraulic cylinders acting against the thrust wall.

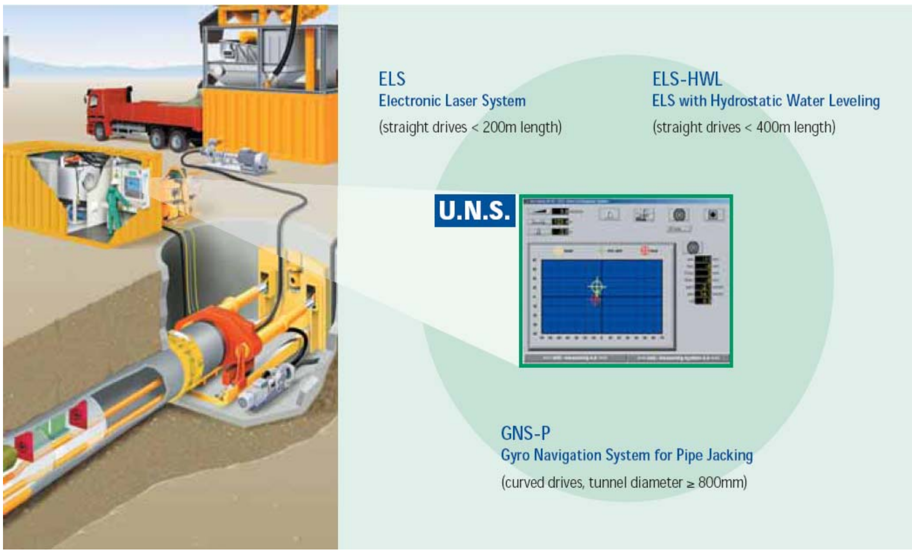



**FIGURE 5.2: TYPICAL MT GUIDANCE SYSTEM (Graphic Courtesy of Herrenknecht)**

**FIGURE 5.3: AN EXAMPLE OF JACKING FRAME (Courtesy of Bradshaw Corp)**

The jacking system, comprises of the hydraulic jacks, a jacking frame and a bench (as seen in figure 5.3). Jacking capacity of up to 1000 tons is common.[2] The frame is designed to provide the level of pressure required and the suggested jacking force (JF) can be estimated by:

$$JF = \pi \times OD \times L \times F ,$$

where[4]

OD = Pipe Outer Diameter (m)

L = Drive Length (m)

F = Friction Factor (tons/$m^2$)

## 5.2 MT& PJ Methods

### 5.2.1 Spoil Removal Method

The three types of MT spoil removal methods outlined below, they are the auger, slurry (with vacuum extraction) and PTMT systems.

#### Auger

The auger method makes use of a large diameter unidirectional auger for excavation.[3] This method also uses helical auger flights rotating in a steel casing to remove spoil back to the drive chamber.[1] The spoil is transferred to a mud skip, usually located under the jacking frame. The slap is emptied at each pipe change.

Auger boring cannot control the pressure at the MT head, nor can it deal with harder, granular soils and high water tables. Auger boring is typically used to install pipelines ranging from 250mm to 1000 mm in diameter up to 150m in length.[3]

Generally, auger type MT is limited to less than 3m below groundwater level.[4] This is to ensure the operation is not affected by the hydrostatic pressure generated by the groundwater.

#### Slurry

The slurry method of soil removal utilises a watertight head at the front of the MTBM to prevent the ingress of soils and liquids. The movement of the slurry is controlled by variable speed pumps and monitored by pressure sensors in the MTBM. The excavated spoil is extruded through the boring face into a mixing chamber where it is combined with a slurry. The slurry is then transported to a solids separation system on the surface.[2] This system allows the slurry to be recycled and reused in the MT process.

The slurry Microtunnelling excavation process can work in high water table conditions and in soft soils (without dewatering or ground treatment being required). The pressure of the slurry is used to balance the groundwater and face pressure. Slurry MT systems can operate for pipelines ranging in diameter from 250mm to 3000 mm and can be installed to distances of over 2500 m.[3]

### Vacuum Extraction

Vacuum extraction for the removal of spoil from the cutting head is used in firm soil ground -clayey sands, clays- to rock. It is not suitable for soft soil below the water table.

All ground water created by the microtunnelling process and in the shaft needs to be managed by recycling, treatment, then on-site or off-site disposal. Drilling in a downhill direction causes the ground water to flow to the face which will need to be managed, as this will affect the spoil removing process.

### Pilot Tube

A number of systems PT exist and some of these specialised systems have the cutter head collapsed inward and withdrawn back through the jacking pipes. In other systems which use mechanical drive rods rather than the jacking pipes to impart the thrust to the MTBM, free-boring is possible in self-supporting ground. Free-boring allows a microtunnel to be bored to a dead-end and the head withdrawn back through the microtunnel thus eliminating the need for an exit shaft.

Shafts always need to be specifically designed and built, based on the MTBM selected. Different methods of constructing the shafts exist, including sheets and shoring, trench boxes, driven sheet piles, and linear plates.

If in areas of high ground water, for geotechnical or economic reasons, dewatering or grouting is not feasible, then concrete caissons may be used to construct the shaft. Interlocking sheet piles may be used if a deep shaft is required in a high water table environment.

Cantilevered bracing is preferred for shallow shafts. However, for excavation depths of greater than 3m, lateral bracing may be required to prevent the inflow of ground water and to stabilize the shaft walls.[1] The ground condition of the entry shaft should also be taken into consideration to prevent in flow of ground water and MTBM instability. Figure 5.4 shows a typical MT system.

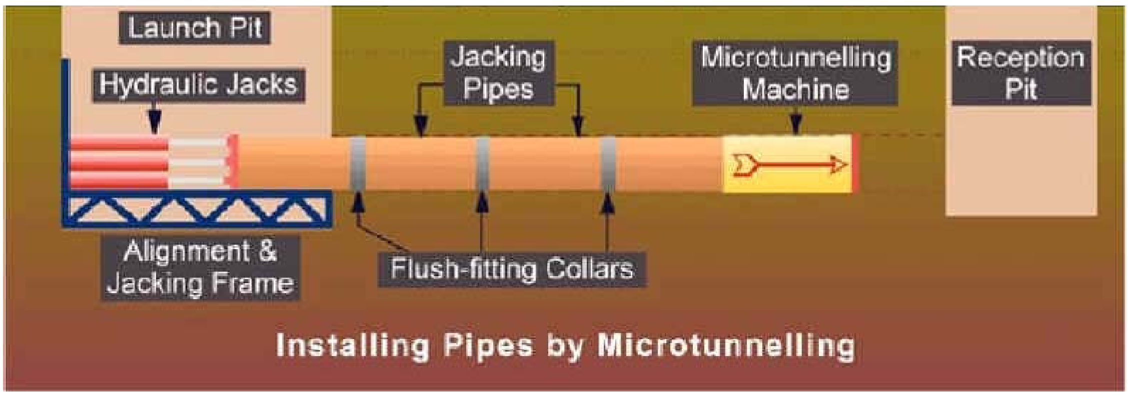
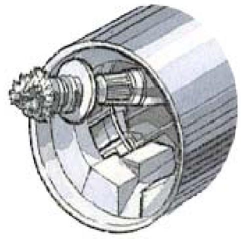



**FIGURE 5.4: TYPICAL ARRANGMENT OF MICROTUNNELLING METHOD (Graphic Courtesy of ISTT)**

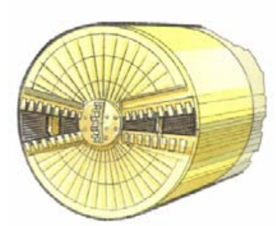
### 5.2.2 Pipe Jacking Method

PJ is a cyclic procedure that uses the thrust force of hydraulic cylinders (jacks) to force the pipe forward through the ground while the front face is excavated. The spoil is transported through the inside of each pipe to the entry shaft, where it is removed and disposed off. After each pipe segment has been installed, the rods of the jacks are retracted so that another pipe segment can be placed in position for the jacking cycle to begin again.

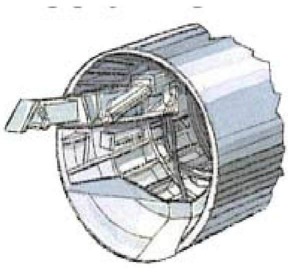
There are five types of PJ excavation methods, Open Hand Shield, Cutter Boom Shield, Earth Pressure Balance (EPB), Backacter Shield, and Microtunnelling Boring Machine (MTBM), as indicated in Figure 5.5. The choice of excavation method selection will depend on the ground conditions support technique.



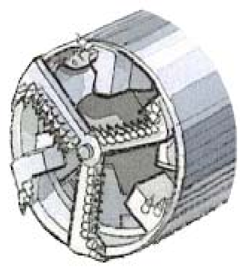
**OPEN FACE CUTTER BOOM**



**EARTH PRESSURE BALANCE MACHINE**



**BACKACTER**



**TUNNEL BORING MACHINE**

**FIGURE 5.5: PIPE JACKING EXCAVATION METHODS**

| SOIL EXCAVATION METHODS | METHODS OF SPOIL REMOVAL |
|---|---|
| Open Hand Shield | Auger system |
| Backactor Shield | Slurry and pressure |
| Open face Cutter Boom Shield | Vacuum Extraction |
| Tunnel Boring Machine | Wheeled carts or skips |
| Earth Pressure Balance Machine | Auger system or Belt and Chain conveyors |

**TABLE 5.1: PIPE JACKING EXCAVATION METHOD**

The spoil removal systems listed in table 5.1 function for both MT and PJ systems. The spoil is removed from the back of the cutting head and transported to the entry shaft using one of the methods listed. The spoil is then hoisted to the ground level from the shaft bottom.

### 5.2.3 Excavation Suitability

#### Open Hand Shield

Open Hand Shield must be equipped with at least four steering jacks spaced around the lead pipe. The shield should be of a diameter slightly greater than the outside pipe diameter to allow it to be steered and provide an annulus for lubrication. The aspect ratio of diameter to length of a shield can be critical to its steering ability.

#### Backacter and Cutter Boom Shield

Backacter and cutter boom shields are essentially open face shields with mechanical means of excavation. The backacter shield is suitable in semi-stable to stable soil with high cohesion values. The cutter shield is more suitable in higher strength soils, marls and some rock types. The excavation may proceed with a slight overcut to the shield diameter circumference in firm ground. Alternatively the shield can be used to trim the under excavated face. In loose ground conditions, consideration should be given to the protective hood and ground breasting boards [a1]or sand tables.

#### Earth Pressure Balance

Earth Pressure Balance (EPB), another excavation method used in PJ, excavates by utilising an EPBM. The cutter head is much like the cutter head in the slurry spoil removal method. However, in this process, the chamber in the cutting head is kept full of excavated material under pressure to counter balance the geological pressures encountered at the front of the MTBM. The spoil is transported after excavation via a screw auger and then removed either by a conveyor belt system, which transports the spoil from the head to the muck skip, or by a pumping system to the ground level.[3] Coarse granular soils may present problems in maintaining a seal in the rising auger flights which in turn may reduce the effectiveness of pressure and groundwater control. For this reason, the EPB system is best suited for fine cohesive soils and relatively low groundwater heads.[3] EPB MT pipelines can range in diameter from 250mm to 3000 mm and can be installed to distances of over 2500 m.

## 5.3 When to Apply MT & PJ

Due to the use of guidance and control systems (fitted in the shield), Microtunnelling and Pipe Jacking is suitable for installations where high accuracy is required in the line and level of the pipeline.

Typical fields of application include sewage and drainage lines, gas and water mains, oil pipelines, electricity and telecommunications cable installation, and culverts. The technique is capable of negotiating obstacles such as roads, railways, rivers and buildings. Table 5.2 shows the general assessment of MT & PJ trenchless methods against different soil types.

For any MT and PJ process, the correct pipe selection is critical. The ultimate success and quality of the work is largely affected by the choice of pipe. The jacked pipes require high strength and stiffness to be able to withstand the drive forces encountered. The pipes form a continuous string in the ground, which forms the final pipeline. [5]

There are very limited repair options for non-man entry pipes, if the pipe cracks or fails during the installation process. In the case of a pipe failure near the beginning of the pipe string, additional sections may be able to be added and jacked until the failed pipe can be removed from the exit shaft. This may not be the preferred solution in all cases as it depends on the position of the failed pipe. In these cases, other methods of replacement may be used. (Such as excavation at point of failure and replacement?)

**TABLE 5.2: GENERAL ASSESSMENT OF MT&PJ TRENCHLESS METHODS AGAINST TYPICAL SOIL AND ROCK TYPES[3]**

| PARAMETER | PIPE JACKING | MT AUGER | MT SLURRY | MT VACUUM EXTRACTION | PILOT TUBE |
|---|---|---|---|---|---|
| Hard rock | Possible | No | Possible | Yes | No |
| Soft rock | Possible | No | Yes | Yes | No |
| Hard Clay | Yes | Yes | Yes | Yes | No |
| Soft Soils | Possible | Possible | Yes | Possible | Yes |
| Sand & Gravel | Possible | No | Yes | Possible | No |
| Sand | Possible | Yes | Yes | Possible | Yes |
| Cobbles/ boulders | Possible | No | Possible | No | No |
| Obstruction | Possible | No | Possible | Possible | No |
| Below water table | Possible | No | Yes | No | Possible |

Note: Possible - Indicates that the method may be suitable in specific circumstances but requires further investigation.

### 5.3.1 Capabilities

Microtunnelling and pipe jacking is a versatile technique that can achieve a very high degree of alignment accuracy (usually with a deviation of less than 20mm over 100m)[4] and gradient. Many MT methods have been designed that are able to deal with a variety of ground conditions. The boring heads can be designed to crush boulders with a diameter of up to 20% of the machine diameter and for tunnelling through hard rock (usually with the addition of drag bits, button cutters or disc cutters).[4]

Microtunnelling and pipe jacking is often a relatively quick process compared to open trench, thereby reducing associated labour costs and personnel risks. Unlike standard trenching methods, a large increase in depth typically only results in small increases in relative cost. The product pipe can be jacked directly without the need for a separate casing pipe,[2] further reducing equipment and installation costs. MT[a2] is economically feasible if the average depth of the pipe exceeds 6m, or if the depth of cover is greater than 1.5 m and the depth of cover to pipe diameter ratio is 3:1 or greater.[4]

### 5.3.2 Limitation

MT & PJ methods often have the following limitations:

- Higher[a3] initial capital cost.
- Can have difficulties in soils containing boulders with sizes greater than 20% of machine diameter due to the liability to crush them.
- MT is unable to make rapid changes in alignment or level.[6] [a4]
- Auger type MT machines are usually limited to tunnelling less than 3m below ground water levels[4]. [a5]

# 6.0 PIPE BURSTING GUIDELINE [a6]

Pipe bursting (PB) is a trenchless method/process which is used to replace defective or under capacity pipelines utilising the original pipe alignment.

The process uses a bursting head to crack the defective installed pipe and displace the cracked pipe outwards into the surrounding soil. A new replacement pipe of the same or larger diameter is simultaneously pulled in behind the bursting head. Some PB process such as Expandit, TenBusch, and Hydros also involved pulling and pushing the new pipe in place during the bursting process. A typical example of a PB process is shown graphically in Figure 6.1.

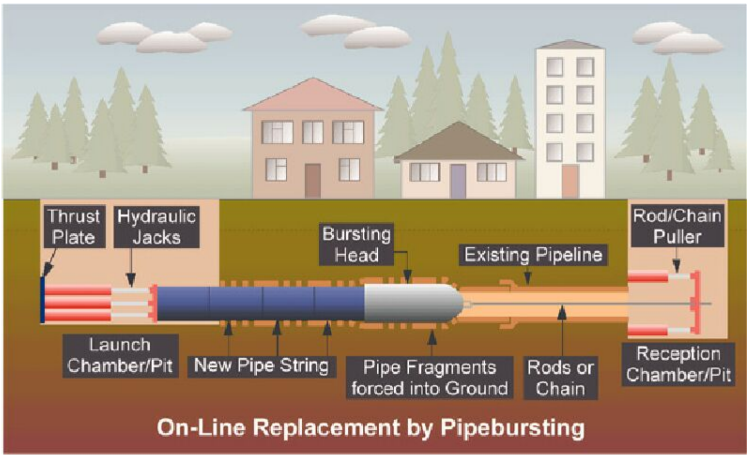



**FIGURE 6.1: TYPICAL EXAMPLE OF PIPE BURSTING PROCESS (Courtesy ofASTT)**

## 6.1 PB Process

The main components involved in a pipe bursting operation are:

- Winch or hydraulic pulling assembly,
- Hydraulic jacking unit (not always required),
- Guide (cable, rod, chain) in held in tension,
- Bursting head and,
- Replacement pipes.

The general process for pipe bursting requires the inserting of a guide cable, rod or chain from an excavated exit chamber, through the installed defective pipe, to an excavated entry chamber, see (Figure 6.2). In addition to the entry and exit chambers, access chambers are also excavated at locations where The pipe will crosses other utilities point. These are used to facilitate the monitoring of the pipe bursting process.

A winch is installed at the exit chamber that is used to pull in the guide cable and attachments from the entry chamber. In certain applications (describe[a7]), the guiding cable is replaced by rods or chains. The guide cable and the bursting head is pulled back to the exit chamber, dragging the replacement pipe into position. In the process the original pipe is burst and the pipe fragments are forced outward into the surrounding soil by the bursting head.

The bursting head, which is bigger in diameter than the existing pipe effectively creates a new bore hole following the same alignment as the old pipe.

The most commonly utilised PB methods fall into the following categories and more details of each methods will be described later in this guideline:

(a) Pneumatic bursting.

(b) Hydraulic bursting.

(c) Static bursting.

Additional Pipe Bursting methods, including Pipe Splitting, Pipe Implosion, Pipe Eating, Pipe Ejection and Extraction, and Pipe Reaming, are also used in the industry, although far less frequently. This is due to the fact that the methods are very specialized and the low frequency of situations that require these methods to be use.

The decision on which PB method to use is dependant on the type of installed pipe needing replacement, the actual replacement pipe, and the conditions likely to be encountered in the process. In some situations static bursting is preferred to pneumatic bursting method as it has lower noise emissions and lower impact on the nearby structures.

**FIGURE 6.2: ANOTHER EXAMPLE OF PIPE BURSTING (Picture Courtesy of TT.)**

Bursting head being fed into the pipe at the entry chamber

## 6.2 PB Methods

### 6.2.1 Pneumatic Bursting

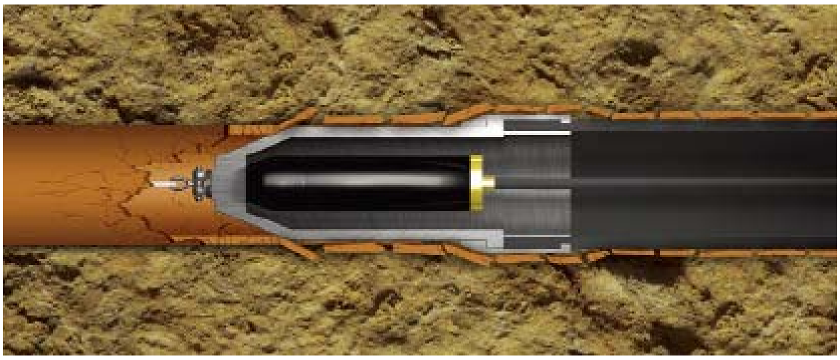


**FIGURE 6.3: AN EXAMPLE PNEUMATIC BURSTING HEAD**
**(Graphic Courtesy of Miller Pipelines)**

The pneumatic pipe bursting method utilises a bursting head that bursts the defective pipe with a horizontal hammering force (Figure 6.3).

The bursting head delivers a horizontal impact load transmitted to the pipe through a tapered cone thereby applying a hoop stress into the pipe, large enough to ensure it to burst, and induces a force in the longitudinal direction causing shear failure. An air compressor supplying the air to generate the hammering forces is setup on the ground level by the entry chamber. The hose supplying the air is connected to the bursting head and connected to the compressor through the new pipe.

The bursting head is pulled through the pipe with a tension cable inserted though the pipe prior to bursting. The tensioned cable ensures that continuous contact between the bursting head and the defective pipe is maintained keeping the new pipe within the alignment of the host pipe during the bursting process.

With PB Phenmatic Bursting, it is the air-powered hammer truces rather than the constant tension of the pulling cable that causes the host pipe to crack.

Operator intervention is minimal in the bursting process. The compressor and winch are set at constant pressure and tension for the entire process.

### 6.2.2 Hydraulic Bursting

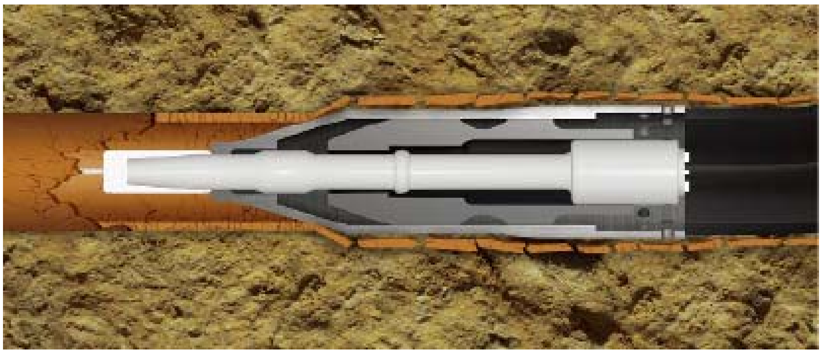


**FIGURE 6.4: EXAMPLE OF AN HYDRAULIC BURSTING HEAD**
**(Graphic Courtesy of Miller Pipelines)**

Hydraulic pipe bursting utilises a bursting head that expands radially under hydraulic pressure to burst the defective installed pipe from the inside (Figure 6.4).

Using an axially mounted hydraulic piston in the hydraulic bursting head, the bursting head expands, causing the pipe to burst. Then it contracts allowing the bursting head to be advanced incrementally, pulled by a tension cable. The replacement pipe is connected to the rear of the bursting head and is pulled along by the tension cable. This process is repeated until the host pipe is eventually replaced with a new pipe.

Hydraulic pipe bursting is powered by a hydraulic power pack on the surface. The hoses are connected to the bursting head through the new pipe via the entry chamber.

### 6.2.3 Static Bursting

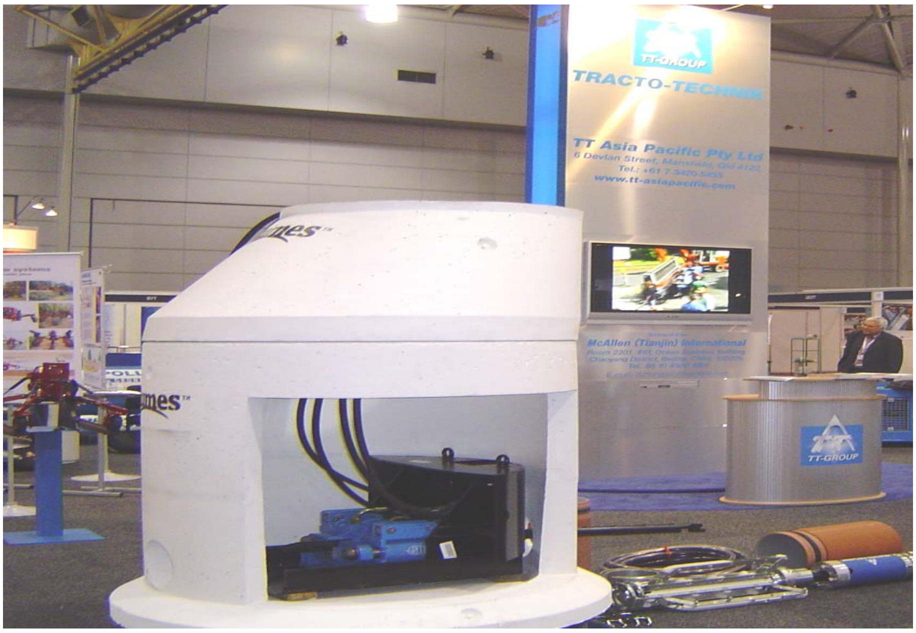



**FIGURE 6.5: STATIC ROD BURSTING SYSTEM (Graphic Courtesy of TT)**

Static pipe bursting does not utilize any additional mechanism inside the bursting head. The forces necessary to burst the pipe are generated using the tensioning device and a tapered bursting head.

A winch or hydraulic system is used on the surface or in the exit chamber to connect to the cable or rod which is used to apply a pulling force to the tapered profile bursting head.

When utilising a rod assembly, bursting rig, the rods are inserted into the defective host pipe one at a time, starting from the exit chamber. Subsequent rods are attached after each pull by the rod and push until the entry chamber is reached. The new pipe is attached to the bursting head in the entry chamber, and pullback is commenced. A pushing system inside the entry chamber assists with bursting the host pipe and pushing in the new pipe. The pull rods are removed one at a time after each bursting pull until the new pipe reaches the exit chamber. The rods used in bursting rigs can be either ladder rods or threaded rods. Ladder rods are connected via quick couplings that ensure a tension and thrust resistant joint. Greasing is not required on ladder rods because they have no threads. Figure 6.5 shows an example of a rod bursting system.

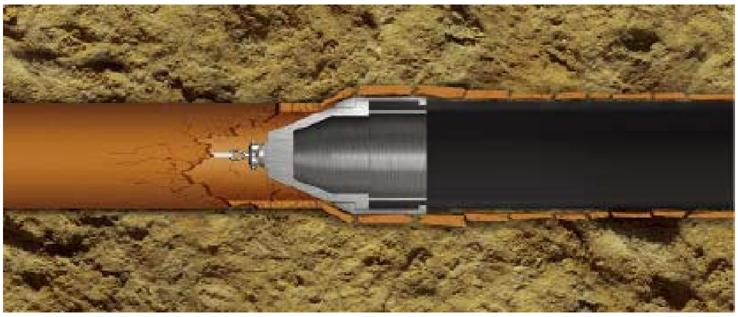


**FIGURE 6.6: STATIC BURSTING HEAD (Graphic Courtesy of Miller Pipelines)**

If a cable and winch system is used, the pulling process continuous. However, this system cannot generate the same pulling forces as rod systems.[7] The rod system is setup with anchors at both the entry and exit chambers, whereas the cable system hydraulic unit is stationed on the surface of the entry chamber without anchoring onto any support. The cut-off for using the cable system is pipe diameters of greater than 250mm or where the pipe is particularly strong- such as....

### 6.2.4 Additional Pipe Bursting Methods

The following are recognized methods: Pipe Splitting, Pipe Implosion, Pipe Eating, Pipe Ejection and Extraction, and Pipe Reaming. They are used only in specific applications or situations.

Some industry pipe bursting methods effectively combine static pipe bursting methods described above.

Some typical combinations are:

- static bursting and splitting
- reaming and splitting

This type of combination is used in particularly difficult applications.

In many pipe bursting operations the use of pipe splitting combined with other pipe bursting methods has been gaining popularity due to increases in bursting productivity.

#### Pipe Splitting

Pipe splitting is a variation of the static bursting method which utilises a bladed head to cut through the wall of the defective pipe (Figure 6.6). This method is used primarily for splitting ductile pipe such as steel or iron. It can also be used for plastic pipes.

**FIGURE 6.6: PIPE SPLITTING (Picture Courtesy of AUI INC)**

## Pipe Implosion

Despite its name, pipe implosion is a variation of the static PB method. The defective pipe is first broken inwards by using a cylinder shaped crushing head, containing steel blades radially extended from its centre. Then the pipe fragments are displaced outwards with a following steel cone bursting tool. The new pipe is pulled in by a rod assembly.

## Pipe Eating

Pipe eating is a modified microtunneling method developed for replacing predominantly concrete sewer pipe. A microtunneling boring machine (MTBM) machine the defective pipe. The debris /spoil is then removed by a circulating slurry system. The new pipe is simultaneously jacked in behind the MTBM. One of the key advantages of pipe existing is that the replacement pipe path is not limited to following the alignment of the existing pipe path, which may not be ideal in line and level. The MTBM machine is capable of “eating” not only the old pipe, but the ground as well.

This method requires a jacking frame to be inserted in the chamber to jack the MTBM and replacement pipeline forward.

The advantages of using this system are that the whole of the old pipe material is removed in the process, and the ability to accurately control the line and level of the new replacement pipe, independently of the old pipe.

## Pipe Ejection and Extraction

Pipe ejection is a modified pipe jacking method. The replacement pipe is used to push the old pipe out. The new pipe is jacked forward in segments pushing against the old pipe, which results in the old pipe being ejected at the exit chamber, where it is broken up removed.

Conversely, pipe extraction replaces pipe by pulling the old pipe out. This requires the use of a rod assembly pulling device situated in the exit chamber, and a rod string fed back to the entry chamber. The pulling device pulls in new replacement segments, which in turn push the old pipe back to the exit chamber. Once the old pipe is back into the exit chamber, it is broken up and removed.

These methods are only applicable for existing pipes with sufficient remaining thrust capacity to withstand the push and pull forces from the jacking machine or pulling device. Before deciding to use these methods are careful analysis of the existing pipe should be ensured that sufficient strength is still available.

### Pipe Reaming

Pipe reaming is a modified HDD process.

A drill string is inserted through the existing pipe. A reaming head is then attached to the end of the drill string. HDD rig is then used to pull the reaming head back through the old pipe, whilst the reaming head is rotated.

The reaming head has cutting teeth which fragment the pipe. The cutting are carried back with the drilling fluid and removed. The cutting fluid, can either be recycled on the surface in a mud recycling system, or retrieved using a vacuum truck for disposal.

The new pipe, which is attached to the reaming head via a swivel and towing head, is pulled in during the reaming process.

Due to the type of cutters on the reaming head, this technique is limited to plastic and concrete pipeline replacement. It is capable of handling varying ground conditions including rock, concrete encasements, service taps, and collapsed or misaligned pipes.

## 6.3 Which type of Pipe Bursting to Apply

When you have an existing pipe that is deteriorated and requires replacement, PB is a TT method to be considered.

As part of the feasibility study, the pipe condition must be determined prior to the commencement of any PB procedure. If the existing pipe has 1 section or number of sections collapsed, then most type of bursting procedures will not be suitable or possible. A pipe condition assessment report will assist in determining the most suitable method of replacing the pipe.

The International Pipe Bursting Association (IPBA) categorizes PB works into three classifications of difficulty. This is shown in Table 6.1.  If the combinations of the selected parameters fall into more than one classification, then, the overall classification of the work will be governed by the highest.

If the new pipe is significantly larger in diameter than the existing pipe, the replacement procedure may be considered too difficult or risky. A TT standard industry practice for PB recommends that upsizing of between 0% and 25% is most commonly considered in PB Works.

| | PARAMETERS | | | |
|---|---|---|---|---|
| **CLASSIFICATION** | **DEPTH OF PIPE (M)** | **EXISTING PIPE DIAMETER** | **NEW PIPE DIAMETER OPTIONS** | **BURST LENGTH (M)** |
| A - Routine | < 4 | DN100 to DN300 | Size for size to 1 up size | < 100 |
| B - Challenging to Moderately Difficult | 4 to 6 | DN300 to DN500 | 2 up size | 100 to 150 |
| C - Difficult to Extremely Difficult | > 6 | DN500 to DN900 | 3 or more up sizes | > 150 |

**TABLE 6.1: GENERAL PIPE BURSTING CLASSIFICATIONS[8]**

### 6.3.1 Capabilities

The pipe bursting replacement method is ideal when the pipe quality, performance or durability of repair is more cost effective than installing a new pipe. This also applies to defective pipes that cannot be, rehabilitated by methods such as relining and where the reduction in carrying/pumping capacity can not be tolerated.

Tools, expanders and cutters used during PB work are another area that if not properly planned out could affect the success of the PB work. Table 6.2 shows a list of recommended common PB types and the type of pipe materials can be burst. Factors that could influence the selection of these accessories include new pipe materials type, depth and profile of pipe alignment, jobsite layout, burst length and soil conditions. Table 6.3 indicates typical applications for pipe bursting.

| TYPE OF PIPE | TYPE OF CUTTER | | | | |
|---|---|---|---|---|---|
| | STATIC | | | | PNEUMATIC/ HYDRALIC |
| | ROLLER BLADE | LEAD PIPE BLADE | PLASTIC PIPE BLADE | BLADED BURSTING HEAD | BLADED BURSTING HEAD |
| **Cast Iron Pipe** | ✓ | | | ✓ | ✓ |
| **Ductile Iron Pipe** | ✓ | | | | |
| **Steel Pipes** | ✓ | | | ✓* | ✓* |
| **PE/PP Pipes** | | | ✓ | ✓ | |
| **PVC Pipes** | | | | ✓ | ✓ |
| **Asbestos Cement Pipes** | | | | ✓ | ✓ |
| **Lead Pipes** | | ✓ | | | |
| **Vitrified Clay Pipes** | | | | ✓ | ✓ |
| **Concrete/Reinforced Concrete Pipes** | | | | ✓ | ✓ |
| **Glass Reinforced Plastic Pipes** | ✓ | | | ✓ | ✓ |
| **Brick Pipes** | | | | ✓ | ✓ |

*only thin wall steel pipes without bell and spigot joints

**TABLE 6.2: TYPE OF PIPE CUTTER**

Is pipe bursting applicable?

| PIPELINE TYPE | NOTES / REMARKS |
|---|---|
| Sewers | Yes |
| Gas pipelines | Grooves in the pipe surface must be documented and ventilation must be provided to avoid gas pockets |
| Potable water pipelines | Yes |
| Chemical or industrial pipelines | Yes |
| Pipelines with bends | Bends up to 20 degrees can be accommodated over a certain distance |
| Circular pipes | Yes |
| Noncircular pipes | The new pipe must have a circular shape |
| Pipelines with varying cross sections | The new pipe must have a constant diameter |
| Pipelines with lateral connections | Ensure lateral connections connected properly |
| Pipelines with deformations | Yes |
| Pressure pipelines | Yes |

**TABLE 6.3: PIPE BURSTING APPLICATIONS[2]**

Specialist types of PB application selection require careful consideration on a case-by-case basis.

### 6.3.2 Limitation

Pipe Bursting works well with a wide variety of fracturable pipe materials and over a large range of diameters. General limitations for pipe bursting operations are mentioned:

- A large number of lateral connections on a short length, shallow burced host pipe might prove PB less cost effective compared to open-trench replacement,
- Potential damage to neighbouring utilities and structures. Proper identification and location of the existing utilities and repaired sections of pipe has to be carried out,
- Technical aspects such as inadequate forces to complete the operation.[2]

Existing pipes materials such as ductile iron and steel pose a limitation to the pneumatic PB method.

Unfavourable site conditions for pipe bursting include:

- Saturated expansive soils, or ground containing a number of different soil types,
- Completely collapsed pipe which forms an obstruction,
- Valves, steel clamps or repair bands, point repairs, which forms an obstruction,
- Concrete encasement of the pipe,
- Adjacent pipes or utility lines that are very close to the pipe being replaced. The recommended clearance to parallel pipelines is greater than 3 times the new pipe outside diameter,
- Shallow host pipe, within 1m of the surface cover,
- This is already covered in the other section.

### 6.3.3 Replacement Piping

In pipe bursting projects or gas, portable water and waste water lines, fused lengths of High Density Polyethylene (HDPE) pipe are used.

Hot fusing long segments of pipe together prior to insertion reduces the likelihood of needing to interrupt the bursting process. HDPE also allows pipe insertion into the entry chamber at an angle due to its flexibility.

It is preferable that all pipe joints have a nominally flush exterior profile to ensure less frictional resistance during installation. Recent developments have introduced a special flush-joint for ductile iron pipe, suitable for sewer and potable water applications.

When installing segmented pipe such as steel, concrete, clay or fibreglass, it will be necessary to use a push-pull system to develop the necessary thrust to ? the pipe.

This method requires an additional hydraulic jacking machine in the entry chamber to push the pipe through to the exit chamber. This method prevents the newly installed pipes from being exposed to high tensile forces. It is also recommended that lighter coloured pipe is used to further assist in the inspection after the installation.[10] This can be done by clearer and more obvious in locating the defectives area during CCTV inspection.

Exterior pipe damage assessment is difficult to carry out and detect once installation is completed. Inspection for exterior damage should be carried out prior to installation to ensure the integrity of the pipe. Hydrostatic testing should also be performed prior to installing the pipe to ensure any defects are addressed.

One of the common practice testing technique is to pull out 2 – 7m of pipe and examine it after installation from the receiving chamber . This front section of the pipe tends to receive the most impact and damage from the installation process. And is used as a guide for determing the general condition of the rest of the pipe. Internal of replacement pipe is often carried out by the use of CCTV techniques inspection.[11]

Sections of pipe joined in the insertion chamber should be connected by mechanical coupling, electro fusion coupling or a non-shear restraint coupling. All connections should conform to the manufacturer's specifications. [9]

# 7.0 FRONT END ENGINEERING

## 7.1 Technical Feasibility

### 7.1.1 New Pipe On A New Alignment (HDD, MT&PJ)

Prior to any pipe installation, a feasibility study should be performed to quartify the costs and benefits of installing new pipe using both open cut and TT methods.

A detailed survey of the proposed site conditions including existing ground features and characteristics should be carried out. The survey should be conducted along the proposed alignment centreline to a width of no less than 30m. The conditions encountered play a key part in decisions related to new pipeline installation.

Key characteristics include earth type, stratification and groundwater conditions, as well the existing surface infrastructure, including areas occupied by people. Aerial photographs, can assist greatly with this process.

Consideration of the surface infrastructure is important since sufficient space and area has to be allowed for the TT and ancillary equipment, and the layout of product pipe.

In order for an HDD project to be considered technically feasible, it must be within the current limitations imposed on the process by length of HDD bore, the product pipe diameter, and the maximum thrust that can be applied.[12]

### 7.1.2 New Pipe On An Existing Alignment (PB)

Technical feasibility considerations for PB will be different when compared to HDD, MT&PJ; as the replacement method uses the existing pipeline alignment. Pipe bursting has the main advantage of being able to replace or upsize the existing service lines without compromising the pipe current capacity. Pipe eating is 1 specialised TT replacement method that can modify the grade of the existing pipe and correct unwanted sags in the existing pipe alignment.

In many instances for waterlines, open-cut replacement may be the preferred option as the existing pipeline is often shallow burced. This would make trenching a cheaper process. Waterlines for housing estates include many connections that require individual reconnections which would necessitate many detailed excavations additional to the TT technique, adding to the cost .

However, under many conditions pipe bursting has numerous advantages over the open cut replacement method. Many of the benefits the detailed in the next section.

## 7.2 Economic and Social Feasibility

The economic and social feasibility of a TT installation process should be determined especially in high-density built-up areas. The economic and social costs associated with any construction process also require careful assessment in addition to the standard monetary values comparison. In order to ensure accuracy of comparison, care must be taken to ensure all associated costs with comparative methods are accounted for. An example of this is possible extensive site restoration.

Economic feasibility consideration should be determined by using historical data that is available from past projects.

Most TT installations benefit from low social cost by reducing impact to the environment. Other possible considerations are mobilisation and de-mobilisation, site clean up, and site restoration traffic diversion during operation.

Some challenges will be the multiple disconnection and reconnection of any services or lateral pipes (applies to waterline and gas line) and bypass pumping of flows (applies to wastewater) in the process of any TT works on an existing pipeline replacement.

The HDD installation method is faster than other comparative TT methods when it comes to new pipe installation, and has a smaller “footprint”, due to the reduced need for an entry pit. However it has a higher installation risk. The risk associated with HDD is the possibility of intersecting other utilities or pipelines. HDD is also the most practical (technically feasible) method and low cost installation (economically feasible). This is based on a variety of considerations and conditions, including pipe diameter, crossing length and depth, geotechnical data (and concerns), hydrological and substrate data, project schedule, equipment availability, and other constraints and issues.

Some economic and social benefits to be considered for TT method mentioned in this document include:

- Overall cost savings on reinstatement of all surface infrastructures,
- Social cost benefits by not affecting businesses, residents or customers, and less disruption to surface traffic, business and trade,
- Faster and more efficient process,
- Duration of project and installation processes: (e.g.)

  - pilot bore, pre-reaming and reaming, and pipe pull back,
  - Disconnections and re-connections of services,
  - Constructions of chamber and shaft and
- Damage to pavements, and surface structures;
- Vibration,
- Noise and environmental impact,
- Pipes can be installed at greater depths, thereby avoiding existing shallower utilities and infrastructures,
- Significantly reducing the volume of waste material and spoils created during construction, when compared to the use of trenching techniques,
- A smaller carbon footprint than open cut; less environmental disturbance,
- Accessing otherwise inaccessible subsurface environments, such as areas beneath building, ponds, landfills, roads, runways, wetlands, pipelines, and off-property locations.

## 7.3 Constructability

Construction issues should take into account the pipeline route, crossing location, and chosen crossing method. The pipeline route should make adequate allowances for layout areas (including ancillary equipment), entry and exit points, and suitable access,.Crossing locations with other utilities and pipelines should allow some flexibility for all TT methods.[2] Soil conditions such as densely compacted soils, backfills, soils below the water table and dilatant soils tend to increase the force require of the equipments for the TT operation.

### 7.3.1 New Pipe On A New Alignment

HDD and MT & PJ are suitable methods for installing under roads, rivers, protected habitats and urban areas, due their ability to leave the surface undisturbed. They can also be used under construction sites, as long as appropriate risk assessments have been conducted.

MT process can leave the surface (pipeline alignment) practically undisturbed if enough depth of cover (6m or more) is provided between the MTBM and the surface. As entry and exit shafts require excavation, this may require a significant work area. A big advantage that microtunnelling has over trenching methods is that the worksites are fewer in number and remain stationary. Road traffic and pedestrians do not have to adapt to a different set of road conditions that change on a daily basis.

### 7.3.2 New Pipe On An Existing Alignment

PB is a TT pipe replacement method that utilises the existing pipeline alignment. The re-instatement of lateral service connections must be considered when planning a pipe replacement project for both water and sewer services. The excavation and exposure of these services should be undertaken prior to bursting to prevent damage to the service lines. Identifying existing repair points can also prevent surface heaving and avoid stoppage of the bursting process. For a PB waterline project, a temporary bypass system should be initiated to protect these lateral services and provide continuous water supply to the residents during the duration of the waterline replacement. Damage from heaving should also be taken into consideration by monitoring the bursting process and take precaution at locations where the existing pipe is shallower.

Reconnection of lateral services to the main pipeline must be delayed to allow for HDPE pipe shrinkage due to the pulling force when it was pulled in during the bursting process this is normally for a minimum of 4 hours. After the relaxation period, the replacement pipe will be reconnected and sealed to the access chamber via a smooth watertight joint. Services can then be reconnected to the pipe via means of fusing or compression fit connections.[2] The pipe is ready for operation after inspection and approval as detailed documents (give reference numbers!) in the inspection and testing section of the PB standard and specification.

Entry and exit chambers are usually excavated in the location of either existing access chambers or service connections. Often additional excavation is required as the existing access chamber or service connection chamber will not be large enough to accommodate the PB machine and associated equipment.

## 7.4 Geotechnical Investigation

The geotechnical data report should include for the provisions of AS 1726 – Geotechnical Site Investigations, Geotechnical Data Report (GDR), and Geotechnical Evaluation Report (GER).

A full geotechnical investigation is a critical part in the planning phase for any HDD and MT & PJ undertaking. The scope for this should include a background review, field reconnaissance, field sampling and geophysical surveys, surface borings, samplings and laboratory sieve analyses to identify subsurface conditions.[1] Results should be presented in a geotechnical report which clearly indicates the ground conditions and important physical properties of the soil including, strength, grain size, moisture, compressibility, permeability and plasticity of the proposed alignment, potential size and frequency of boulders, structural characteristics of bedrock formations and strengths, groundwater levels and any artesian conditions present.

It is likely that vibrations resulting from the application of the Pneumatic bursting method may affect adjacent buried pipes or sensitive surface structures. Special measures may need to be taken to protect these, e.g. excavating an access chamber around the existing pipe to relieve the stress during the PB process, and/ or the use of surface movement monitoring devices.

Another consideration is the base soil foundation at the entry chamber. It is critical that the base soil is able to support the weight of the pipe bursting equipment, the bursting force and the product pipe. Ideally, the ground conditions around the pipeline would also be uniform although the length of the alignment.

In the case of variability in materials around the host pipe during the PB process the bursting head will tend to displace towards the lower density materials resulting in a change in the pipe gradient. This is a key consideration if the gradient of the pipe is critical for the installation.

## 7.5 Environmental Impact Assessment

Pipe bursting operations can cause ground movements and vibrations that may damage the environment. An environmental impact assessment study should be conducted if it is believed that this will cause stress or damage to wild life or vegetation.

Environmental issues must be addressed before any TT project commences. Both clients and contractors are seen as liable parties when consequential environmental damages are assessed. All parties should be aware of which federal, state and local laws and regulations tare pertinent to the project.

Environmental impact assessments should be undertaken in the planning stage of the project in situations involving fish habitat impact zones, rare flora or fauna species, heritage sites, critical habitats, archaeological sites, aboriginal landmarks, or nearby residents.

By utilising any TT method of installation, noise, vibration and pollution are minimised compared to trenching. This can significantly reduce the impact on environmentally sensitive areas. Wetlands, public parks, natural habitats, rivers and other bodies of water, such as schools and hospitals. Trenchless methods are able to reduce the amount of material being excavated, transported and imported compared to trenching.

If a slurry excavation method is to be utilised, then prior arrangements for slurry disposal will need to be made, as some landfill sites may not accept waste slurry. A proper procedure for the disposal of the slurry/ soil cuttings mix is required to be established and accepted as part of any TT operation.

Environmental issues that need to be considered should include inadvertent spillage of drilling fluid into the environment.

If, during an HDD and MT&PJ operation, a body of water needs to be crossed, then an aquatic habitat assessment may be require to ensure there is no contamination of the water and to ensure natural wildlife movements/migrations are not disturbed.

Negative effects on vegetation and wildlife can occur from the following:

- Clearing of site vegetation,
- Destruction of natural habitats,
- Leakage of slurry or surface soil upheaval,
- Creation of a layer of clay preventing germination of new plants,
- Change in soil conditions,
- Stress to wild life,
- Direct wild life mortality(death),
- Release of toxic substances using from drilling fluid additives

In a situation when the bursting force is very high or if there is a lack of depth of cover, heaving may occur, resulting in surface deformation. If heaving is experienced, the contractor should reduce the bursting force, or seek other methods of installation.

It is possible to minimise surface heave by drilling a relief bore path adjacent to the new pipe. This allows the bursting path to transfer pressure into the newly drilled borehole. This can prevent damage to the new pipeline during the bursting process.

## 7.6 Risk Management Assessment

A risk management and assessment study should be undertaken and the planned ground works and location of services identified before commencing any TT methods. A risk assessment of potential interferences should be performed if the pipe installation process could affect or interfere with any current or new works.

Suitable geotechnical, environmental and risk analysis studies, work health and safety practise can greatly reduce the risks associated with any project. The majority of construction risks typically stem from a lack of knowledge.

Inadequate planning, inexperienced personnel, insufficient capital, or poor subsurface knowledge can lead to high risk and costs in any construction work. Table 7.1 below incorporates a general list of potential risks that TT operation could encounter. Conditions such as boulders, existing utilities, flooding, groundwater and other obstacles may be detrimental to the selected or preferred TT process.

Pipe-bursting projects commonly face challenges of the bursting head becoming stuck at an unexpected obstruction in or around the pipe due to items such as steel repair clamps, concrete encasements and tree roots. It is recommended that a more powerful and specially designed tool such as cutting blade be attached to the bursting head to offset these difficulties. However, these precautions need to be identified through a risk analysis before undertaking a job.

| POTENTIAL RISK | IMPACT |
|---|---|
| Loss of drilling fluid thru seepage into water body and land. | Varied, depends on volume of fluid that has been lost. Can result in seepage from increased operation friction, and the borehole collapsing, Sediment load and deposition, can affect fish habitat and hydrology as well as downstream water users, additional adverse effects on wildlife, vegetation and land. |
| Collapsed hole and Right-of-way, Washout of cavities and, Surface Heave. | Possible extended area of disturbance duration due to loss of topsoil, Associated Socio-Economic and Environmental costs of damaging the surface. |
| Stuck drill stem, tools becoming unattached | May need to give up drilling, and excavate area if necessary to retrieve equipment. Extended duration of disturbance. |
| Damaged pipe or coating | May need to re-drill. Extended duration of disturbance. |
| Abandonment | Due to Equipment failure, changed/ unforseen ground, due to obstruction. [a8] |
| **Pipe Bursting Risk** | |
| Bursting through curves | Pavement cracking from heaving, disturbance to adjacent utilities, excavation of rescues chamber, Damage to laterals. |
| Large pipe upsize | Detached bursting head, Disturbance to adjacent utilities lines, Pavement heaving. |

**TABLE 7.1: HDD AND MT&PJ CONSTRUCTION RISKS[13]**

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