

# HDD Training



## HDD Construction Process

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# What is HDD



Horizontal Directional Drilling (HDD) is meant to be a convenient method of installing utilities beneath sensitive areas and existing infrastructure without disturbance to the surface. However, HDD is not always necessary or even appropriate in some circumstances.

In essence, HDD is the directional drilling of a small diameter pilot hole from one side of the crossing to the other followed by one or more reaming passes, which enlarge the hole to a size adequate to install the pipeline. Once the hole has been enlarged adequately to accept the pipeline, a prefabricated string of pipe is pulled into the hole using the downhole drill pipe string that was used to ream the hole.

When considering an HDD installation for a project, it is important to consider several aspects that are discussed in more detail later in these training materials. These include ROW/land constraints, minimum required HDD length, sensitive areas, existing infrastructure, subsurface conditions, topography, geologic hazards and permitting requirements.

During the design process, the construction risks associated with the installation must be evaluated and mitigated if necessary by thoughtful design and possibly by special construction procedures.

# HDD History

Horizontal Drilling started in the 1960s to install small diameter utilities in California. At the time there was no true directional control of the drill bit.

Martin Cherrington, who had worked for his father's utility construction company, started his own company, Titan Contractors in 1964 to get into the Horizontal Drilling business.

Cherrington experimented with various ways to control the direction of the drill bit while drilling. Martin had noticed that certain types of drilling tools would naturally climb back to the surface over the course of drilling. By combining this phenomenon with the correct entry angle and drilling techniques he could have some control over the length of the crossing but still no horizontal control.



Titan's most notable Horizontal Drilling project included the installation of 1,530 feet of electrical cable using a 2,000 pound push/pull drill rig with 500 ft-lbs of rotary torque.

# HDD History



In 1971, Cherrington was the first person to utilize downhole drilling tools and survey methods from the oil field with Horizontal Drilling, which is how the term Horizontal *Directional* Drilling was born. The single shot survey method of the time was not ideal because it was time consuming. Therefore, it wasn't used over short enough periods to provide accurate survey. In addition, the tooling of the time still didn't provide adequate direction control of the drill bit such that steering corrections could be made.

It would take a few more years before downhole tools that provided directional control and better downhole survey tools would be developed.

# HDD History

In 1979, Martin Cherrington sold his patent rights to Reading and Bates. Over the next 5 years several other new HDD contractors came into being.

- Berco
- Drilled Crossings
- InArc Drilling, Inc.
- Visser & Smit Hanab

Since HDD was still in it's infancy, contractors had to make their own drill rigs and many of their own tools.

Current HDD contractors like Michels Directional Crossings, Laney, ARB and Mears were started in the mid 80s to early 90s. Several of the current HDD contractors either were spawned as a result of personnel leaving the first few original companies or have personnel that had worked for those early pioneers of the HDD industry.



An early cable operated drill rig from from InArc Drilling

# HDD History



A modern fully hydraulic HDD drill rig with separate drill cab and power unit (hidden behind the drill cab).

As more contractors got into the HDD industry in the 1990s, new technologies were introduced and new ideas were tested and improved upon.

Drill rig carriages were originally operated by cables and the drill rig operator sat on the carriage during operation. Over time the drill rigs were converted over to fully hydraulic operation with the operator working from a separate drill cab adjacent the drill rig.

Downhole survey systems advanced from the single shot method used by Martin Cherrington in 1971 to downhole survey probes that allowed the taking of multiple downhole surveys quickly and frequently during pilot hole operations. Additional survey technologies were developed to allow for a secondary survey system to be utilized in conjunction with the downhole survey probes which greatly increased the accuracy of the survey data.

Downhole tooling also evolved to allow for the drilling of most soil and rock formations.

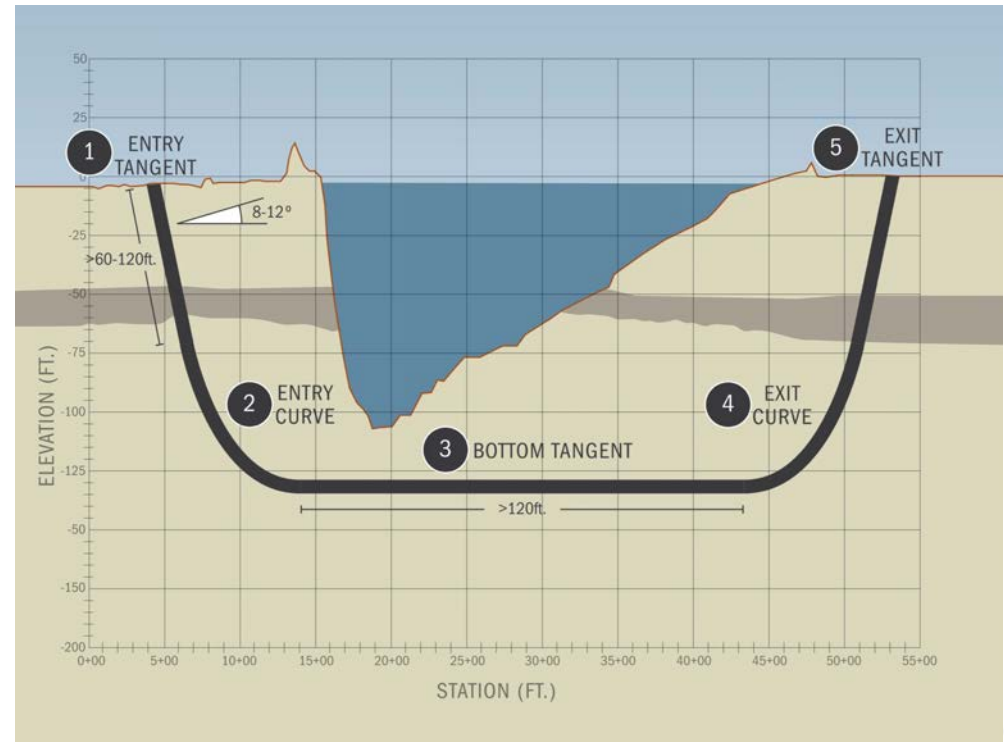
# HDD Geometry

A standard HDD profile is made up of five individual segments. Three straight tangent segments and two vertical curve segments as shown on the figure to the right.

During the design of the HDD geometry, each segment is specified to achieve the necessary depth, length and radius of curvature. Standard design parameters are given below.

- Entry Angle: 10 – 14 degrees
- Exit Angle: 8 – 10 degrees
- Entry Tangent: Minimum of 60 to 90 feet
- Bottom Tangent: Minimum of 90 to 120 feet
- Radius of Curvature (ft.): 100 x pipe diameter in inches
- Minimum Depth of Cover: 30 feet

These are not absolute values and there are many instances when parameters outside of these values may be warranted. When designing a crossing there are many factors that need to be considered in the geometry. This is discussed in more detail in the HDD Design section of this training material.

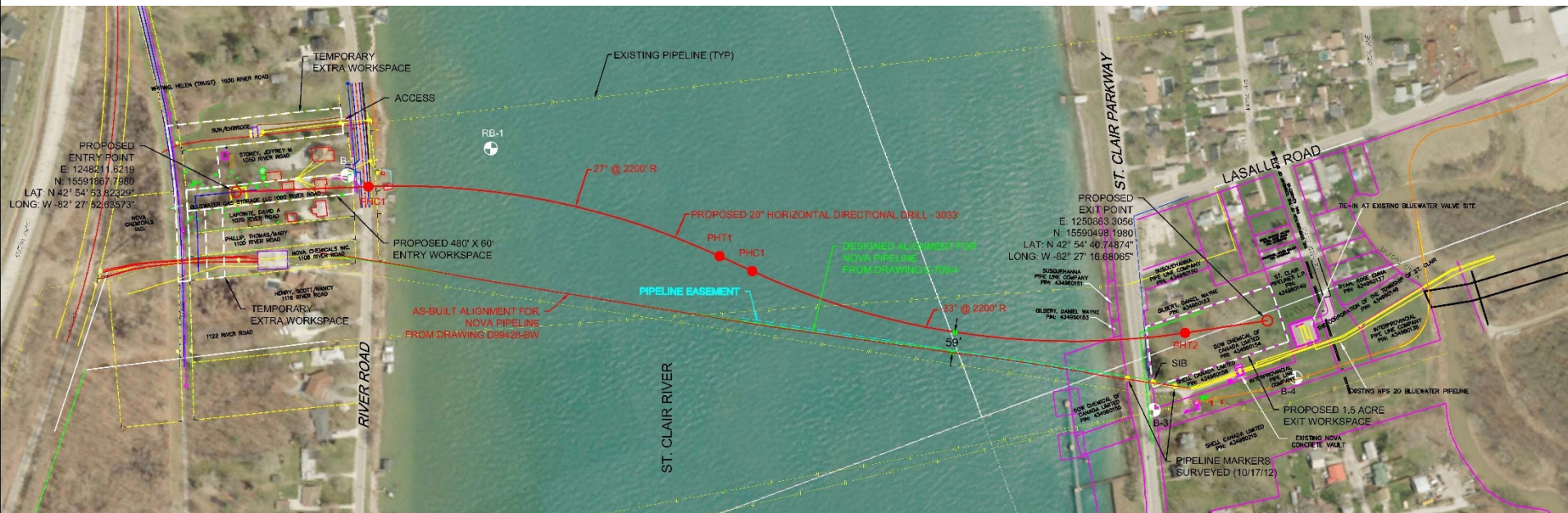


Here is a typical HDD profile.

# HDD Geometry

As a general rule you want to keep the geometry of the HDD alignment and profile as simple as possible to reduce the risk of complications during HDD operations. It is not advisable to add more complexity to the design if it's not necessary.

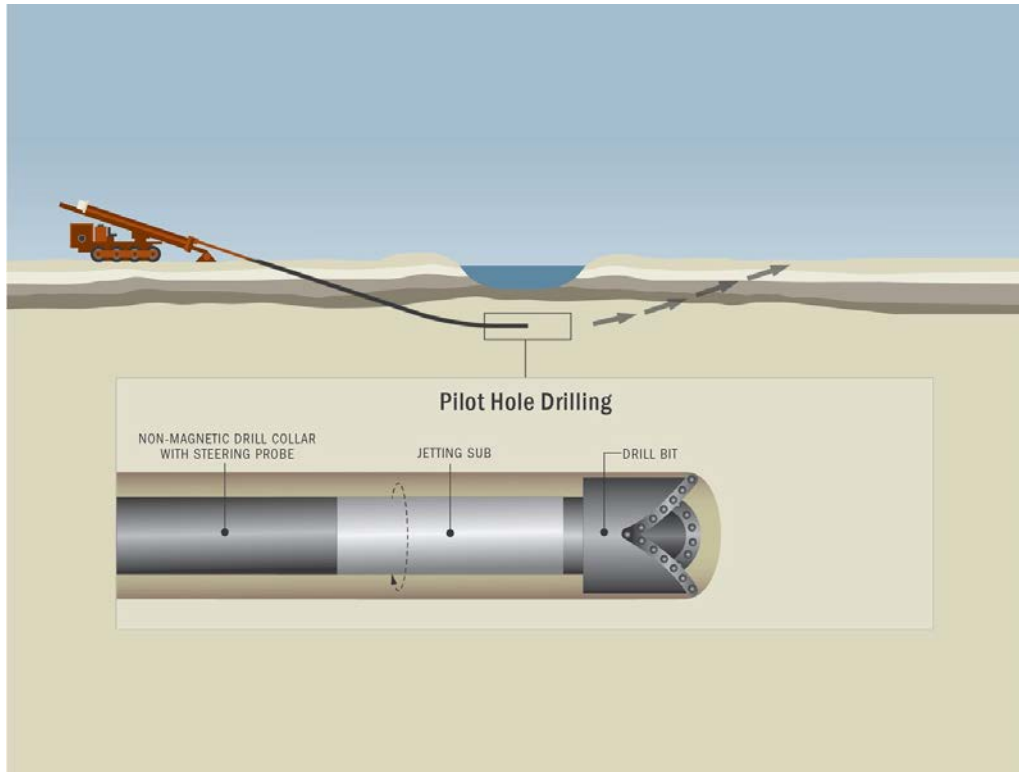
In some cases, simple geometry is not able to fulfill the project needs. When considering more complex geometry, the subsurface conditions and contractor's experience may have much more influence on the feasibility of completing the drill. If a horizontal curve in the alignment is required, try to design straight tangent segments between all curved segments. Try to avoid combined radius curves where the profile is curving in both the horizontal and vertical planes.



An example of a highly complex HDD geometry resulting from ROW limitations.



# HDD Construction – Pilot Hole



A schematic showing a typical Bottom Hole Assembly (BHA) drilling the pilot hole through soil.

Drilling the pilot hole is one of the most critical aspects of the HDD process. During pilot hole operations the risk of hydraulic fracture and inadvertent returns (frac outs) is highest because of the small annulus between the drill pipe and hole wall. In addition, the geometry of the pilot hole will dictate the shape of the final reamed hole that the pipeline must be pulled through.

Frac outs during construction can lead to violating permit stipulations, negatively impact the project schedule and possibly result in bad publicity.

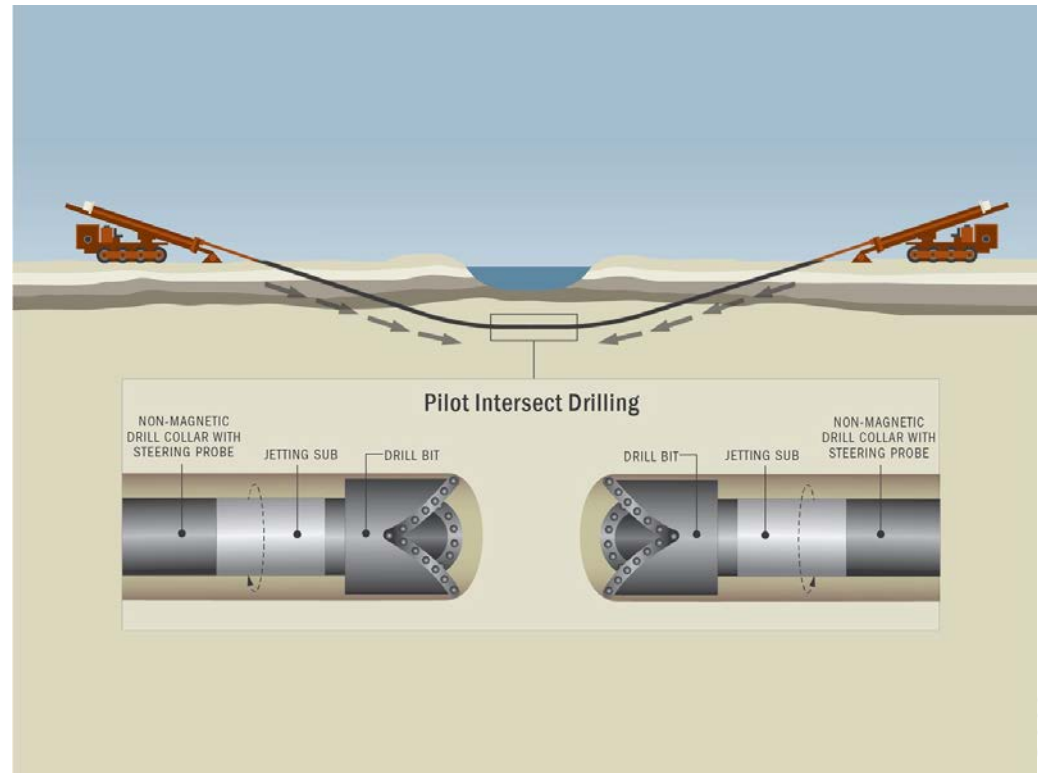
If the pilot hole is not drilled within the required tolerances, the alignment of the pilot hole may leave the permanent ROW, the hole may be drilled through zones of problematic soil or rock, or the radius of curvature of the hole may not allow for the passage of the pipeline during installation.

# HDD Construction – Pilot Hole

In general terms, the pilot hole is advanced with a Bottom Hole Assembly (BHA) consisting of a drill bit attached to either a jetting assembly (soil) or a mud motor (rock). The jetting assembly or mud motor is attached to a non-magnetic drill collar (monel) that houses the downhole steering probe.

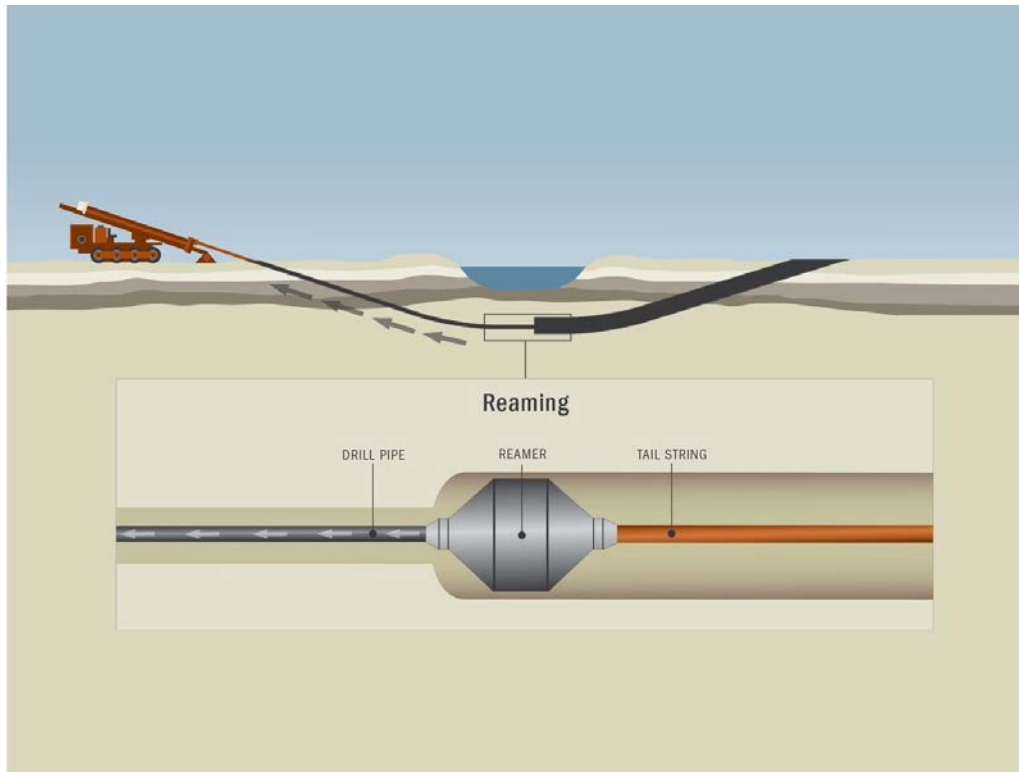
Directional control is achieved by a slight bend ( $1^{\circ}$  -  $3^{\circ}$ ) in the jetting assembly or mud motor. Steering corrections and curves are achieved by orienting the bend in the desired direction of travel, while advancing the BHA without rotation of the drill string. In soils, the drilling fluid pumped out of jets in the bit cuts the formation allowing advancement, while in rock formations the mud motor turns the bit which cuts the rock and allows advancement without having to rotate the entire drill string.

Straight drilling is achieved by advancing the BHA with rotation in both soils and rock.



A schematic showing the completion of a pilot hole intersect in soil.

# HDD Construction – Reaming



A schematic showing a typical reaming operation in soil using a barrel reamer. In a rock installation, a hole opener would be used in lieu of a barrel reamer.

After the pilot hole is completed, the BHA is removed from the drill string and a reaming tool is attached. The reaming tool is then rotated and pulled back toward the drill rig while drilling fluid is pumped downhole through the drill pipe string. Sections (joints) of drill pipe are added behind the reamer so that a continuous string of drill pipe is maintained through the entire length of the hole.

The drilling fluid pumped downhole through the drill string is expelled at high pressure from jets in the reaming tool. The drilling fluid mixes with the cuttings being generated as the hole is reamed. The drilling fluid then, flows back to the surface through the annulus of the hole, which carries the cuttings to the surface.

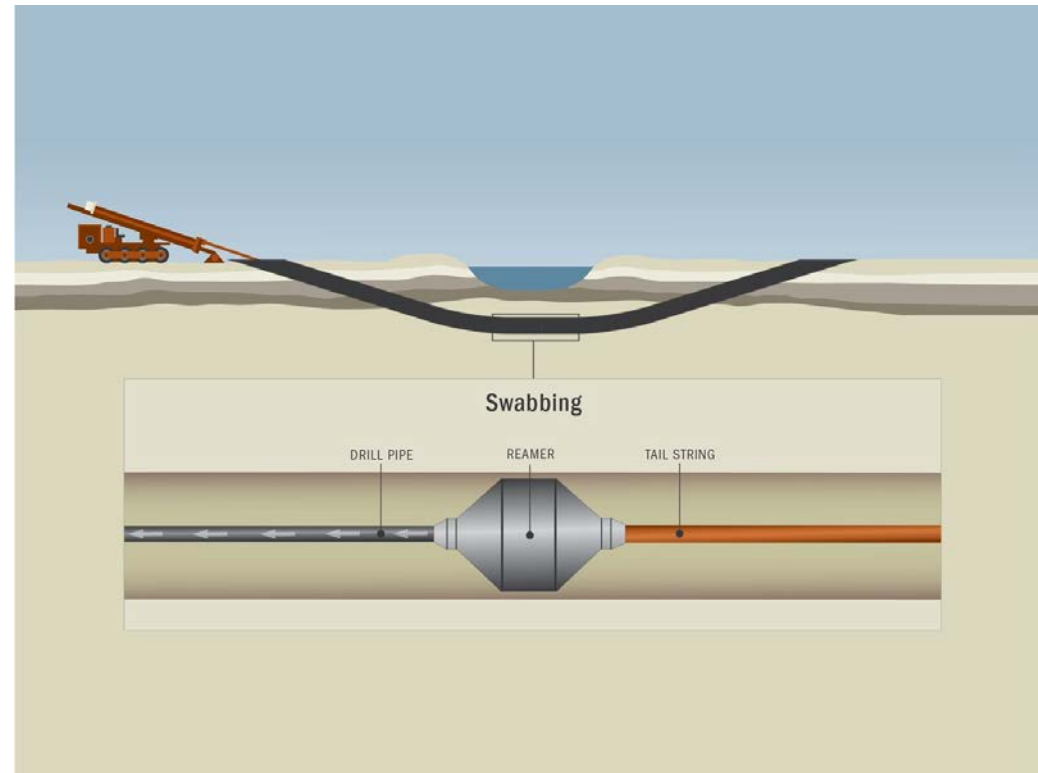
During reaming, the volume of drilling fluid pumped downhole should be balanced with the rate of penetration, so the volume of cuttings being generated does not overload the ability of the drilling fluid to carry the cuttings from the hole. The cuttings load in the drilling fluid should not exceed 30% of the drilling fluid volume.

# HDD Construction – Reaming and Swabbing

The hole is typically reamed to a minimum of 1.5 times the pipe diameter or 12 inches larger than the pipe, whichever is less. In some instances where the subsurface conditions are problematic or the pilot hole geometry is not ideal, the hole may be reamed to even larger diameters.

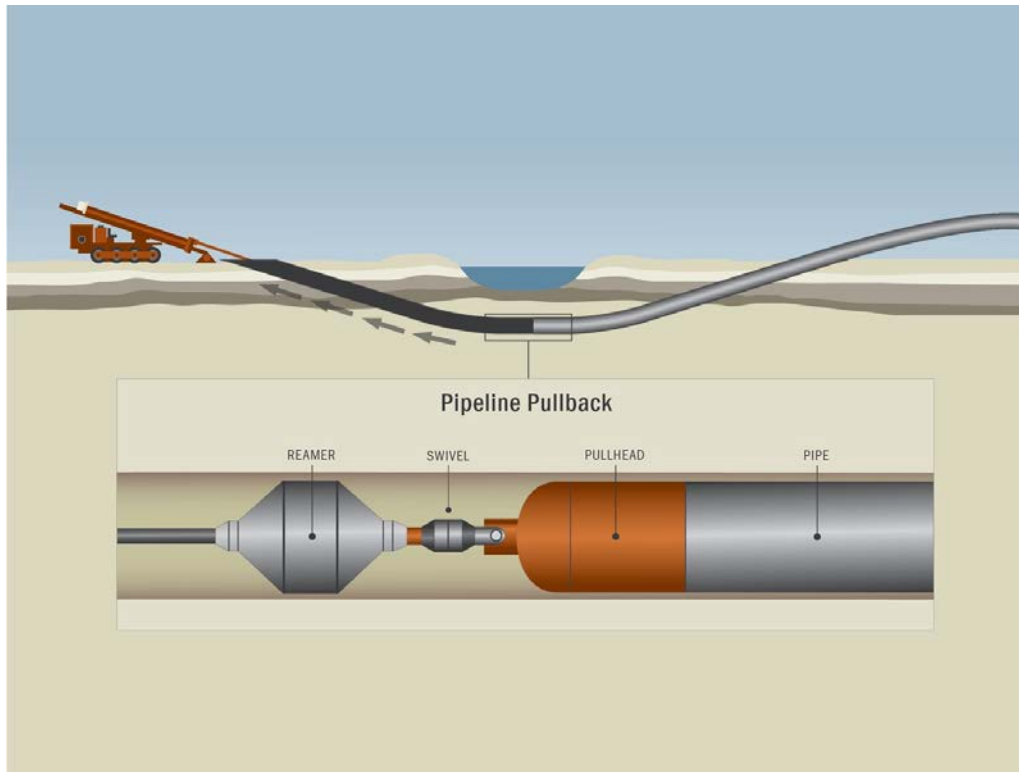
Once the hole is reamed to its final diameter, one or more swab passes are conducted to evaluate the condition of the hole prior to pullback operations. The swab pass also helps flush out cuttings still remaining in the hole. The swab pass is usually conducted with a reaming tool the approximate size of the pipe to be installed.

If an abundance of cuttings remain downhole after reaming, several swab passes using slow penetration rates and high pump rates may be required to condition the hole prior to beginning pullback operations.



A schematic showing a typical swabbing operation.

# HDD Construction – Pullback



A schematic showing a typical pullback operation in soil.

Once the hole is ready to receive the pipeline, a pullback assembly is made up to the prefabricated pull section. The pullback assembly consists of a prefabricated pullhead that is welded onto the leading end of the pull section, a swivel and a reaming tool. The swivel allows the rotation of the drill string and reamer without rotating the entire pull section.

As the pull section is pulled in, the drill pipe string and reamer are rotated and drilling fluid is pumped downhole through the reaming tool. This helps to clear out cuttings and blockages that may exist in front of the pullback assembly.

During installation, the pull section will displace its own volume of drilling fluid. Arrangements must be made in advance to contain, collect and dispose of the drilling fluid displaced during installation. During the early portion of the installation process, drilling fluid generally flows to the pipe side of the crossing before eventually flowing primarily to the entry side of the crossing.

# HDD Construction – Pullback

During pullback, the pull section must be properly supported to align the pipeline with the prepared hole and reduce the pull force required to install the pipeline. Typically, sidebooms, excavators and cranes with roller cradles are used to support the pull section at the correct angle for installation.

The exit angle of the HDD profile and the pipe diameter will dictate how high the pipe must be supported off of the ground to achieve a suitable overbend. Lower exit angles are preferred because it requires less break over angle, keeping the pull section closer to the ground and making it easier to handle with smaller equipment.

For pipeline installations greater than 24 inches in diameter, buoyancy control (water) is often used inside the pull section during pullback to reduce the buoyancy of the pipe and lower the pull forces required for installation. Positive buoyancy in large diameter installations can significantly increase pull loads.



Pullback operations for a 48-inch pipeline in the Republic of Georgia.

# HDD Construction – Cuttings Removal



A three-stage drilling fluid recycling system.

The solids laden drilling fluid returns that surface at either the entry or exit point during HDD operations need to be “cleaned” prior to being pumped back downhole.

Most drilling fluid recycling systems (a.k.a cleaning systems) consist of a mixing unit for mixing fresh drilling fluid and a two or three stage cleaning system. A three stage cleaning system consists of a scalper shaker, which separates out the largest particles, a desander filters out the sand size particles and a desilter filters out the silt and clay size particles.

Once the drilling fluid has passed through each stage of the cleaning system, it can be pumped back downhole.

Screens in the shaker beds can be changed to adjust the screen size depending on the materials being removed from the hole.

The cuttings are usually collected in bins adjacent the cleaning system where they can be loaded into trucks for offsite disposal.

# HDD Construction – Cuttings Removal

The removal of cuttings from the hole is critical to help maintain drilling fluid returns, keep downhole drilling fluid pressures low and to provide enough space for the pull section to be pulled through the hole without getting stuck.

Drilling fluid properties can be adjusted to optimize it for the conditions at hand. Poor drilling fluid properties can in some cases lead to a failed drill.

Where HDD profiles pass through high plasticity clay soils, the soil cuttings can tend to stick together forming large particles that continue to grow until they eventually plug the hole and cause drilling fluid returns to cease. When drilling fluid returns stop, the risk of hydraulic fracture and inadvertent drilling fluid returns increases substantially.

In gravelly soils, no amount of drilling fluid modifications can be made to transport large gravel sized particles from the hole. If the gravel content of the formation is great enough, the build up of these particles downhole can restrict the hole enough to cause the pull section to get stuck during pullback operations.



Cuttings generated from a sandy soil HDD installation.