TRENCHLESS CONSTRUCTION METHODOLOGIES

Paragraph 2 of the Administrative Order issued by the Pennsylvania Department of Environmental Protection on January 3, 2018, to Sunoco Pipeline, L.P., ("Sunoco") requested that Sunoco submit a detailed description of any method of trenchless pipeline construction techniques that have been used or will be used in the completion of the Project. The specific construction techniques are described below.

Conventional Auger Bore

Conventional auger bores are a motor powered, pit launched, non-steerable method for the installation of pipes, conduits, and cables. The bore unit assembly is guided by rails or tracks inside a pit. The cutting tool is installed at the front of a screw auger in front of and inside a casing as a composite unit. The cutter and auger is "pushed" by the drive motor while simultaneously turning the cutter head and screw auger inside the casing. The cuttings are returned to the entry pit through the casing by the screw auger. The cutter is cooled by water injection if necessary. The exterior casing of the auger bore is lubricated during operations by water, or a bentonite/water slurry to prevent binding or sticking to the surrounding subsurface. Conventional auger bores are subject to deflection by rock geology, rocks in the subsurface, or other unknown hard objects in the bore path.

Guided Auger Bore

A guided auger bore is a variation of the conventional auger bore above where a "pilot" is installed first and the pilot stem is then attached to the front of the auger on a swivel during the reaming phase. Because a conventional auger bore is non-steerable and is subject to deflection, the pilot stem in front of the ream in this variation keeps the direction of the auger true during the reaming phase. The pilot can be installed by a small self-propelled HDD unit, or a pneumatic or hydraulic pilot unit, drilled or hammered through from the target exit point. Because a guided auger bore is an auger bore variation, water is used to cool the cutter if necessary, and water or a bentonite slurry, is used to lubricate the exterior of the casing to prevent sticking.

Cradle Bore

A cradle bore is a variation of the conventional auger bore above, except that the boring unit is suspended within a trench using side booms and track hoes, which saves time and effort over a conventional auger bore because it is operated without the need to build a pit for construction workers. Like conventional auger bores, cradle bores are subject to deflection by rock geology, rocks/boulders in the subsurface, or other unknown hard objects in the bore path.

Jack Bore/Hammer bore

Jack or hammer bores are a non-steerable pit launched horizontal or directional means of pushing casing pipe using repeated percussive blows using a ramming tool powered by hydraulic forces to install pipes, conduits, or cables. The hydraulic tool (jack or hammer) uses water, synthetic fluid, or compressed air to push the tool and casing through the subsurface. The exterior of the casing is lubricated during operations by water, or a bentonite/water slurry to prevent binding or sticking to the surrounding subsurface. The cuttings are contained in the casing and removed by gravity and vibration or after pull back of the pipe, conduit, or cable. Like conventional auger bores, jack or hammer bores are subject to deflection by rock geology, rocks/boulders in the subsurface, or other unknown hard objects in the bore path.

Guided Bores

Guided boring is a steerable trenchless method for the installation of pipes, conduits and cables using a surface or pit launched self propelled or trailer mounted drilling rig. Exits are typically, but not always, into an open trench for pull back of the pipe segment. Alternately, the drilling unit can be set back from the entry point face to allow for a depth of pipe only entry point, and receiving pits can be extended to allow for stem and tool exiting at shallow depth and pull back of the pipe. Guided bores can use air and water, water, or bentonite slurry during pilot or ream. Cuttings during pilot or ream return along annulus. Since a pilot tool is used that is suited to the specific substrate and is steerable, this method has better precision, and is commonly used when working adjacent to or when crossing other utilities.

FlexBor

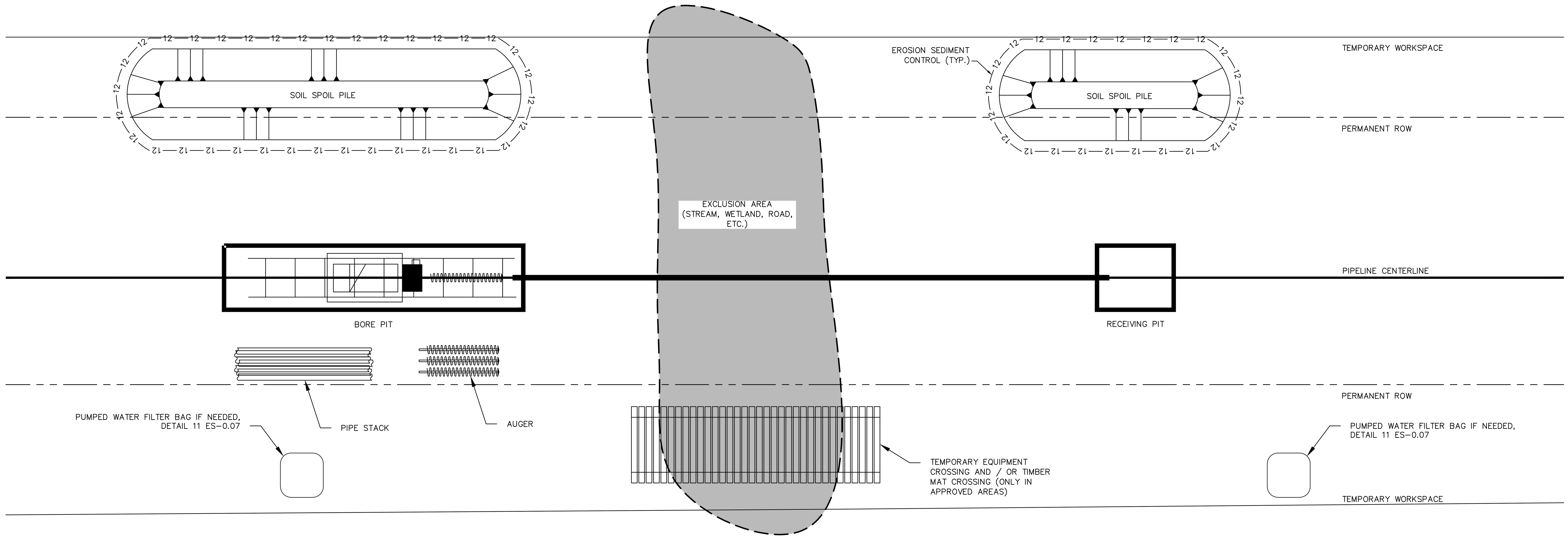
FlexBor is a hybrid of Horizontal Directional Drilling (HDD) and auger boring that can be pit or surface launched and is designed to minimize inadvertent return potential during the reaming process. Water and pressurized air is used during pilot if drilled, or the pilot may be forwarded by a tracked/steered hydraulic tool. The FlexBor technology is specifically designed to not use bentonite in the reaming phase, which could introduce a foreign material in the event of an inadvertent return (IR). Cuttings in the pilot phase return along annulus using air and water if drilled. Cuttings during the ream are returned inside a “casing” behind the reamer using high pressure air with water injection blown down the casing. As a result, IR potential during the ream is substantially reduced. A FlexBor can be employed using a small hydraulic powered unit, or converted standard HDD unit.

Horizontal Directional Drilling

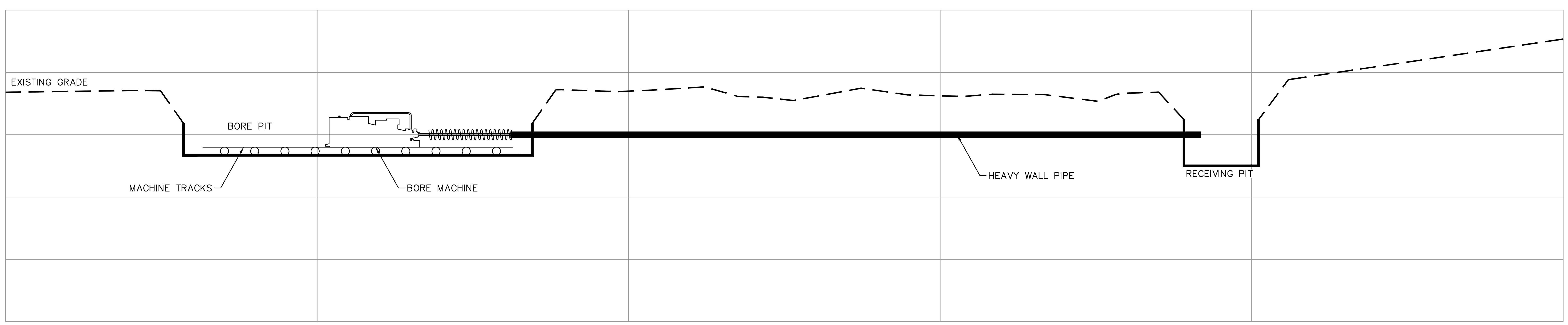
HDD is a steerable trenchless method of installing underground pipe, conduit, or cables in an arc along a prescribed path by using a surface launched drilling rig. Typically, the trailer mounted HDD unit is set immediately at the point of entry and elevated for an “entry angle” to rapidly proceed to the desired overall depth. As the tool approaches the desired or design depth, the tool progresses on an arc or “entry radius”, as determined by the allowable pipe stress. The tool then proceeds into the “horizontal run” where the length of the HDD is then completed, before it proceeds into the “exit radius” and subsequent return to the land surface. HDDs can use water for pilot and ream on short lengths, while bentonite slurry, or appropriate native cutting slurry is used in pilot or ream on longer distances. Cuttings in pilot or ream always return in the annulus.

Exhibit A-Table 1
Summary of Trenchless Construction Methods

Trenchless Construction Method	Pilot Equipment Type	Ream Equipment Type	Profile Type	Water Use	Bentonite Use	Loss of Circulation Potential	Inadvertent Return Potential
Conventional Auger Bore	None	Screw auger, motor drive	Flat	Used to cool cutter for bores through rock. Low volume, typically 1-2 gallons a minute in rock	Bentonite slurry applied to casing during ream to prevent binding.	None, returns enclosed by casing	None, returns enclosed by casing
Guided Auger Bore	Small diameter spoon cutter, machine or hydraulically driven, or self-propelled drill unit	Screw auger, motor drive	Flat	Used to cool cutter for bores through rock. Low volume, typically 1-2 gallons a minute in rock.	Bentonite slurry applied to casing during ream to prevent binding.	None to low varying by pilot type. None during ream, returns enclosed by casing	None to low varying by pilot type. None during ream, returns enclosed by casing
Cradle Bore	None, or small diameter spoon, machine or hydraulically driven	Screw auger, motor drive	Flat	Used to cool cutter for bores through rock. Low volume, typically 1-2 gallons a minute in rock.	Bentonite slurry applied to casing during ream to prevent binding.	None to low varying by pilot type. None during ream, returns enclosed by casing	None to low varying by pilot type. None during ream, returns enclosed by casing
Jack or Hammer Bore	Pneumatic or hydraulic driven hammer pilot	Pneumatic or hydraulic driven hammer hole enlargement	Flat	None	Bentonite slurry applied onto casing during enlargement to prevent binding.	None, hole enlarged by crushing tool at face and compression into surrounding subsurface	None, hole enlarged by crushing tool at face and compression into surrounding subsurface
Guided Bore	Small to medium size self-propelled drilling unit, spoon, jet head, or mud motor driver cutter	Open face rotated cutting tool	Flat to minor arc; surface or pit launch to pit or trench exit	Low to high pressure water, or water/bentonite slurry pumped through stem pipe to pilot head or reaming tool	Pressurized water, or water/bentonite slurry pumped through stem pipe to pilot head or reaming tool	None to high varying by surrounding soils or geologic strata, open annulus	None to high varying by surrounding soils or geologic strata, open annulus
FlexBor	Pneumatic or hydraulic driven hammer pilot; Small to medium size self-propelled drilling unit, trailer mounted drill unit, spoon, jet head, or mud motor drive cutter	High pressure air with low pressure water injection to open face injection cutter; enclosed drive stem, motor or drill unit drive	Flat, minor arc, or surface to surface radius	Low pressure water injection into high pressure air stream pumped through pilot casing	May or may not be used during pilot phase. Not used during reaming phase.	None to high varying by pilot type. None during ream, cuttings blown through enclosed annulus, no circulated fluids	None to high varying by pilot type. None during ream, cuttings blown through enclosed annulus, no circulated fluids
Horizontal Direction Drill	Medium self-propelled, or trailer mounted drilling unit, jet head, or mud motor drive cutter	Open face rotated cutting tool, drill unit drive	Surface to surface radius	Pressurized water, or water/bentonite slurry pumped through stem pipe to pilot head or reaming tool	Pressurized water, or water/bentonite slurry pumped through stem pipe to pilot head or reaming tool	None to high varying by surrounding surface soils or geologic strata	None to high varying by surrounding surface soils or geologic strata



PLAN VIEW



PROFILE VIEW

TYPICAL CONVENTIONAL BORE CROSSING LAYOUT
NOT TO SCALE

NOTES:

1. LAYOUT WILL VARY ACCORDING TO AVAILABLE WORK SPACE AND FIELD CONDITIONS.
2. WORKSPACE AVAILABLE FOR PARKING, STAGING, AND OTHER USES WHEN NOT BEING USED FOR BORING.
2. INSTALL COMPOST FILTER SOCKS/SILT FENCE ALONG THE DOWN GRADIENT PERIMETERS OF THE BORE PITS. SEE SITE PLANS FOR E&S CONTROLS.
3. EXCAVATE BORE PITS IN ACCORDANCE WITH SITE-SPECIFIC PLANS AND SEGREGATE TOP SOIL IN ACCORDANCE WITH STANDARD E&SC PLAN NOTES. POSITION BORE PITS A MINIMUM OF 50 FEET FROM THE NEAREST TOP OF BANK, WHERE TECHNICALLY FEASIBLE.
4. THE CROSSING LENGTH IS DEPENDENT UPON THE OBSTACLE TO BE CROSSED, AND THE SURFACE AND SUBSURFACE CONDITIONS.

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REVISIONS

NO.	BY	DATE	REMARKS

SUNOCO PIPELINE L.P.
SINKING SPRING, PENNSYLVANIA

PENNSYLVANIA PIPELINE PROJECT

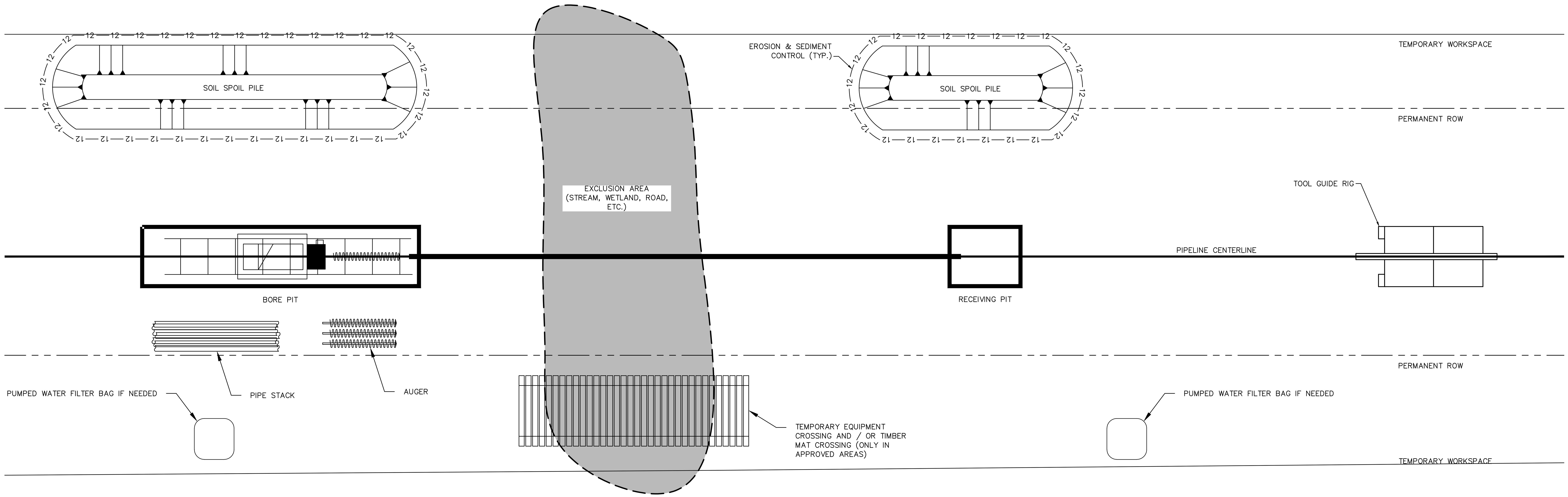
1-20" & 1-16" PROPOSED WELDED STEEL NATURAL GAS LIQUIDS PIPELINES

TYPICAL CONVENTIONAL AUGER BORE DETAIL

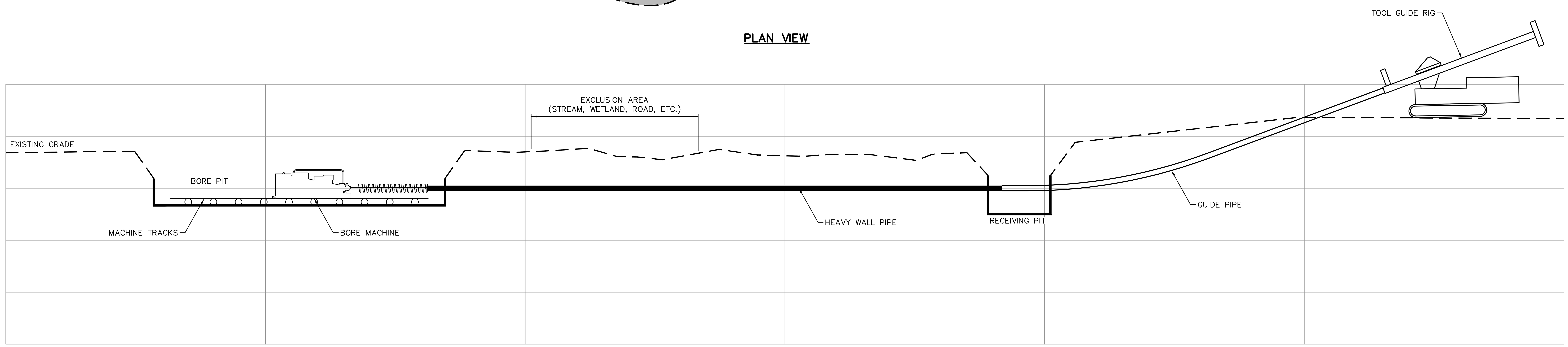
DATE:	2/6/2017
PROJECT NO.:	112C05958
DESIGNED BY:	JB
DRAWN BY:	BH
CHECKED BY:	RS

FIGURE 1
SHEET 1 OF 8

R:_Marcellus Shale Projects\Sunoco\5958 – Penn Pipeline Project\Reference\Drawings\Bore Drawings\Figure 1 – Conventional Bore.dwg PIT BEN.HOPPE 1/11/2018 6:52:07 AM



PLAN VIEW



PROFILE VIEW

TYPICAL GUIDED BORE "A" (UNCASED) LAYOUT

NOT TO SCALE

NOTES:

1. LAYOUT WILL VARY ACCORDING TO AVAILABLE WORK SPACE AND FIELD CONDITIONS.
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SUNOCO PIPELINE L.P.
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PENNSYLVANIA PIPELINE PROJECT

1-20" & 1-16" PROPOSED WELDED STEEL NATURAL GAS PIPELINE

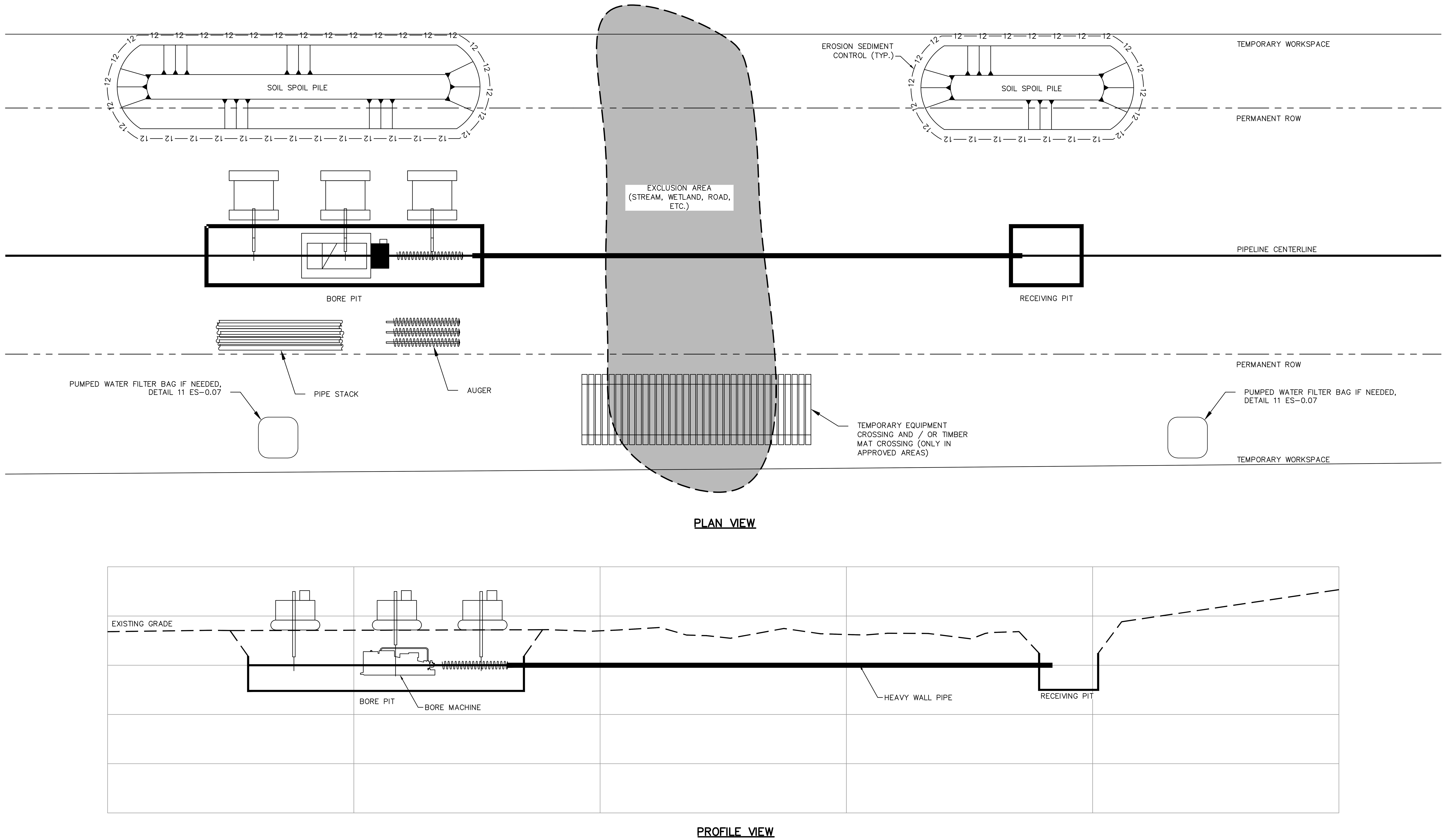
TYPICAL GUIDED AUGER BORE DETAIL

DATE:	1/5/18
PROJECT NO.:	112C05958
DESIGNED BY:	JB
DRAWN BY:	BH
CHECKED BY:	RS

FIGURE 2

SHEET 2 OF 8

R:_Marcellus Shale Projects\Sunoco\5958 – Penn Pipeline Project\Reference\Drawings\Bore Drawings\Figure 2 – Guided Bore Detail.dwg PIT BEN.HOPPE 1/11/2018 6:55:21 AM



NOTES:

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TYPICAL CRADLE BORE CROSSING LAYOUT

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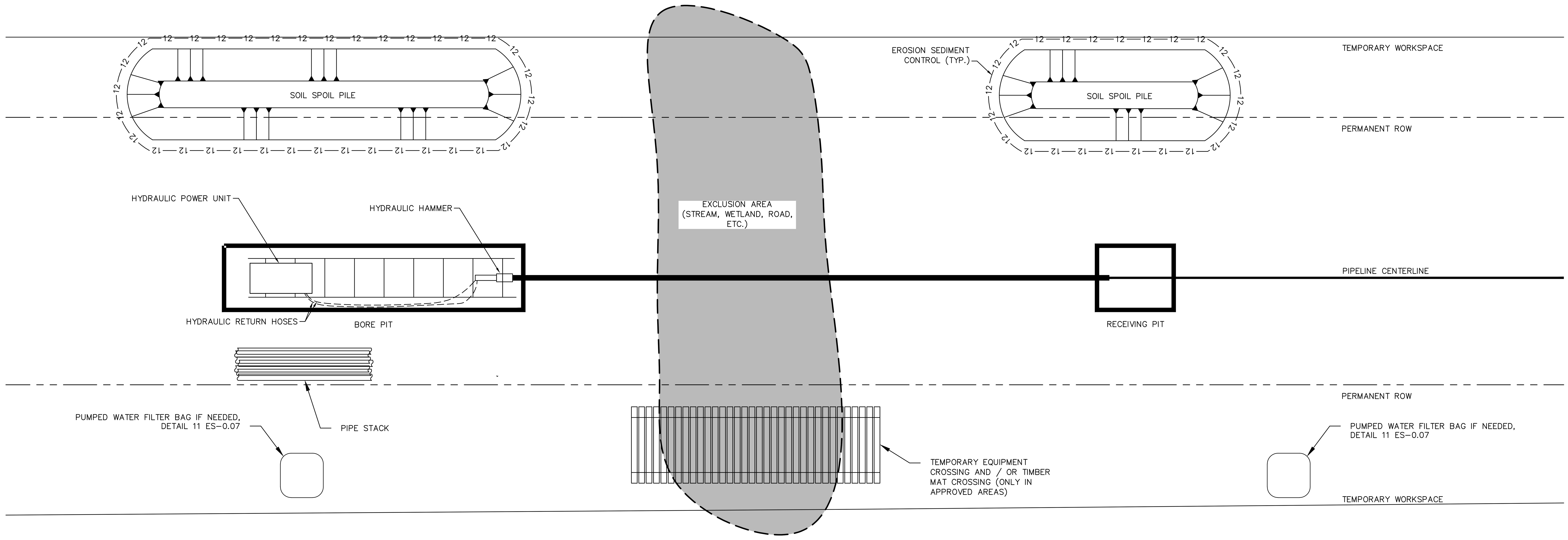
1-20" & 1-16" PROPOSED WELDED STEEL NATURAL GAS LIQUIDS PIPELINES

TYPICAL CRADLE BORE DETAIL

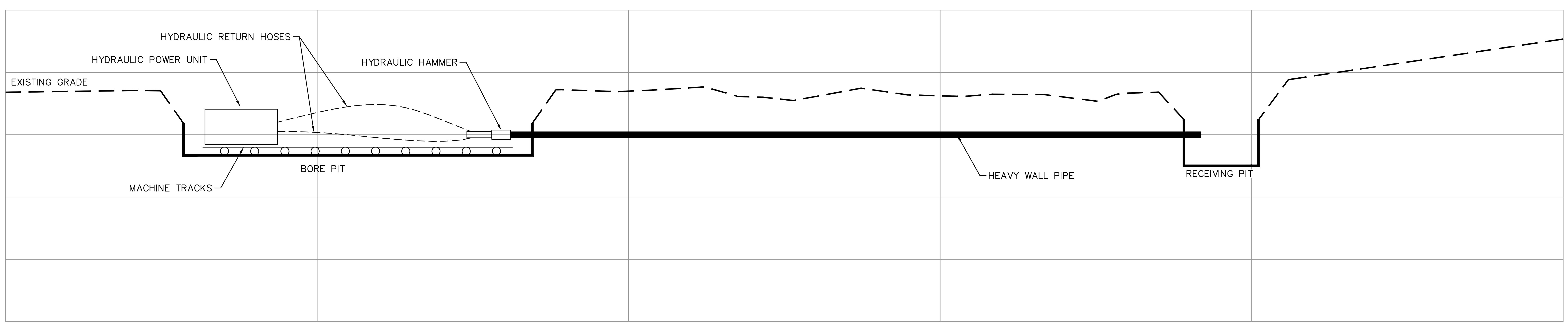
DATE:	1/11/2018
PROJECT NO.:	112C05958
DESIGNED BY:	JB
DRAWN BY:	BH
CHECKED BY:	RS

FIGURE 3

SHEET 3 OF 8



PLAN VIEW



PROFILE VIEW

TYPICAL CONVENTIONAL HAMMER BORE CROSSING LAYOUT
NOT TO SCALE

NOTES:

1. LAYOUT WILL VARY ACCORDING TO AVAILABLE WORK SPACE AND FIELD CONDITIONS.
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SUNOCO PIPELINE L.P.
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PENNSYLVANIA PIPELINE PROJECT

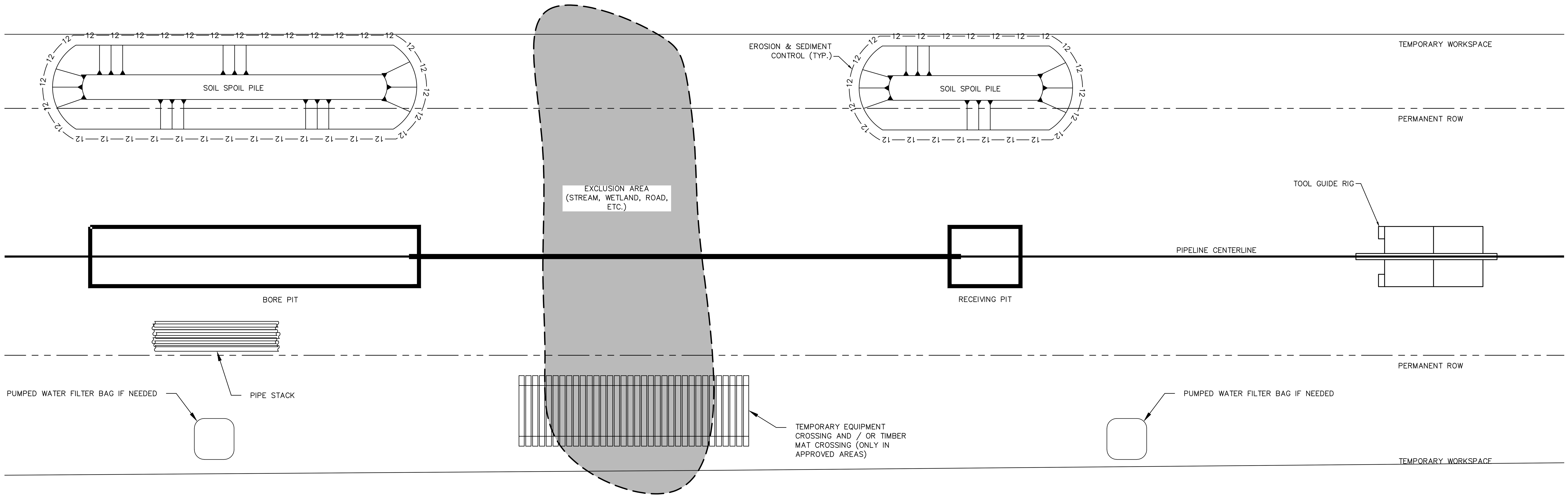
1-20" & 1-16" PROPOSED WELDED STEEL NATURAL GAS LIQUIDS PIPELINES

TYPICAL CONVENTIONAL HAMMER BORE DETAIL

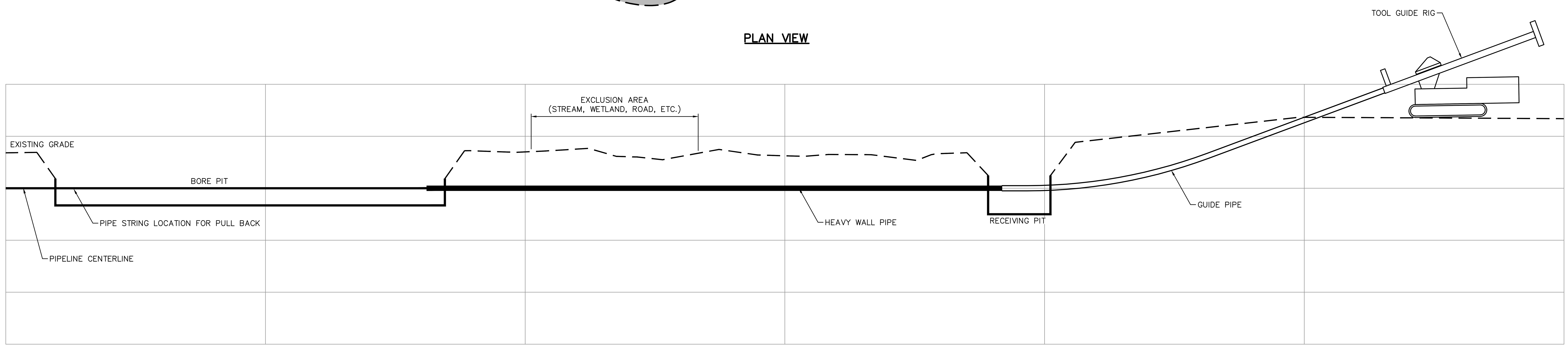
DATE:	1/11/18
PROJECT NO.:	112C05958
DESIGNED BY:	JB
DRAWN BY:	BH
CHECKED BY:	RS

FIGURE 4
SHEET 4 OF 8

R:_Marcellus Shale Projects\Sunoco\5958 – Penn Pipeline Project\Reference\Drawings\Bore Drawings\Figure 4 – Hammer Bore.dwg PIT BEN.HOPPE 1/11/2018 10:10:40 AM



PLAN VIEW



PROFILE VIEW

NOTES:

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TYPICAL GUIDED BORE "A" (UNCASED) LAYOUT

NOT TO SCALE

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REVISIONS

NO.	BY	DATE	REMARKS

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PENNSYLVANIA PIPELINE PROJECT

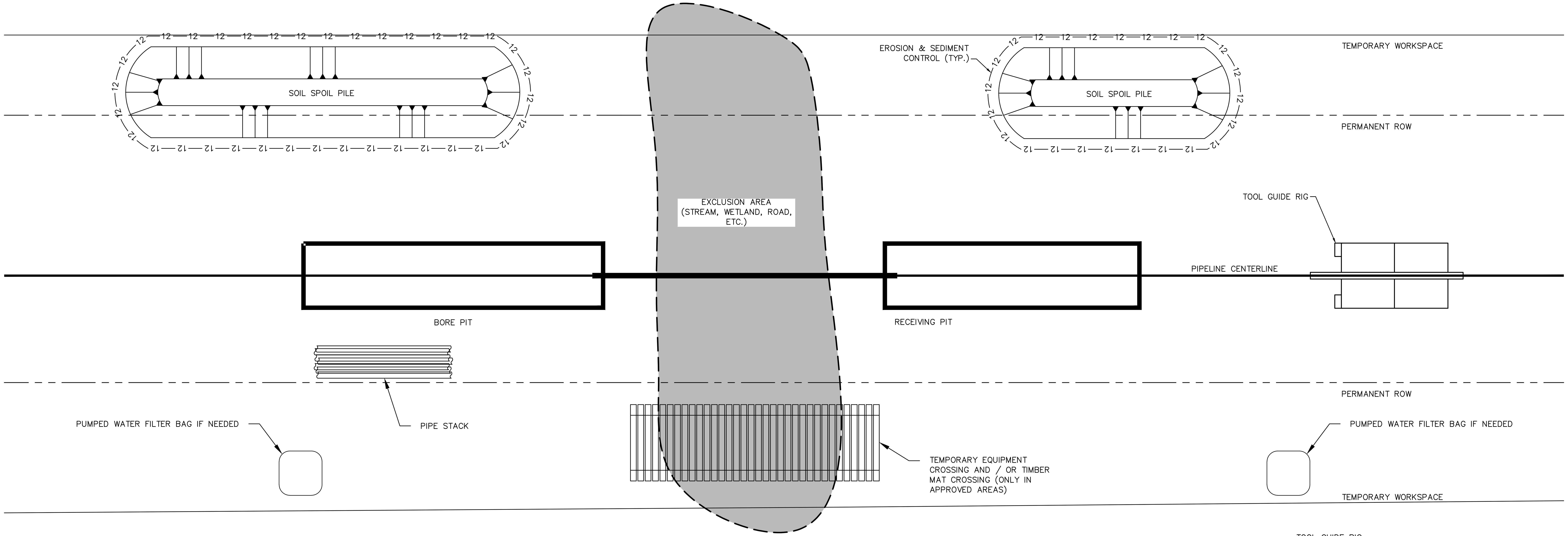
1-20" & 1-16" PROPOSED WELDED STEEL NATURAL GAS PIPELINE

TYPICAL UNCASED GUIDED BORE DETAIL

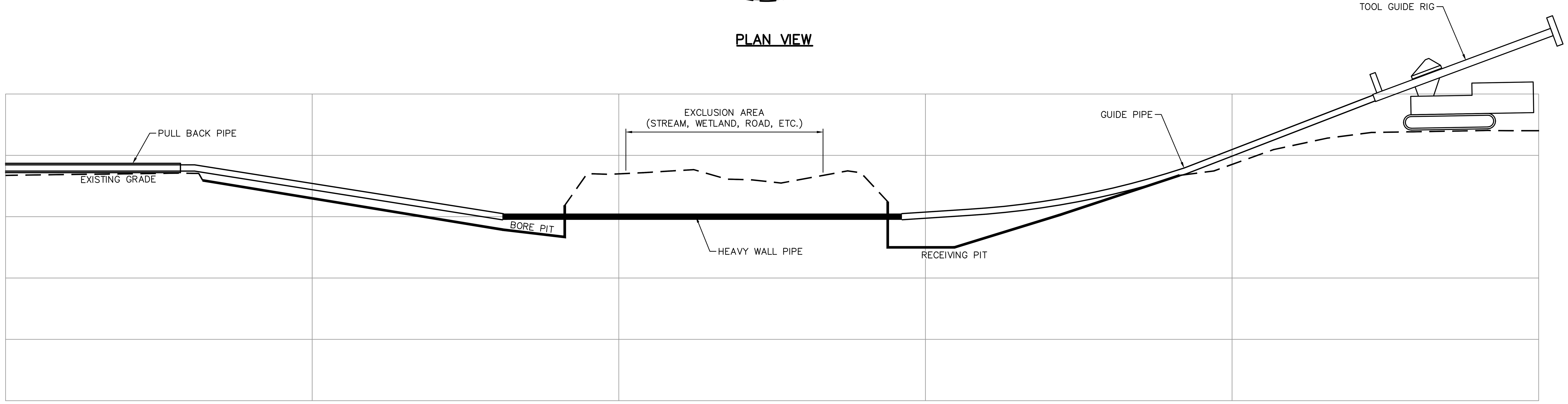
DATE:	1/5/18
PROJECT NO.:	112C05958
DESIGNED BY:	JB
DRAWN BY:	BH
CHECKED BY:	RS

FIGURE 5

SHEET 5 OF 8



PLAN VIEW



PROFILE VIEW

TYPICAL GUIDED BORE "B" LAYOUT

NOT TO SCALE

NOTES:

1. LAYOUT WILL VARY ACCORDING TO AVAILABLE WORK SPACE AND FIELD CONDITIONS.
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1-20" & 1-16" PROPOSED WELDED STEEL NATURAL GAS PIPELINE

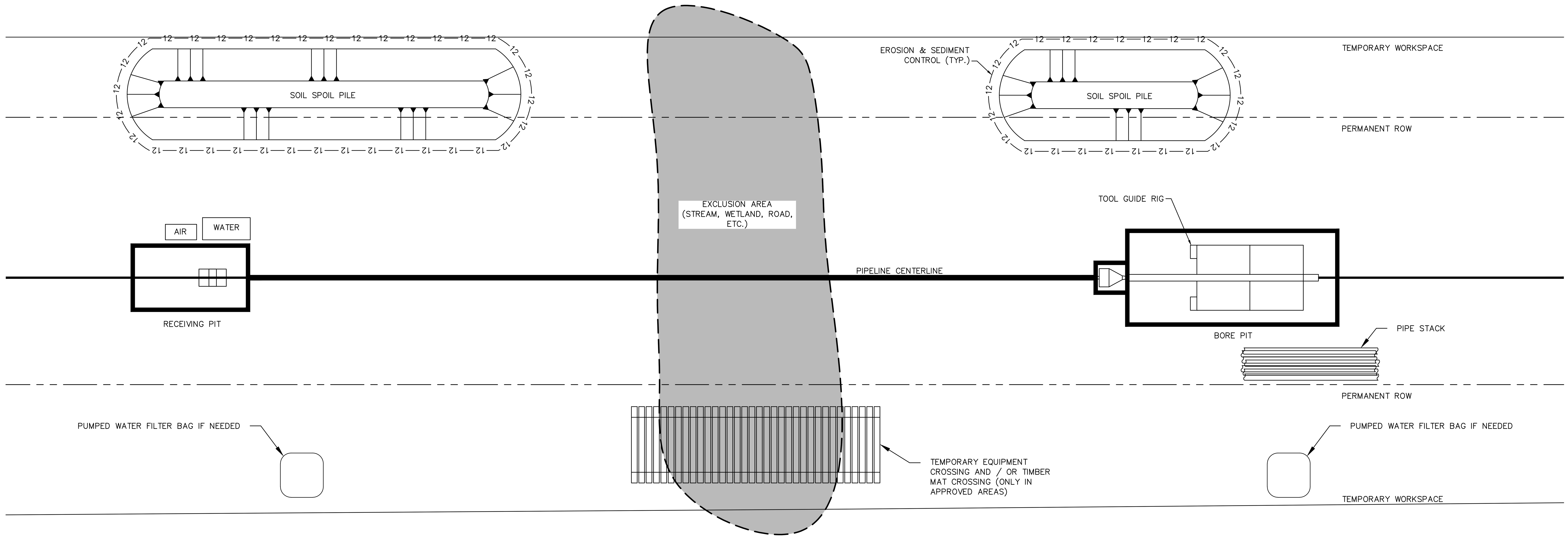
TYPICAL GUIDED BORE DETAIL

DATE:	1/5/18
PROJECT NO.:	112C05958
DESIGNED BY:	JB
DRAWN BY:	BH
CHECKED BY:	RS

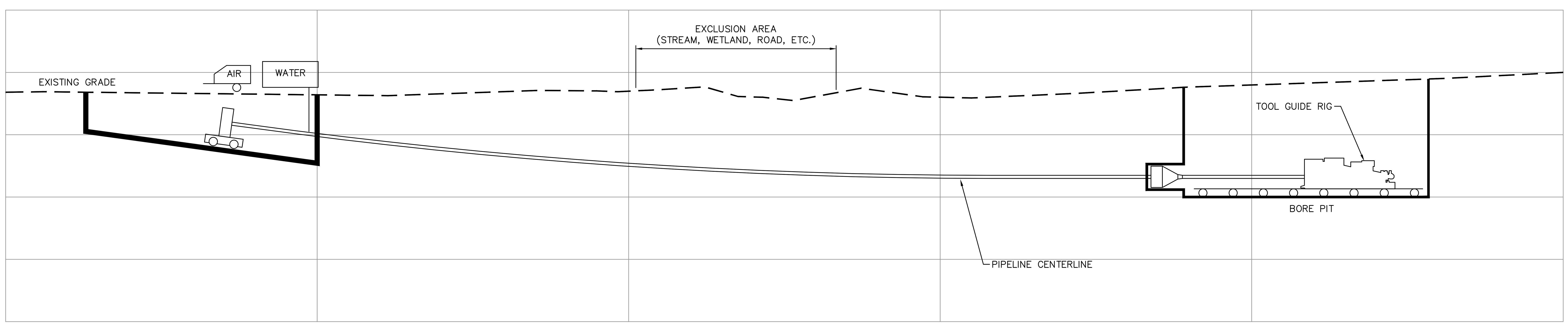
FIGURE 6

SHEET 6 OF 8

R:_Marcellus Shale Projects\Sunoco\5958 – Penn Pipeline Project\Reference\Drawings\Bore Drawings\Figure 6 – Cased Guided Bore Detail.dwg PIT BEN.HOPPE 1/11/2018 10:09:46 AM



PLAN VIEW



PROFILE VIEW

TYPICAL FLEXBOR BORE LAYOUT

NOT TO SCALE

NOTES:

1. LAYOUT WILL VARY ACCORDING TO AVAILABLE WORK SPACE AND FIELD CONDITIONS.
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REVISIONS

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PENNSYLVANIA PIPELINE PROJECT

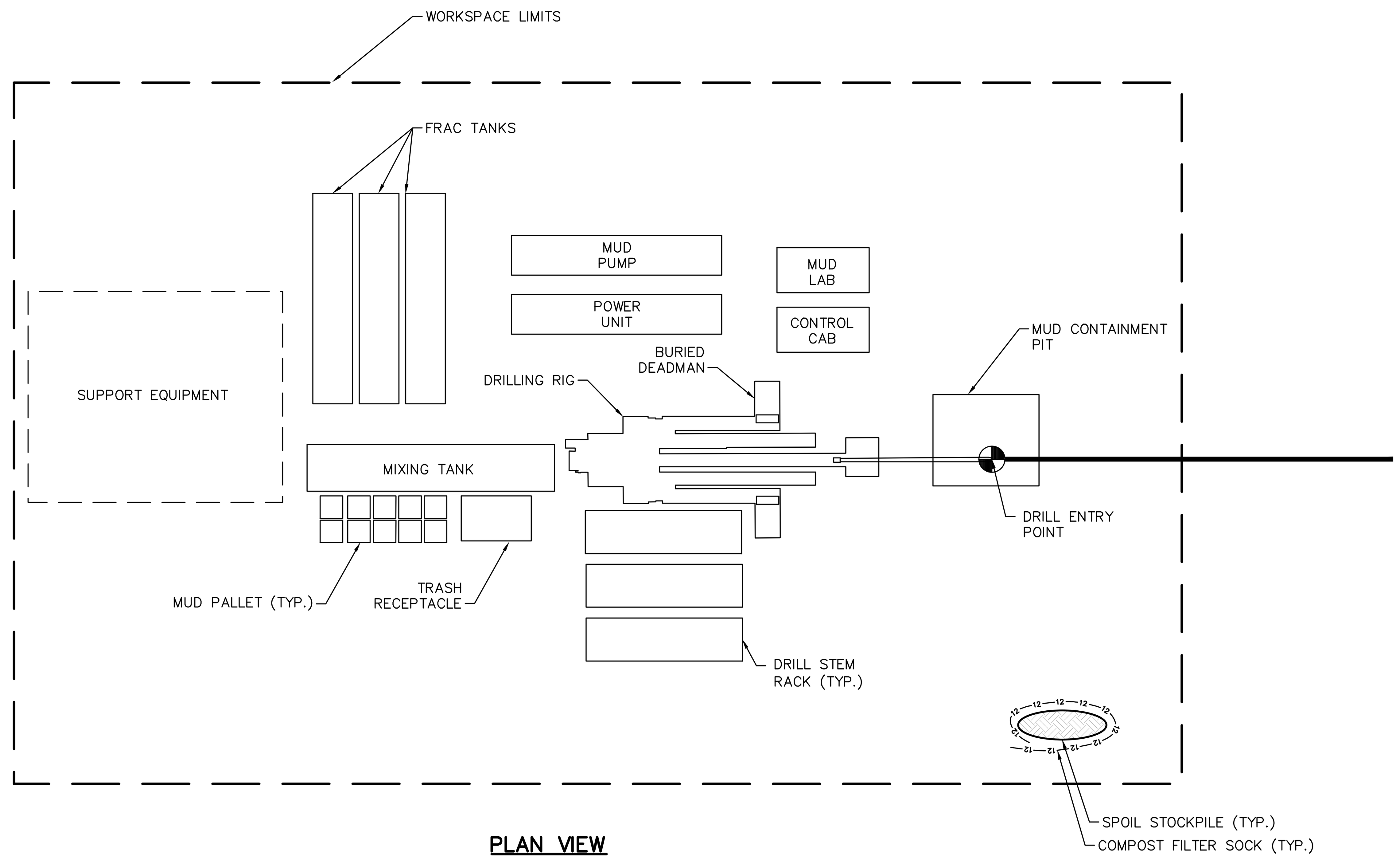
1-20" & 1-16" PROPOSED WELDED STEEL NATURAL GAS LIQUIDS PIPELINES

TYPICAL FLEXBOR DETAIL

DATE:	1/5/18
PROJECT NO.:	112C05958
DESIGNED BY:	JB
DRAWN BY:	BH
CHECKED BY:	RS

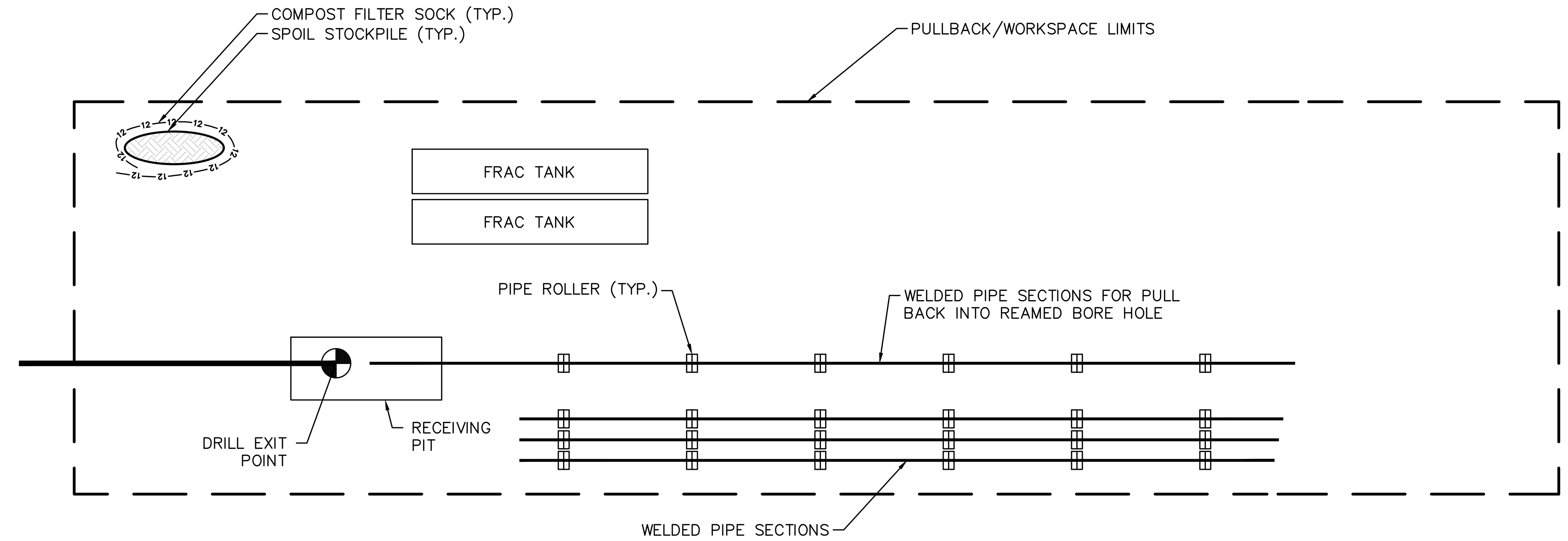
FIGURE 7

SHEET 7 OF 8



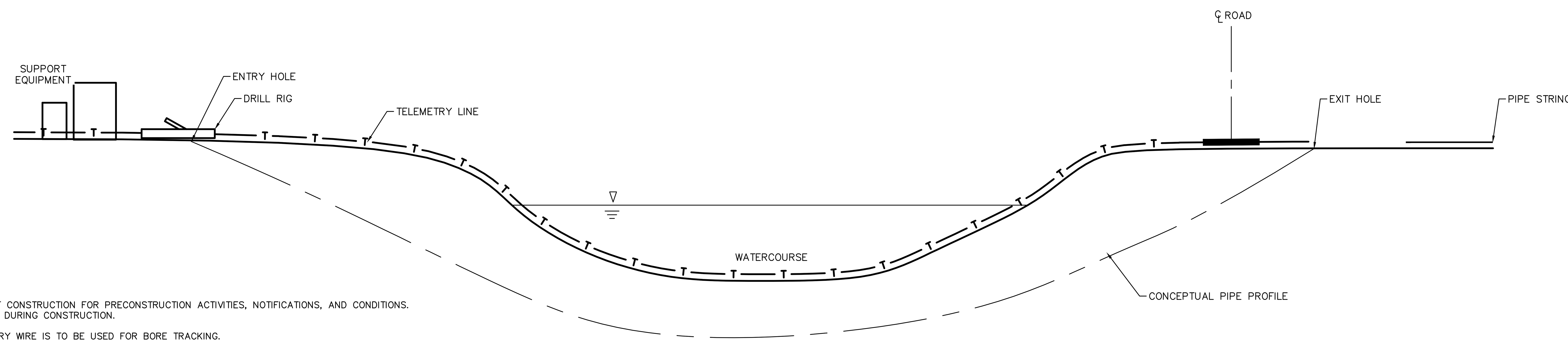
PLAN VIEW

ENTRY SIDE LAYOUT
NOT TO SCALE



PLAN VIEW

EXIT SIDE LAYOUT
NOT TO SCALE



PROFILE VIEW

TYPICAL HDD BORE LAYOUT
NOT TO SCALE

NOTES:

1. REVIEW INADVERTENT RETURN AND PROJECT PPC PLANS AHEAD OF CONSTRUCTION FOR PRECONSTRUCTION ACTIVITIES, NOTIFICATIONS, AND CONDITIONS. MAKE ALL APPROPRIATE NOTIFICATIONS. IMPLEMENT THESE PLANS DURING CONSTRUCTION.
2. REVIEW HDD FOR WRITTEN ATON PLAN AND IMPLEMENT IF TELEMETRY WIRE IS TO BE USED FOR BORE TRACKING.
3. SEE SITE PLANS FOR E&S CONTROLS.
4. LAYOUT WILL VARY ACCORDING TO AVAILABLE WORK SPACE AND FIELD CONDITIONS.
5. GRADE AND TOPSOIL WORKSPACES WHERE NECESSARY TO MAKE WORKSPACE AVAILABLE FOR PARKING, STAGING, AND OTHER USES WHEN NOT BEING USED FOR BORING.
6. HDD BENEATH WETLAND AND WATERBODIES WHERE INDICATED ON E&S PLAN SHEETS. SEE SITE-SPECIFIC DRAWINGS IF NOTED TO BE AVAILABLE.
7. INSTALL TEMPORARY TIMBER WETLAND MATS IF WORKSPACES ARE IN WETLANDS.
8. TEMPORARY WATERBAR TO BE INSTALLED AFTER CLEARING AND PRIOR TO TEMPORARY GRADING IF NEEDED FOR HDD INSTALLATION.
9. PERMANENT WATERBAR TO BE INSTALLED AFTER CLEARING AND PRIOR TO TEMPORARY GRADING IF NEEDED FOR HDD INSTALLATION AND REINSTALLED ONCE FINAL GRADING ESTABLISHED.
10. TELEMETRY WIRE WILL BE STRUNG FROM ENTRY TO EXIT POINTS.
11. INSTALL COMPOST FILTER SOCKS/SILT FENCE ALONG THE DOWN GRADIENT PERIMETERS OF THE HDD BORE PIT.
12. EXCAVATION OF THE DRILL ENTRY AND EXIT LOCATIONS WILL BE NECESSARY TO CONTAIN DRILLING FLUIDS DURING ALL PHASES OF INSTALLATION. THESE FLUIDS AND CUTTINGS MUST BE DISPOSED OF IN AN APPROVED MANNER PERIODICALLY OR AT THE COMPLETE CROSSING INSTALLATION.
13. THE CROSSING LENGTH AND CROSS SECTIONAL GEOMETRY IS DEPENDENT UPON THE PIPELINE DESIGN PARAMETERS, THE OBSTACLE CROSSED, AND THE SUBSURFACE CONDITIONS.

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REVISIONS

NO.	BY	DATE	REMARKS

SUNOCO PIPELINE L.P.
SINKING SPRING, PENNSYLVANIA

PENNSYLVANIA PIPELINE PROJECT

1-20" & 1-16" PROPOSED WELDED STEEL NATURAL GAS LIQUIDS PIPELINES

TYPICAL HDD BORE DETAIL

DATE:	2/6/2017
PROJECT NO.:	112C05958
DESIGNED BY:	JB
DRAWN BY:	BH
CHECKED BY:	RS

FIGURE 8
SHEET 8 OF 8

R:_Marcellus Shale Projects\Sunoco\5958 – Penn Pipeline Project\Reference\Drawings\Bore Drawings\Figure 8 – HDD Bore.dwg PIT BEN.HOPPE 1/11/2018 6:51:33 AM