HDD Training

The HDD Evaluation and Design Process

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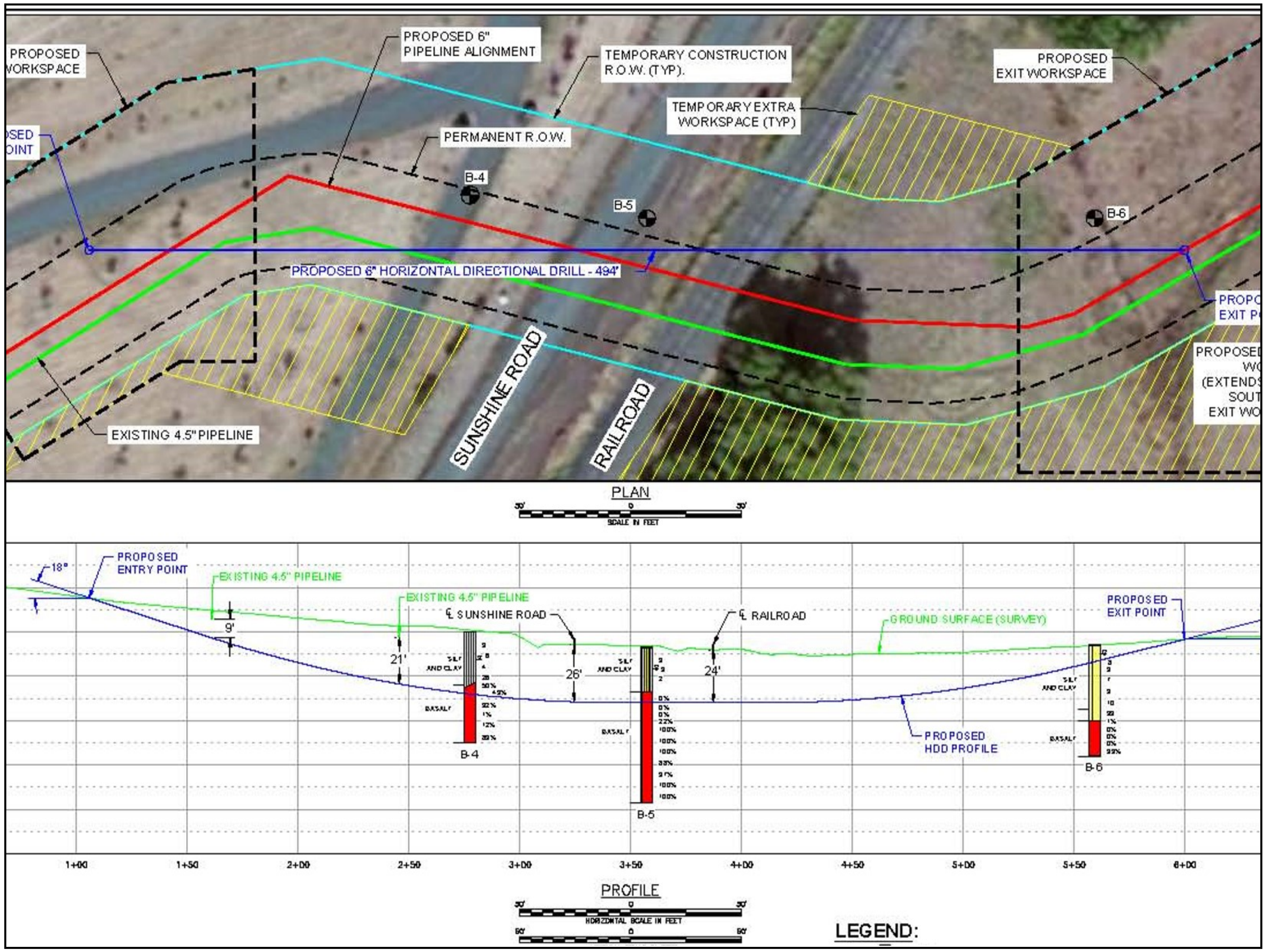
Pipeline Routing



When routing pipelines, there are often obstacles that require the route to deviate from the envisioned route. These obstacle include:

- Highways
- Railroads
- Waterways
- Existing Infrastructure
- Underground Utilities
- Landowner Requirements
- Geologic Hazards
- Wetlands or Sensitive Areas

Through the routing process, pipeline routers decide the preferred route by determining the optimal location to cross these obstacles.

Often, there are several viable options and the shortest route is usually taken, which may include a point of intersection (PI) adjacent to an existing obstacle which may need to be relocated during the HDD design process.

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HDD Overview

HDD can provide significant benefits over cut and cover methods for installing pipelines beneath certain obstacles.

In order to take advantage of there benefits, design engineers should:

- Have a working knowledge of the HDD construction process.
- Be familiar with HDD design considerations and industry standards.

Geotechnical Engineering Services and Horizontal Directional Drill Design

CN-0028/0030 Counts Creek
HDD Dallas County, Texas

for
ExxonMobil Pipeline Company

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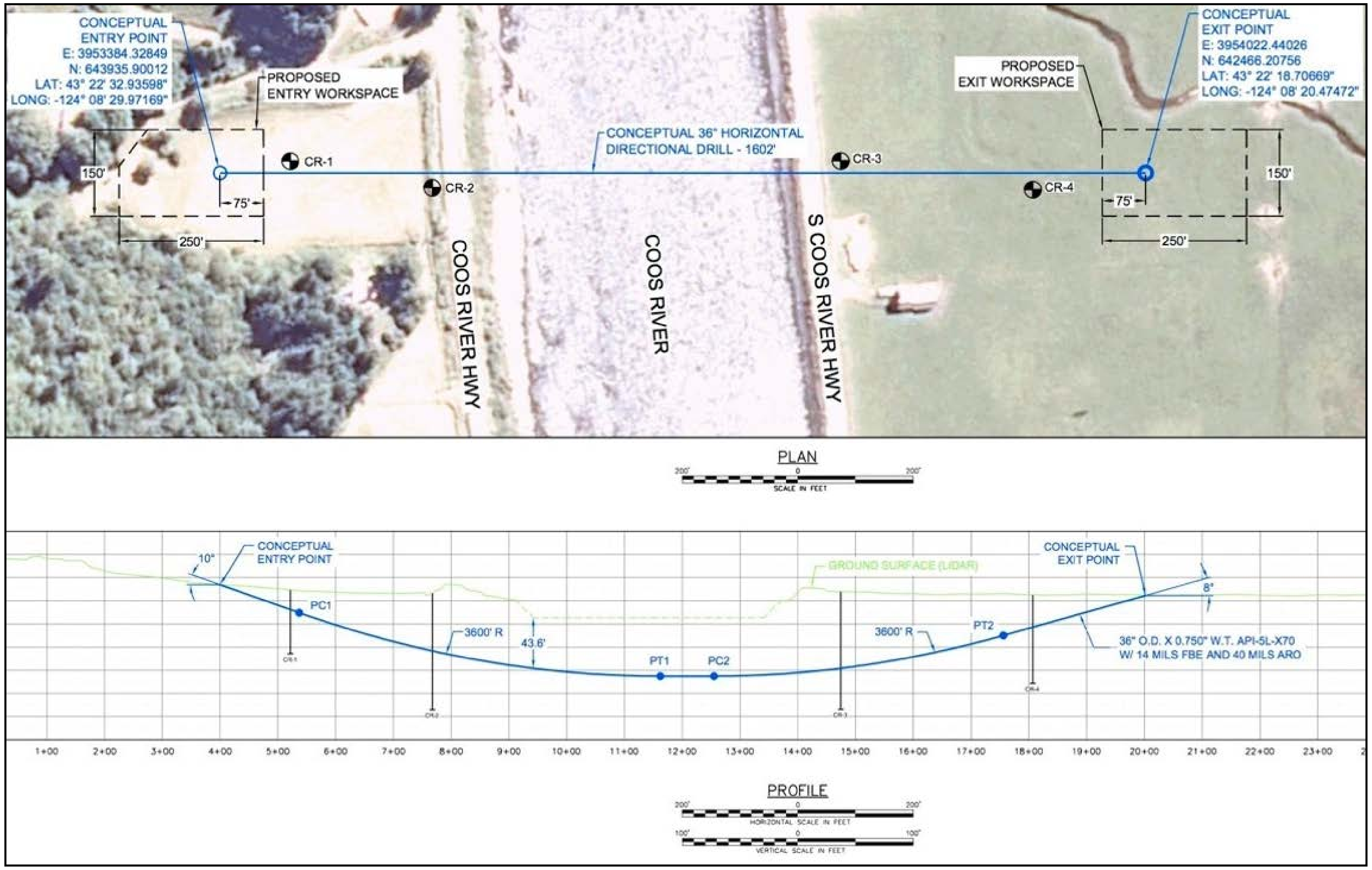
Earth Science + Technology

Desktop Study & Geometric Design



If the existing obstacle is being considered for the HDD construction method, a preliminary desktop study should be conducted to evaluate the initial feasibility based on available project information. If necessary, additional information can be obtained from the internet relative to published geology for the area and to cut an approximate grade along the proposed HDD alignment to produce a conceptual plan and profile drawing.

After obtaining an approximate grade, a preliminary drilled path can be incorporated into the conceptual plan and profile drawing which is defined by the following six parameters:

1. Entry Point – (determined by the site's topographic and geotechnical features.
2. Entry angle – (generally between 8 and 16 degrees)
3. Exit angle – (generally between 8 and 12 degrees)
4. Points of Curvature (PC) and Points of Tangent (PT)
5. Radius of curvature (industry standard, feet) = 100 * nominal pipe diameter, inches)

Once the preliminary drilled path is incorporated into the conceptual plan and profile drawing, the proposed borings can be place on the referenced drawing depicting their proposed locations and depths. Guidance for laying out the borings is included under Subsurface Explorations & Laboratory Testing.

Site Visit

At a minimum, the following items should be evaluated while conducting the site visit and reviewing the conceptual HDD design:

- Site access for the Contractor's HDD equipment relative to public roadways, weight limitations of bridges, height of overhead lines, and additional obstacles that may need to be crossed to gain access to the proposed entry and exit workspaces.
- The proposed locations of the HDD entry and exit points relative to existing utilities, pipelines, roadways, railroads, overhead lines, structures, etc.
- The presence of existing structures, culverts, manholes, utilities, roads, railroads, driveways, or piles along/adjacent to the proposed HDD alignment, within the proposed entry and exit workspaces, and/or within the proposed product pipe stringing and fabrication workspace.
- The contour of the existing grade relative to the conceptual plan and profile drawing, and if there are any existing grade deviations adjacent to the HDD alignment that may increase the probability of inadvertent drilling fluid returns and/or impact the design elevation of the conceptual HDD profile.
- Are there any rock outcroppings, gravel and/or boulders visible along the proposed HDD alignment or within the immediate area.
- The proposed boring locations and access to the proposed boring locations (will an ATV rig be required when contracting the borings).
- The presence of nearby dwellings, schools or business that may be impacted by construction noise.

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Site Investigation

Should include:

- Topographic survey along the HDD alignment.
- Hydrographic survey for significant waterways.
- Site-specific geotechnical investigation extending below the anticipated depth of the pilot hole.
- Identified locations of existing roadways, railroads, driveways, pipelines, utilities (inclusive of overhead lines and support structures), piles, and above ground and underground structures.

Results from the site investigation should be integrated with the HDD design to evaluate the feasibility and finalize the HDD design, when applicable.

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Subsurface Explorations & Laboratory Testing

Should include:

- Ideally, borings should be spaced approximately every 500 feet, and offset from the proposed HDD alignment a minimum of 50 feet and a maximum of 100 feet, when possible. However, the number of borings is generally based on site-specific conditions and practical economic limits.
- The borings should extend below the anticipated depth to the pilot hole a minimum of 20 feet; thereby, including the pilot hole elevation tolerance. If rock is encountered, the borings should confirm that it is bedrock.
- The following data:
    1) Standard penetration test values where applicable.
    2) Standard classification of soils (ASTM D-2488).
    3) Classification of rock types.
    4) Cored samples of rock with rock quality designation (RQD) and percent recovery.
    5) Other soil and groundwater properties as applicable.
    6) Testing on selected samples to evaluate pertinent engineering properties:
        - Moisture Content (ASTM D2216).
        - Atterberg limits determination (ASTM D4318).
        - Sieve Analysis (ASTM D422).
        - Unconfined compression tests of rock core samples (ASTM D 7012).
        - Mohs Hardness for rock samples.

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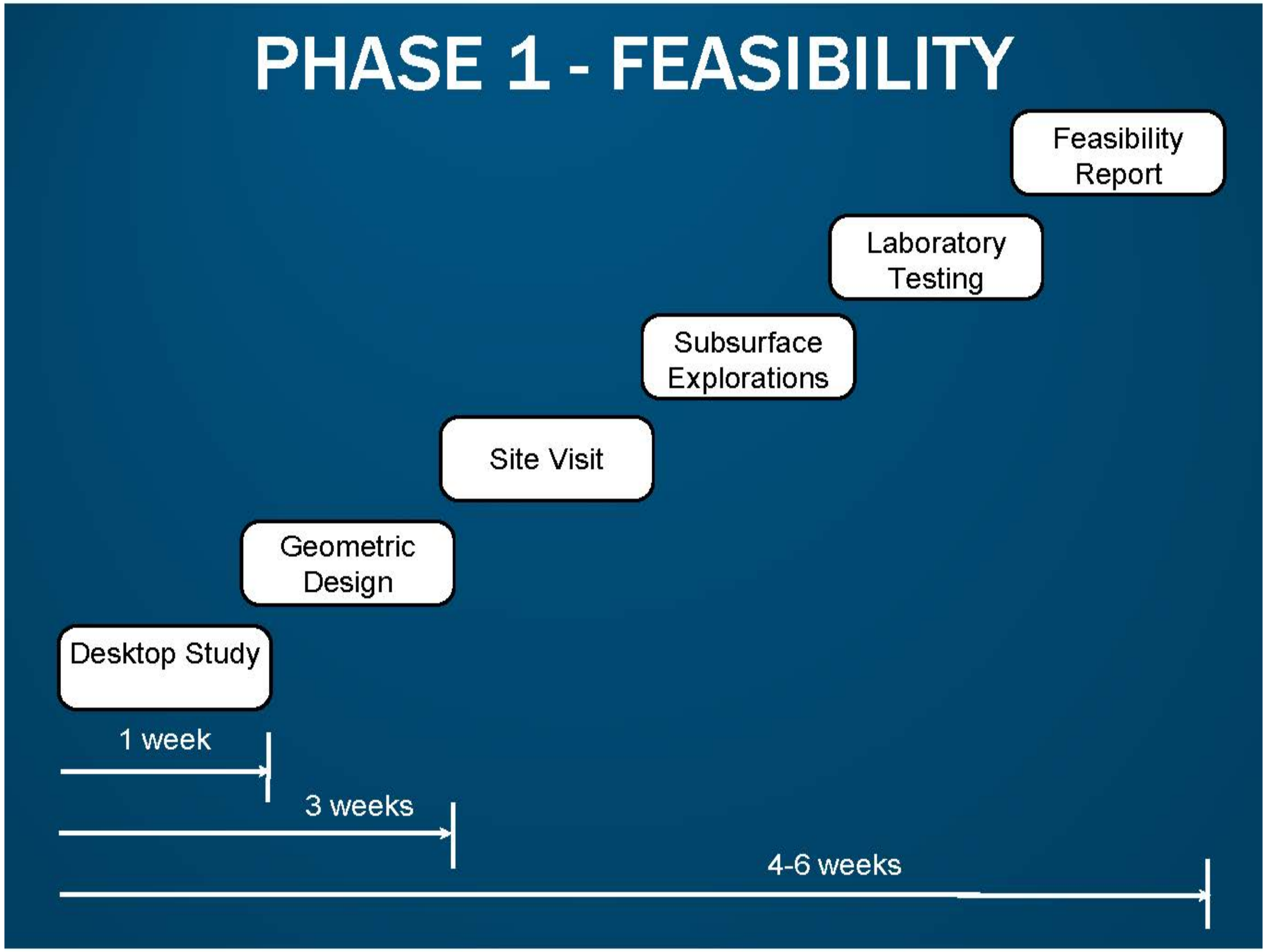
Feasibility Evaluation



Feasibility evaluation considerations:

- Geometry of the proposed HDD based on the site's topographic features.
- Existing subsurface conditions and drill hole stability:
  - Presence of fractured rock, cobble, coarse gravel and/or glacial till.
  - The potential for the HDD profile to enter/exit the rock interface multiple times.
  - The potential presence of existing voids/cavities along the HDD profile common within limestone and karst formations.
  - Artesian groundwater conditions.
  - Elevation differential between the proposed HDD entry and exit points.
- Probability of hydraulic fracture and inadvertent drilling fluid returns relative to the sensitivity of the obstacle being crossed.
- Geologic hazards.
- Proximity of the HDD alignment to existing structures, culverts, manholes, utilities, roads, railroads, driveways, or piles along/adjacent to the proposed HDD alignment, within the proposed entry and exit workspaces, and/or within the proposed product pipe stringing and fabrication workspace.
- Proposed HDD length and product pipe diameter.
- Site access and workspace requirements.

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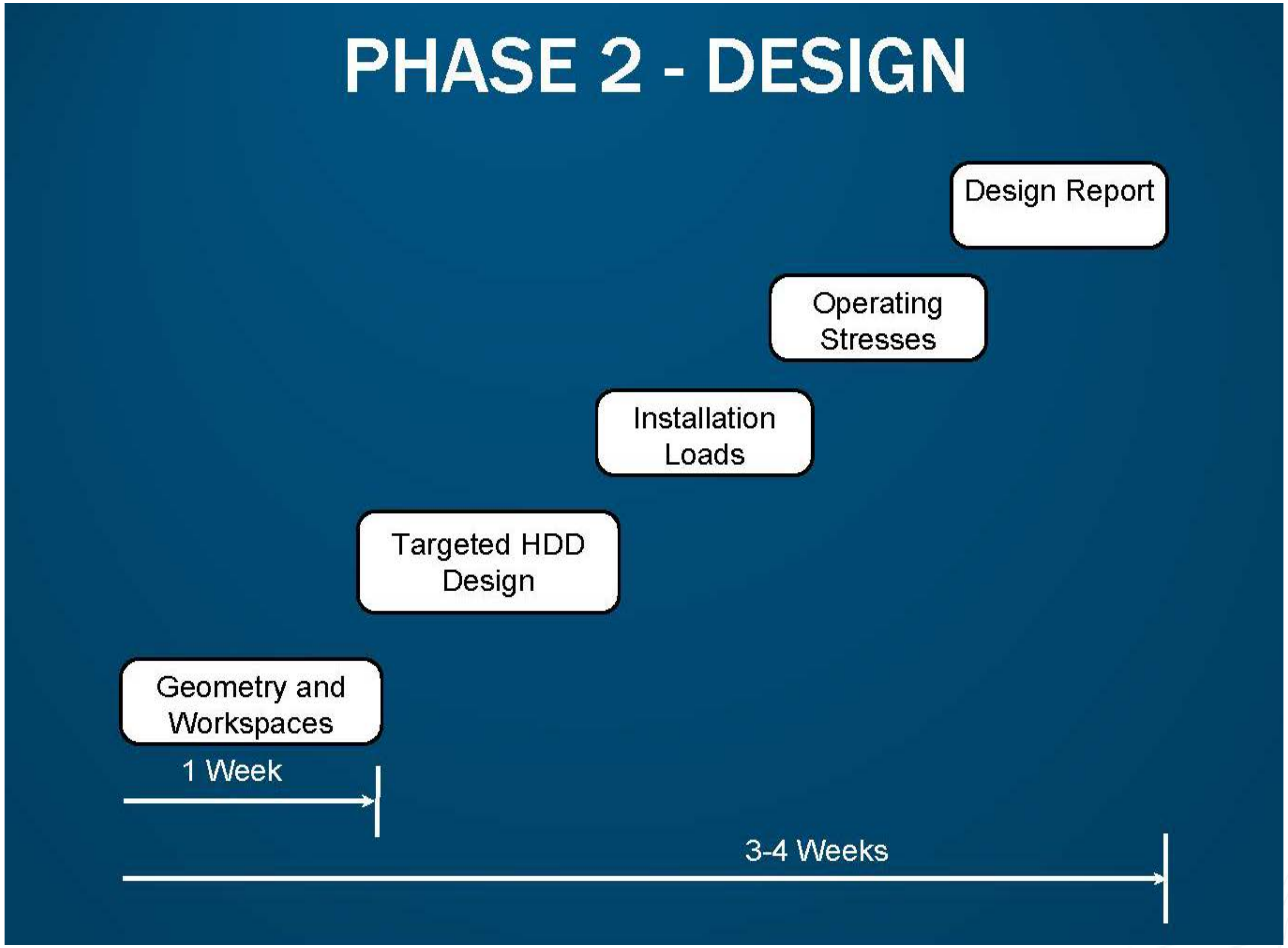
HDD Design

HDD design considerations:

- Vertical separation between the lowest elevation of the obstacle being crossed and the HDD profile.
- Vertical and horizontal separation between HDD alignment/profile and existing pipelines, utilities, roads, railroads, structures, etc.
- When crossing a water body, not only should the water's width and depth be considered, the potential for bank migration and scour during the design life of the crossing should also be taken into account.
- Stabilization of unstable subsurface conditions adjacent to the HDD entry and exit points via either casing installation or excavation.
- Permit and workspace requirements.
- Basis of design:
  - Product pipe properties.
  - Product pipe coating specifications.
  - Maximum allowable operating pressure.
  - Maximum allowable operating temperature.
  - Minimum allowable three joint average radius.



- Pilot hole tolerances.
  - Entry angle and location.
  - Exit angle and location.
  - Pilot hole elevation tolerance.
  - Pilot hole alignment tolerance.

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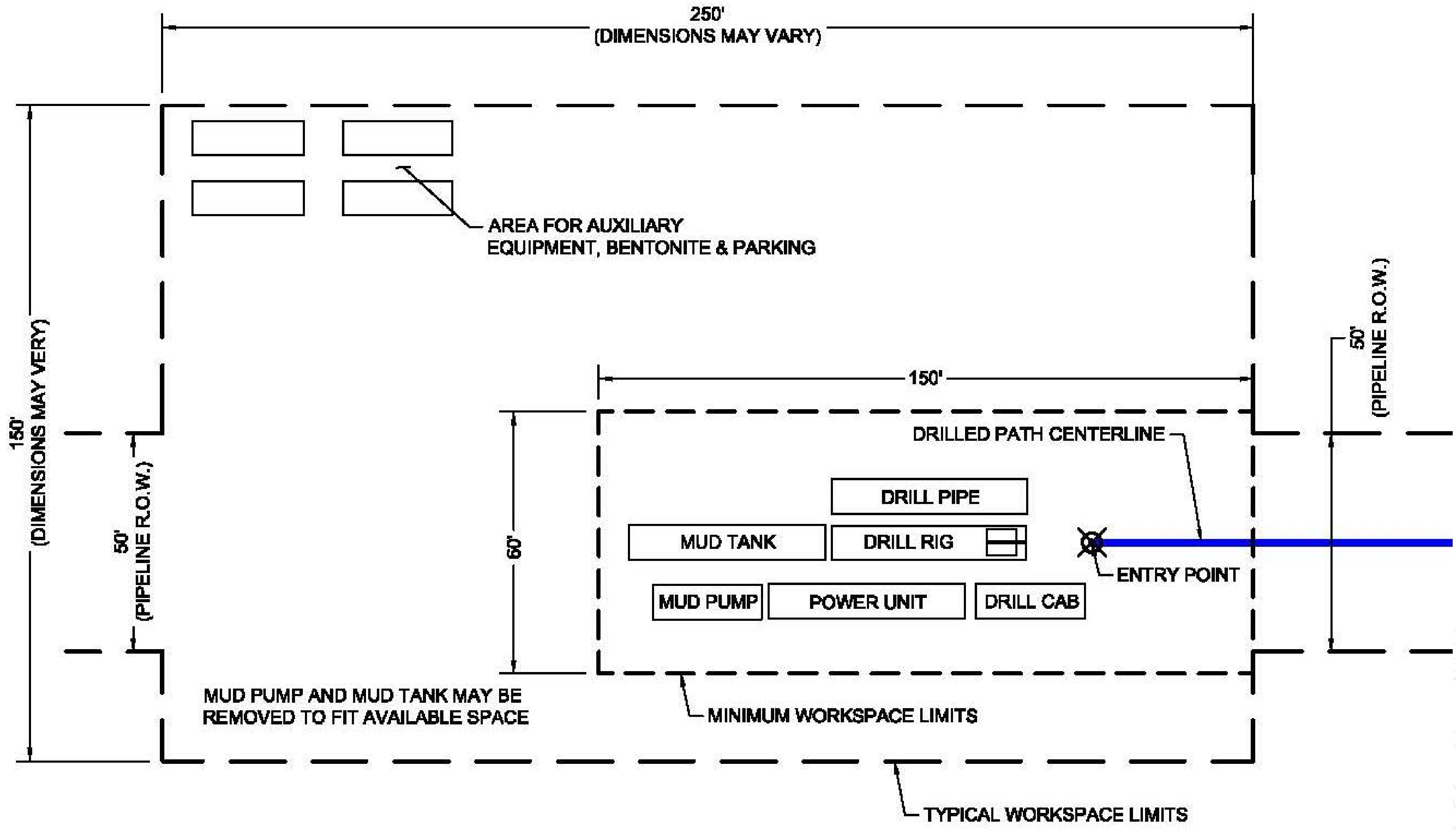
Entry Workspace Requirements



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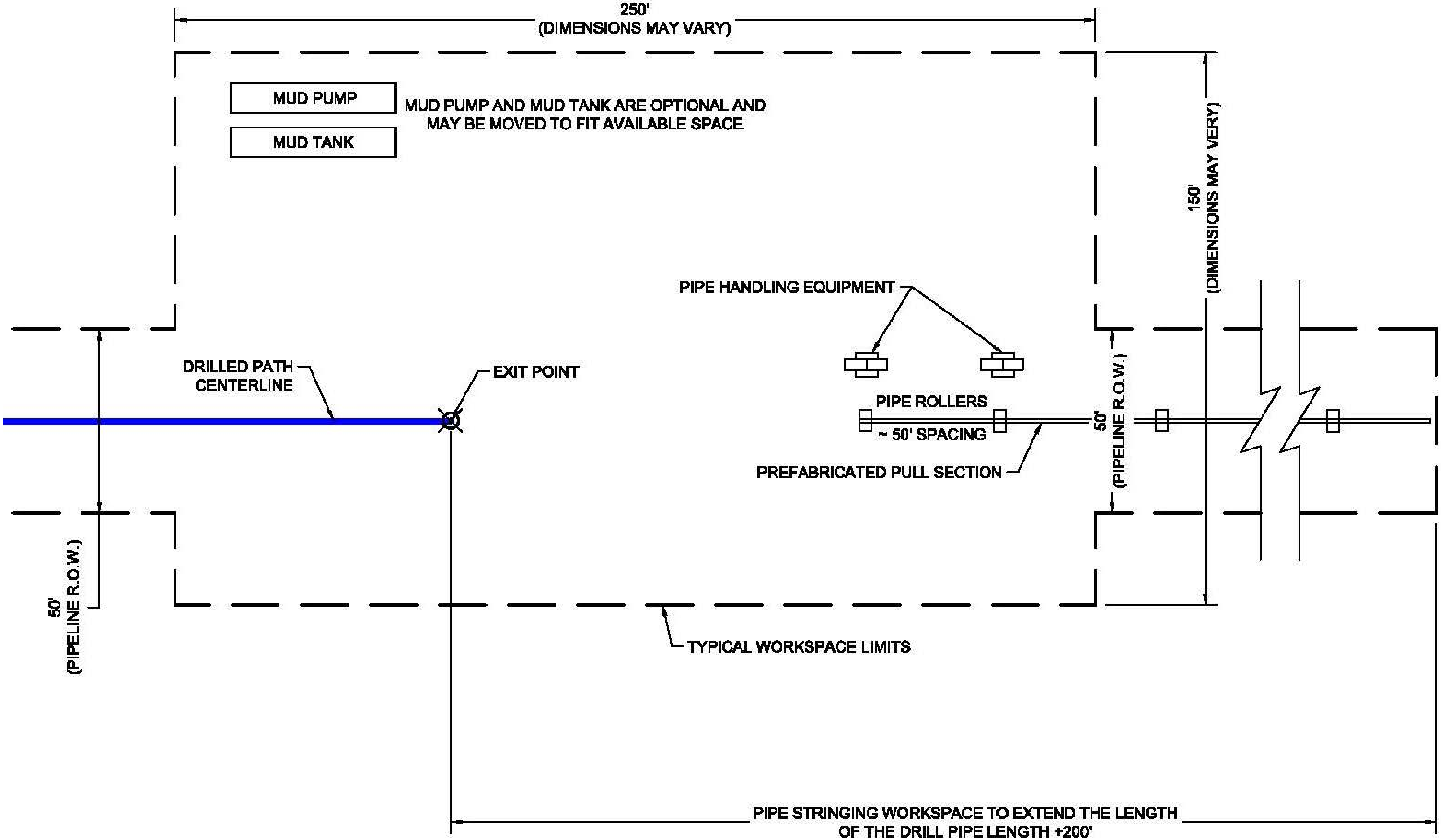
Exit & Pipe Stringing Workspace Requirements



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Installation Loads/Stress Calculations

Pipe requirements for HDD differ from open cut pipelines due to loads and stresses that act on the pipe during pullback operations. Pipe properties must be suitable for both installation and operation.

Installation stresses and the failure potential of the pipe are a result of the interaction of the following loads:

- Tension
  - Frictional Drag
  - Fluidic Drag
  - Effective Weight of Pipe
- Elastic Bending
- External Pressure

Operating stresses and the failure potential of the pipe are a result of the interaction of the following loads:

- Internal Pressure
- Thermal
- External Pressure
- Elastic Bending
  - Besides elastic bending, operating loads are essentially the same as those acting on open cut pipelines.
  - Bending stresses should be checked in combination with other longitudinal and hoop stresses.

Drilling Fluid Weight (lb/gal)	Buoyancy Condition	Effective Pipe Weight[2] (lb/ft)	Pullback Force[3] (lb)	Safe Pull Force (lb)
9.5	Empty	-36.5	119,000	527,000
9.5	Full	42.7	108,000	541,000
12	Empty	-62.6	141,000	522,000
12	Full	16.6	93,000	537,000
10.5	Neutral Buoyancy	0	86,000	525,000

Notes:

[1] See Appendix B for detailed calculations.

[2] Negative values indicate upward force (positive buoyancy).

[3] Assumes a fully open drilled hole.

Stress Component	Stress (psi)	Percent SMYS[1] (%)	Maximum Allowable Percent SMYS[1] (%)
Longitudinal Bending Stress	16,100	31	--
Hoop Stress	17,300	33	50(2)
Longitudinal Tensile Stress from Hoop Stress	5,200	10	--
Longitudinal Stress from Thermal Expansion	0	0	90(3)
Maximum Net Longitudinal Stress	21,300	41	90(4)
Maximum Shear Stress	14,100	27	45(5)
Maximum Combined Effective Stress	28,200	54	90(6)

Notes:

* Operating stress calculations are based on the specified minimum radius of curvature of 1,200 feet and assumed installation and operating temperatures of 70 degrees Fahrenheit

[1] Specified Minimum Yield Stress

[2] Limited by design factor from DOT regulations, Title 49 CFR Part 192.111 for gas

[3] Limited by Section 402.3.2 of ASME B31.4

[4] Limited by Section 833.3 of ASME B31.8 for gas

[5] Limited by Section 402.3.1 of ASME B31.4

[6] Limited by Section 833.4 of ASME B31.8 for gas

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