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HORIZONTAL DIRECTIONAL DRILL - ROOT CAUSE RISK EVENTS

SUB-SURFACE RISK EVENTS		
Root Cause Code	**Root Cause Name**	**Root Cause Definition**
E1	Hydraulic Fracturing	Drilling fluid that escapes the borehole annulus and is released to the surface required a stop in production. Clean-up activities were initiated and decisions made on how to proceed given the location of the fluid release and ability to contain.
E2	Collapsing Soil / Lost Hole	Soft cohesive soils can squeeze into the borehole annulus or loose granular soils can fall into the borehole annulus bridging off the borehole. Drilling production was stopped and mitigative measures established to prevent more risk events from occurring, such as losing drilling fluid circulation, hydraulic fracturing or having the drill rods become stuck in the hole.
E3	Loss of Circulation	Drilling fluid is pumped from the drill rig at surface through the drill stem to the cutting tool at the bottom of the hole, then returns to the drill rig via the borehole annulus to be cleaned of cuttings and re-circulated. When the volume returning to the drill rig at surface is reduced or completely lost into the subsurface, drilling production is stopped and mitigative measures are required to attempt to gain circulation such as modifying the drilling fluid properties, applying lost circulation materials (sawdust, magma fibre, etc.), grouting the thief zone or applying conductor casing.
E4	High Annular Pressure	The downhole annular pressure is monitored during pilot hole drilling and is maintained within empirical thresholds. When annular pressures approach or exceed allowable pressures, the drilling stops and mitigative measures are required.
E5	Abnormally Slow Production	Subsurface conditions that contribute to slow production and require that the drilling/reaming assembly be checked at surface.
E6	Reduced Drill Cuttings Return	Drill cuttings that are not effectively removed from the borehole annulus require a stop in normal production and require mechanical cleaning of the borehole by resizing the annulus with the cutting tool as it is removed from the borehole. Cutting beds and/or a restriction of the borehole annulus diameter may be developed as a result of subsurface conditions that promote swelling or result from circulation loss. Drilling operations reacting to the subsurface conditions such as rate of penetration, drilling fluid condition and volume of material cut may also contribute to reduced drill cuttings return.
E7	Drill String Stuck in Hole	Drilling progress is halted as a result of the drill pipe being stuck in the borehole due to subsurface conditions. This risk event is often precipitated by any/or E1-E6 occurring.
E10	Down-hole Tooling Malfunction/Damage	A stop in production resulting from a rapid or catastrophic degradation of the downhole drilling assembly caused by subsurface conditions and does not represent normal wear and tear.
E14	Pilot Hole Deviations	Schedule delays resulting from a segment of the pilot hole that is outside of the specified tolerances of the planned drill path. The HDD contractor pulls-back and re-drills from the location along the bore path before the deviation to remain within specified tolerances. The subsurface conditions will promote a deviated bore path.
E15	Flow to Exit	A schedule delay results when remedial action is required to respond to drilling fluid flowing to exit, such as using a vacuum truck to clean up the drilling fluid. Subsurface conditoins and an elevation differential from entry to exit can promote fluid flow to exit.
E16	Drilling Fluid / Solids Control Work	Non-schedule delays to production resulting from building or modifying drilling fluid, or unitl drill cuttings have been cleaned out of a holding area. This risk event is precipated by other subsurface risk events. For example, a loss of circulation event will result in building additional drilling fluid and/or building and applying loss of circulation materaisl in an attempt to seal the loss of circulation zone. Encountering formation that react negatively with the drilling fluid result in schedule delays due to modifications/additives required to the drilling fluid. Solids control work results in a schedule delya caused by removing excessive drill cuttings from a holding area resulting from tripping out of the borehole to clean the horehole annulus.

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SUB-SURFACE RISK EVENTS - CONTINUED		
Root Cause Code	**Root Cause Name**	**Root Cause Definition**
E18	Water Production	The borehole can produce formation water as a result of artesian conditions or when drilling above the entry elevation through a perched water table. During these occurrences, drilling fluid clean-up and modification is required and was recorded as a risk event within the construction process.
E19	Conductor Casing Delays	Through drilling operations, such as wash-out at the end of the casing or boyancy of the drill pipe or product line, instances may occur where the drilling assemly or the pdoduct line will not entre the casing resulting in dealys to mitigate the issue.
E20	Damaged Product Line	Instances where the product line or product line coating has become damaged to the point that remedial action must be taken were documented as a risk event. Protective coatings on the product line can be damaged during product installation due to excessive pull-back forces involved and by contact with abrasive soil/bedrock present in the borehole. **Edit** - includes all product lines during pull-back (pipe, cables, coatings, and wrap material). Acceptance is based on Owner satisfaction upon successful coating continuity and/or conductance test, gauge plate pig run, ILI pig run/tether tool, and hydrostatic pressure test.
E21	Product Line Stuck in Hole	Similar to Risk Event E7, the product line can become stuck in the hoole and cannot be pulled ot the entry point for installation. A stuck product line results from a caving borehole annulus or from an annulus that has not been sufficiently cleared of cuttings. **Edit** - includes other downhole obstructions that may have caused stuck product line such as obstructions at any point of intersect, rocks or geoformations causing abrasive resistance to product pipe, or drill/pullback equipment getting stuck on bottom of entry casing.

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SURFACE RISK EVENTS		
Root Cause Code	**Root Cause Name**	**Root Cause Definition**
E8	Wait on Vacuum Truck	A stop in production resulting from the clean-up of drilling fluid using a vacuum truck. Astop in production is often due to waiting for the vacuum truck to arrive on site or as a result of safety protocol as it worked around the HDD equipment. Drilling fluid clean-up/recovery is typically implemented as a result of drilling fluid released to surface (E1) or drilling fluid migrating to the exit side (E15), or as a result of water production (E18). **Edit** - Excessive Vacuum Truck demand may also be caused by upfront project decision to not utilize a drilling fluid recycling unit. In this case the root cause may have been attempts to reduce costs earlier in the project that resulted in increased operational costs. Any schedule delays would proportionally increase vacuum truck and fluid disposal costs.
E9	Wire-line Malfunction/Damage	A schedule delay resulting from a borken or damaged wire-line connection causing an interruption to the flow of power to the downhole steering and/or annular pressure tools. The contractor was required to trip out of the borehole to locate and repair the malfunction to the wire-line to allow for steering and annulare pressure monitoring.
E11	Surface Equipment Malfunction / Damage	A stop in production resulting from a component of the surface equipment such as the drilling fluid recycling system, drill rig, or exit side equipment requireing repair, replacement, or unscheduled maintenance.
E13	Wait on Equipment / Services	A time delay preventing production due to the requirement of necessary equipment or services. Often, HDD site locations are remotely located and a time delay resulted from acquiring necessary equipment / services such as delivery of water, drilling additives, and equipment components.
E17	Weather Delay	Inclement weather can directly result in non-scheduled delays to production such as heavy or extensive rainfall, thunderstorms, and extremely cold temperatures (below ~-30C) and blizzard conditions.

ADMINISTRATIVE RISK EVENTS		
Root Cause Code	**Root Cause Name**	**Root Cause Definition**
E12	Wait on Owner	When a subsurface risk event occurs that stops production, the contractor informs the Owner of the risk event and events leading to the risk and assists in developing mitigation strategies. Production is stopped due to the time required for the Owner or Owner's representative to arrive at a decision or seek authorizations in developing or implementing mitgation strategies as a result of a subsurface risk event. E23 is waiting on Owner if Engineering design change is involved.
E22	Land / Environment / 3rd Party Approvals	In some cases Land, Environmental Regulations, and 3rd party agreements may cause delays to the project while Owner attempts to remediate this cause.
E23	Engineering / Design Change	During construction there may be circumstances that require an engineering or design change. Such changes may be a result of improperly identified entry/exit locations, or actual conditions differing from design or surveyed site conditions. This may result in changes to designed drill path, and drag section. Schedule delays and costs are a result of standby while Owner works with Engineer for design change. This is not to be mistaken with E12 which is standby waiting on owner decision (without engineering design change).