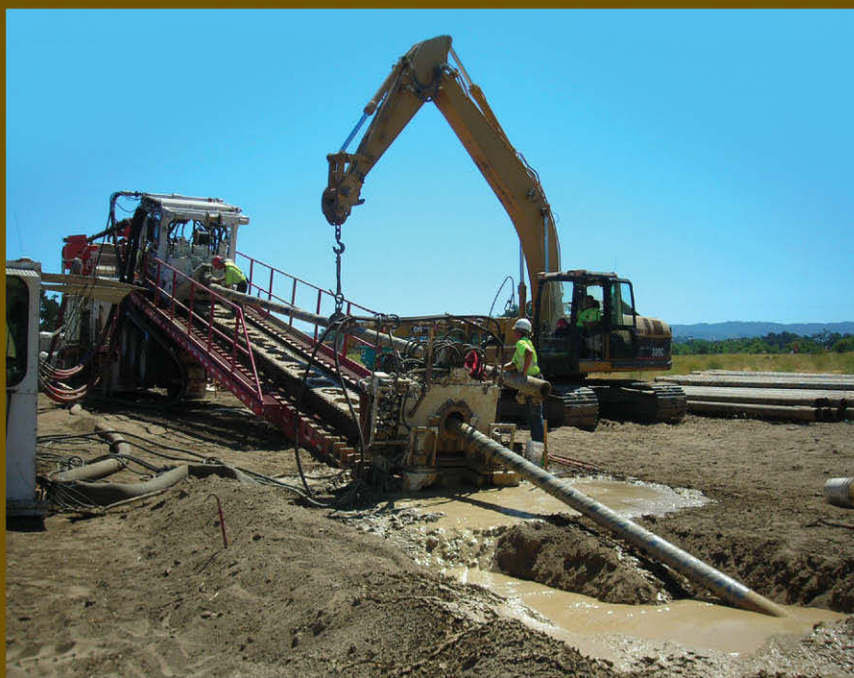




Pipeline Design *for* Installation *by* Horizontal Directional Drilling

*Second
Edition*

Horizontal Directional Drilling
Design Guideline Task Committee

Edited by

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Pipeline Design for Installation by Horizontal Directional Drilling

Second Edition

Prepared by
the Horizontal Directional Drilling Design Guideline Task Committee
of the Technical Committee on Trenchless Installation of Pipelines of
the Pipeline Division of the American Society of Civil Engineers

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CHAPTER 1

INTRODUCTION

1.1 SCOPE

This manual of practice addresses the design of major pipeline or duct segments to be installed by horizontal directional drilling (HDD). Generally speaking, major pipeline segments are greater than 500 ft in length and greater than 4 in. in diameter. They are installed by medium to large HDD drilling rigs (midi- to maxi-HDD drilling rigs). The design practices described in this manual are not generally applicable to small trenchless segments of pipe, duct, or cable installed by “mini-HDD” drilling rigs.

Horizontal directional drilling is a trenchless excavation method that is accomplished in three phases. The first phase consists of drilling a small-diameter pilot hole along a designed directional path. The second phase consists of enlarging the pilot hole to a diameter suitable for installation of the pipe. The third phase consists of pulling the pipe into the enlarged hole. Horizontal directional drilling is accomplished using a specialized horizontal drilling rig with ancillary tools and equipment.

This manual has been prepared to serve as a guide for design engineers and presumes that the user has knowledge of the HDD installation process and pipeline design methods. Topics covered are limited to those related to HDD installation. Other sources of information and design methods should be consulted for guidance on designing the pipeline to satisfy service requirements. This manual is not a general design handbook for pipelines, and it is not meant to replace sound engineering judgment. Users of this manual should recognize that HDD installations are complicated civil engineering works and that only experienced professional engineers should undertake their design.

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CHAPTER 2

PREDESIGN SURVEYS

2.1 INTRODUCTION

A successful HDD project requires that surface features and subsurface geotechnical and utility data be gathered and incorporated into its design. Trenchless installation methods require the design engineer to provide the contractor with sufficient information to reasonably anticipate the obstacles that may be encountered and how drilling operations should be carried out. During the design phase, surface and subsurface survey information assists in determining the suitability of utility installation by the HDD process.

This section describes data that need to be gathered and presented to enhance the prospects for a successful HDD installation. Obtaining and providing accurate surface and subsurface information result in fewer installation problems and change orders during the work.

2.2 SURFACE SURVEY

Once HDD is selected as the installation method, a surface survey is typically performed. Prior to conducting the actual survey, the design engineer should investigate the site to determine the limits of work required for equipment staging and setup, pipe layout, and areas of potential impact such as adjacent utilities or structures. The survey should be performed in an area sufficient in size to show equipment set-up and storage locations. Typical staging areas required for HDD construction projects are discussed in Chapter 5.

The survey should be conducted along the proposed drill path centerline for a width of approximately 100 ft. Each HDD project has specific staging requirements that should be identified by the design engineer prior to initiating the field survey.

Information to be gathered during the survey should include, but not be limited to, the following:

- Existing grade elevation data referenced to a public datum if practical;
- Surface features such as roadways, sidewalks, utility poles, overhead power lines, fire hydrants, etc.;
- Ledge or rock outcrops;
- Boring/test pit locations;
- Waterways;
- Potentially delineated wetlands;
- Culverts;
- Visible subsurface utility landmarks such as manholes or valve boxes; and
- Structures such as buildings, towers, or bridges adjacent to the proposed drilled path.

A plan view of a finished survey for a major HDD river crossing is shown in Figure 2-1. Contours are useful, but not imperative, because HDD activities on the surface are limited to entry and exit point work areas. It is important to note that HDD crossings designed with significant elevation differences between entry and exit present unique challenges to HDD construction and should be readily apparent in the design drawing. Controlled aerial photographs, if recently taken, are commonly used and can eliminate the need for surveying many surface features.

Waterway crossings may also require a hydrographic survey. The hydrographic survey should include tidal ranges and edges of waterways. It should be conducted along the proposed drill path and include data as appropriate upstream and downstream of the path. As with the surface survey, bottom contours are useful but not imperative unless dramatic variations in bathymetric elevations are anticipated. Most drilled paths are designed well below a waterway bottom, and small variations in elevation do not affect design.

2.3 SUBSURFACE INVESTIGATION

Once the surface survey data have been obtained, evaluation of subsurface features can be initiated. Subsurface feature concerns that may affect HDD design and therefore should be investigated include the presence of existing utilities, adjacent structure foundations or other manmade obstructions, and geotechnical and hazardous materials conditions along the proposed HDD alignment.

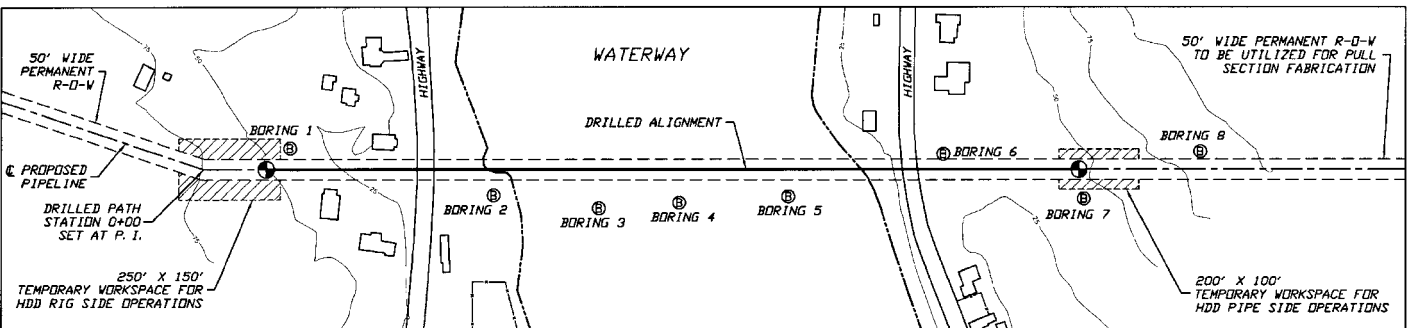


Figure 2-1. Survey of a major HDD river crossing

2.3.1 Utility Research

Utility survey information is important to the planning and execution of the HDD project. Unlike conventional open-cut installations, HDD projects require the contractor to install the utility line in the “blind.” Unable to see possible obstructions, the contractor should be given as complete and accurate a record of potential conflicts and utility clearances as may be obtained by reasonable and diligent inquiry. Guidance with respect to subsurface utility research may be found in CI/ASCE 38-02 (ASCE 2002).

The designer should also be aware of code requirements related to the degree of utility research required. For example, Section 434.13.5(a) of ASME B31.4-2009 (2010, p. 49) requires the crossing plan and profile drawings to include all “pipelines, utilities, cables, and structures that cross the drill path, are parallel to and within 100 ft (30 m) of the drill path, and that are within 100 ft (30 m) of the drilling operation, including mud pits and bore pits.” Alternate codes may not contain such specific details. The designer should research utility location and depiction requirements on a project-specific basis prior to initiation of the process.

The first step in obtaining subsurface utility information is accomplished during the surface survey by locating visible subsurface utility landmarks. Knowing where valve boxes, manholes, and other structures are located provides a starting point for utility research. The design engineer should exercise due diligence in not only identifying what utilities are located along the proposed HDD path, but also in determining their horizontal and vertical positions, especially if the existing utility was installed via HDD construction.

One method of obtaining utility data is to contact the local “One Call” locating service. This service can be reached by dialing 8-1-1 from anywhere in the United States and is a somewhat easy and straightforward way to identify and locate utilities that are members of the One Call network. In areas where One Call assistance is not provided during the design phase of work, municipalities and private utility companies should be contacted to obtain the required information. Additional research is often necessary, however, because not all utilities belong to the One Call Network and One Call Locates are not always clear with respect to depth. This is particularly true in the case of utilities installed by HDD. Post-construction locating methods are often not effective because of the significant depth of HDD installations.

Obtaining as-built record drawings gives the design engineer location information and identify many, if not all, of the utility lines that could be encountered. However, because of the possibility of inaccurate information, relying solely upon record drawings may not be sufficient for construction. Because of the potential impact and damage to utility lines due

to HDD operations, the contractor must conduct additional investigations before beginning work to verify utility line locations where they are at risk of damage by new construction activities.

Generally, if the HDD alignment is expected to pass within 10 ft of an existing utility, physically confirming the location prior to initiating HDD operations if possible is prudent. Utilities located more than 10 ft away may also require physical locating depending on specific requirements of the utility owner or the presence of unusual ground conditions along the proposed HDD alignment near the existing utility.

Methods of confirming subsurface utility locations include

- Pipe locators,
- Ground-penetrating radar,
- Probing,
- Manual excavation,
- Vacuum excavation, and
- Seismic survey.

2.3.1.1 Pipe Locators Utility lines can have both horizontal and vertical locations identified by means of surface applied pipe locators. Pipe locators can be instruments that simply detect underground lines by means of a magnetic field application similar to a metal locator. More sophisticated locators require imposing an electric current on the utility line. Applied current travels along the utility and is detected and traced with the pipe locator. Nonmetallic pipe, such as PVC or high-density polyethylene (HDPE), that has not been installed with a tracing wire cannot be detected with a pipe locator. Some underground utility lines such as electric and cable television lines can produce a detectable signal as long as current is flowing through them. Pipe locators are generally less accurate with depth, but can be extremely accurate in locating utilities buried less than 12 ft deep, depending on conditions.

2.3.1.2 Ground-Penetrating Radar Ground-penetrating radar (GPR) utilizes radio waves to detect underground lines and surfaces. When an object is detected, the radio waves reflect back to the receiver that records the information. The data are downloaded to a computer, and a profile of the utility and geologic information is plotted for interpretation. Subsurface obstructions such as rock and groundwater surfaces are also detected by GPR and can result in misinterpretation of the gathered data. Because interpretation of the data is a critical element in GPR surveys, this method should be used in conjunction with other subsurface survey methods to improve the accuracy of the information. GPR is most useful at depths of less than 20 ft when the density of the object or utility in question contrasts greatly with the surrounding ground. GPR is also highly dependent on

soil type and moisture content. GPR is more effective in dry sands than in wet soils and does not work well in clay soils and soils that are salt contaminated, or in identifying pipe made of clay.

2.3.1.3 Vacuum Excavation Nondestructive vacuum excavation is used to physically remove soil and expose the utility lines being investigated. Unlike test pitting, which is performed by means of excavation equipment such as a backhoe, vacuum excavation removes the soils by means of high-pressure air or water jetting. This method reduces the risk of damage to existing utility lines. The water or air loosens the soil, which in turn is vacuumed into a truck for replacement upon completion of the survey. Vacuum excavation allows for physical identification of horizontal and vertical alignments of utility lines and pipe materials and provides the designer with information concerning soil types and water table levels. Conventional vacuum excavation is limited to depths of approximately 20ft and is most effective in unsaturated, medium density, gravel size, or less granular soils. Excavation holes must be large enough to allow for visual inspection of the uncovered utility lines.

2.3.1.4 Seismic Surveys Seismic surveys require that a small explosive charge or impact by means of sledgehammer be initiated and detected via a series of detectors or geophones spaced along the path of the utility line. A time recorder is used to record the time of origin of the wave and the time of arrival at each detector. Similar to GPR, the water table and type of subsurface material affect the data output; therefore, proper interpretation of the data is critical and greater density contrasts tend to yield more beneficial results. Seismic surveys are generally used in uncongested areas or locations where deep utility installations exist. Once the subsurface utility information is obtained, it should be correlated to determine possible conflicts and then included in the survey base drawings.

2.3.2 Geotechnical Investigation

A second phase of subsurface investigation for HDD projects is the determination of soil conditions. Once the proposed routing has been identified, a geotechnical investigation should be performed. The geotechnical investigation should be tailored to suit the complexity of the installation being designed. Investigations for complex installations should consist of two phases: a general geologic review and a geotechnical survey. A geotechnical survey alone may be sufficient for simpler installations.

A general geologic review involves examining existing geological data to determine what conditions might be encountered in the vicinity of the installation. Existing data may be available from construction project records in the area of the HDD (buildings, piers, bridges, levees, etc.).



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Such an overall review provides information that may not be developed from a geotechnical survey consisting only of exploratory borings. It also allows the geotechnical survey to be tailored to the anticipated conditions at the site, thus enhancing the effectiveness of the survey.

A typical geotechnical survey consists of taking exploratory borings to collect soil samples for classification and laboratory analysis. Methods utilized in the survey of underground utilities, as described previously, can also be incorporated into the geotechnical survey.

The number, location, and depth of exploratory borings should be determined taking into account site-specific conditions such as the general geology of the area, availability of access, availability of existing data, cost, etc. Borings should be located off of the drilled path centerline to reduce the possibility of drilling fluid inadvertently surfacing through the borings during HDD operations. The borings should penetrate to an elevation 20 to 30 ft below the depth of the proposed drill path to provide information for design modifications and anticipated pilot-hole deviations during construction. Areas of geologic transition and/or significant contrast in physical ground properties can present unique challenges to HDD construction and should be carefully scrutinized with greater frequency of investigation.

Sampling interval and technique should be set to accurately describe subsurface material characteristics taking into account site-specific conditions. Typically, split spoon samples are taken in soil overburden at 5-ft depth intervals in accordance with ASTM D1586-11 (2011). Where rock is encountered, it should be cored in accordance with ASTM D2113-08 (2008), to the maximum depth of the boring. The following data should be developed from exploratory soil borings:

- Standard classification of soils in accordance with ASTM D2487-10 (2011);
- Gradation curves for granular soils containing gravel;
- Standard penetration test (SPT) values where applicable (generally unconsolidated ground);
- Cored samples of rock with lithologic description, rock quality designation (RQD), and percent recovery;
- Unconfined compressive strength (UCS) for representative rock samples (frequency of testing should be proportionate to the degree of variation encountered in rock core samples);
- Mohs hardness for rock samples;
- Unit weight;
- Atterberg limits;
- Cohesion coefficient;
- Soil friction angle; and
- Depth to water table.

Steps for abandoning the exploratory borings based on local requirements must be undertaken. At a minimum, borings must be backfilled in a manner that will minimize the possibility of drilling fluid migration along the borehole during subsequent HDD operations. A mixture containing cement grout and a bentonite product to promote expansion is recommended. Cuttings from the drilling operation may be incorporated into the backfill mixture if considered beneficial. The upper 5 ft of land-based borings should be backfilled with the surrounding soil.

The results of the subsurface survey should be presented in the form of a geotechnical report containing engineering analysis, boring logs, test results, and a profile of the subsurface conditions. It is also useful, but not imperative, to present exploratory boring logs on the drilled path profile. An example of this is shown in Figure 2-2.

It should be noted that the presentation of geotechnical information by the design engineer can have significant contractual implications. This topic is examined in ASCE (2007), which also discusses concepts of a geotechnical baseline report (GBR) and a geotechnical data report (GDR). If establishing a contractual statement of subsurface geotechnical conditions that may be encountered during the directional drilling is desired, a GBR or GDR may be included in the contract documents.

A GDR can include detailed descriptions of the field and laboratory methods and procedures utilized in the subsurface exploration program. Typical information includes boring logs, laboratory test results, and profile data.

For more complex projects, consideration may be given to preparing a GBR for inclusion in the documents. The GBR is typically limited to interpretive discussion and baseline statements and refers to the information contained in the GDR.

However, in establishing a contractual statement of subsurface geotechnical conditions for an HDD project, it should be remembered that the conditions along a drilled path are rarely visible. Verifying actual subsurface conditions encountered versus the established baseline conditions is generally not possible. Experienced engineering judgment should be applied in evaluating and allocating risk, while taking into account site-specific conditions.

2.3.3 Hazardous Material Investigation

Because the drilling operations produce spoil materials that require handling and disposal, soil and/or groundwater samples should be taken during the utility and geotechnical investigations. During the geotechnical and utility excavation programs, soils and groundwater should be examined by both visual and olfactory means to determine if potential hazardous materials exist. Samples should be analyzed to identify



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hazardous waste problems. Testing varies depending upon the site and actual conditions encountered; however typical analysis can include

- Volatile organic compounds (VOCs),
- Base/neutral extractable organic compounds,
- Total petroleum hydrocarbons (TPH),
- RCRA 8 metal analyses,
- Pesticides, and
- Polychlorinated biphenyls (PCBs).

Samples should be taken and analyzed in accordance with applicable state and EPA regulations and methods. When hazardous materials or contaminated soils are encountered, special consideration should be given to selecting an appropriate pipe material for these conditions.

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CHAPTER 3

DRILLED PATH DESIGN

3.1 INTRODUCTION

A properly designed HDD installation includes a specific drilled path design. The first step in designing a drilled path consists of defining the obstacles to be crossed. At first glance this seems to be a simple task; however, obstacles in today's construction environment can be complicated and subtle. This can be illustrated by considering a river crossing.

The water body is the obvious obstacle; however, a river is a dynamic entity. Channels can migrate vertically and horizontally. A successfully designed drilled path takes into account not only the present location of the channel, but also its potential future locations (Hair and Hair 1988, O'Donnell 1978). Additional obstacles can be associated with a river. A riparian barrier of trees may need to be preserved and thus included in the drilled path. An environmentally sensitive wetland may be associated with the river and included in the drilled path. Conversely, the actual bank-to-bank distance of a river may exceed that which is technically or economically feasible for an HDD installation. In this case the drilled segment may be designed to cross the deep channel of the waterway using marine equipment to support the rig and construct approaches through shallower water where cut-and-cover construction is more economical.

Once the obstacle has been defined and the approximate desired HDD length is established, designing and specifying a drilled path is an exercise in geometry (Hair and Hair 1988). The location and configuration of a drilled path are defined by

- Penetration angles,
- Design radius of curvature,

- Points of curvature and tangency, and
- Desired vertical depth of cover.

A consideration in designing the drilled path is the minimization of drilled length. Minimizing the drilled length of an HDD crossing reduces installation costs. However, the design must also consider availability of workspace at the entry and exit locations such that the HDD can be feasibly constructed within the physical site constraints. Lastly, the design is often influenced by the geologic conditions identified and placed at depths most amenable to the HDD process. A typical designed drilled path is shown in Figure 3-1.

The typical drilled path shown follows a straight alignment in the horizontal plane. The designer should be aware that HDD offers the flexibility to change alignment through horizontal curves, similar to the change of vertical position through the use of vertical curves. However, horizontal curves can be difficult to drill accurately and, depending on the deflection angle, can significantly increase pulling forces. The three-dimensional combined curvature in both the vertical and horizontal planes should also be considered. Therefore, horizontal curves should only be used after due consideration and analysis have been given to their potential negative effect on constructability.

3.2 PENETRATION ANGLES

Penetration angles are measured from horizontal. Entry angles are limited by equipment capabilities and should generally be designed between 8° and 20° (Directional Crossing Contractors Association 1995, Hair and Hair 1988). Most horizontal drilling rigs are designed to function best between 10° and 12° . However, for large-diameter pipelines, entry angles may be less than 8° .

Exit angles should be designed to provide ease in breakover support of the pull section. High exit angles require the pull section breakover bend to be supported at an elevated position during pull back. Exit angles should generally range from 5° (for large-diameter steel pipelines) to 12° . As part of a general constructability review, the design engineer should check pull section handling requirements to evaluate the constructability of the design.

3.3 DEPTH OF PENETRATION

The depth of penetration is controlled primarily by the definition of the obstacle. However, the design engineer should also consider other

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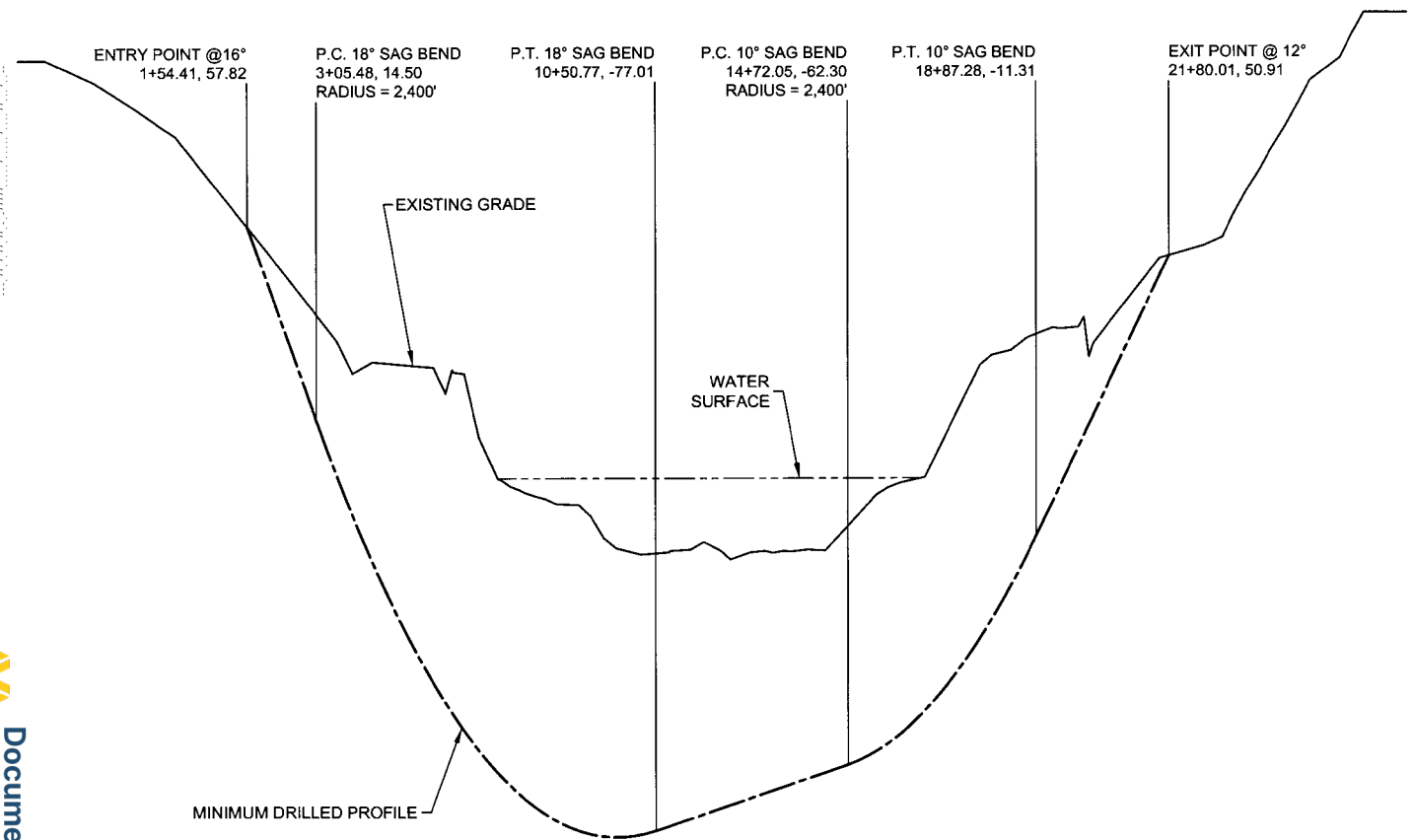


Figure 3-1. Typical designed drilled path