

**Exhibit F**  
**Tetra Tech Report**

# Report of Geohazard Evaluation South Bend Pipeline Segment West Central North Dakota

Tetra Tech Project No. 117-0533085

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## PRESENTED TO

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## **TABLE OF CONTENTS**

1	INTRODUCTION .....	1
1.1	PURPOSE AND SCOPE OF FIELD EVALUATIONS .....	1
2	SLOPE SELECTION AND DATA COLLECTION .....	1
2.1	SLOPE SELECTION .....	1
2.2	DATA COLLECTION .....	2
2.2.1	Public Sources and Types .....	2
2.2.2	Private Sources and Types .....	2
3	GEOHAZARD IDENTIFICATION .....	2
3.1	GEOLOGIC SETTING .....	2
3.2	GEOHAZARD RANKING CRITERIA .....	3
4	FIELD EVALUATION .....	4
4.1	FIELD EVALUATION SUMMARY .....	4
4.2	FINDINGS AND CONCLUSIONS .....	4
4.3	ADDITIONAL ANALYSIS .....	5
5	GEOHAZARD SUMMARIES, MITIGATION ALTERNATIVES, AND RECOMMENDATIONS .....	5
5.1	GEOHAZARD SUMMARIES .....	5
5.1.1	Potential Slope 1, Golden Valley County, North Dakota .....	5
5.1.2	Potential Slope 2, Golden Valley County, North Dakota .....	6
5.1.3	Potential Slope 4, McKenzie County, North Dakota .....	6
5.1.4	Potential Slope 5, McKenzie County, North Dakota .....	6
5.1.5	Potential Slope 6, McKenzie County, North Dakota .....	7
5.1.6	Potential Slope 7, McKenzie County, North Dakota .....	7
5.2	MITIGATION ALTERNATIVES SUMMARY .....	8
5.3	GENERAL RECOMMENDATIONS .....	10
6	LIMITATIONS .....	11

## **LIST OF TABLES**

Table 4-1: Slope Geohazard Ranking Criteria

## **LIST OF FIGURES**

Figure 1: 2020 South Bend Project Segment – Overview and Slope Crossings Map

Figure 2: Slope 1, Golden Valley County, North Dakota

Figure 3: Slope 2, Golden Valley County, North Dakota

Figure 4: Slope 4, McKenzie County, North Dakota Photo Map

Figure 5: Slope 5, McKenzie County, North Dakota Photo Map

Figure 6: Slope 6, McKenzie County, North Dakota Photo Map

Figure 7: Slope 7, McKenzie County, North Dakota Photo Map

## **APPENDIX**

Appendix A: Field Forms

## ACRONYMS / ABBREVIATIONS

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Acronyms/Abbreviations	Definition
BMP	Best Management Practice
ESRI	Environmental Systems Research Institute
GIS	Geographic Information Systems
RTK GPS	Real-Time Kinematic Global Positioning System
USGS	United States Geological Survey

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## **1 INTRODUCTION**

At the request of Belle Fourche Pipeline, LLC (Belle Fourche Pipeline), a field geologic hazard evaluation has been completed at six (6) sites of concern identified by Belle Fourche Pipeline along the proposed South Bend segment in the Little Missouri Badlands area of west central North Dakota. Six (6) field evaluation sites were located along the corridor for the proposed South Bend pipeline segment. The field evaluation locations along the proposed and existing pipeline routes are included in Figure 1. This report describes the preliminary field evaluation results of slope geohazards in the evaluation area.

The proposed South Bend pipeline segment will include installation of a 16-inch diameter pipeline across 137 miles to collect and transport petroleum products from various well pads to tankage. The pipeline segment will begin east of Watford City at the Johnson's Corner Station and will then intersect the Wilson Station south of Watford City. The pipeline will then continue to the Bowline Station located southwest of Arnegard, then to the Bicentennial Station near Trotters. After leaving the Bicentennial Station, the South Bend pipeline will terminate near Baker, Montana at the Sandstone Station. Portions of the proposed pipeline alignment will share its corridor with existing pipelines.

### **1.1 PURPOSE AND SCOPE OF FIELD EVALUATIONS**

A field evaluation was completed for slope geologic hazards at six (6) locations of concern selected by Belle Fourche Pipeline along the proposed South Bend pipeline segment within McKenzie and Golden Valley Counties, North Dakota. The purpose of the evaluations was to observe and document site conditions and assign slope failure potential rankings to each selected slope geohazard location along the proposed and existing pipeline routes.

The field evaluations and rankings included in this report are intended to be used by Belle Fourche Pipeline as a pipeline management tool to monitor potential geologic hazard areas and reduce the potential risk presented by the identified hazards. Understanding the geologic hazard behavior presented in this report will allow contingency plans relative to pipeline operations to be formulated and implemented by Belle Fourche Pipeline to manage pipeline performance and minimize potential pipeline failures.

This report presents the results of the geologic hazard field evaluations, summaries of findings, conclusions of risk, and next steps in the geohazard evaluation process.

## **2 SLOPE SELECTION AND DATA COLLECTION**

### **2.1 SLOPE SELECTION**

The list of potential slope crossings evaluated in the field by Tetra Tech for the proposed South Bend project was developed by Belle Fourche Pipeline, derived from potential areas of concern to the proposed and existing pipeline segments. Six (6) potential slopes were selected by Belle Fourche Pipeline and were provided to Tetra Tech for evaluation. Each site was subsequently visited and evaluated for potential geohazards. Summaries of the completed field evaluations and slope failure potential rankings, based on field evaluations and background data, are discussed in Section 5.

## **2.2 DATA COLLECTION**

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Multiple public and private data sources were reviewed and utilized as part of the field evaluations and subsequent evaluation of the six (6) sites identified by Belle Fourche Pipeline, listed in the following subsections.

### **2.2.1 PUBLIC SOURCES AND TYPES**

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- Environmental Systems Research Institute (ESRI)
  - Aerial imagery
  - Topographic maps
- North Dakota GIS Hub Data Portal
  - LiDAR elevation dataset
- United States Geological Survey (USGS)
  - The National Map
  - National Geologic Map Database
  - Topographic maps
  - Mineral Resources Data System, which provides surficial and bedrock geology information

### **2.2.2 PRIVATE SOURCES AND TYPES**

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Belle Fourche Pipeline provided GIS data related to the existing pipelines and proposed South Bend pipeline in the assigned geographic area. Data included:

- Pipeline polylines
- Pump stations
- Valves

## **3 GEOHAZARD IDENTIFICATION**

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### **3.1 GEOLOGIC SETTING**

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A basic understanding of the geology of a region or locale is important for evaluating geohazard concerns. Following is a brief description of the regional geology.

The project is located within the semi-arid climate of the northern Great Plains, on the southwestern side of the Williston Basin. The proposed and existing pipeline segments cross McKenzie and Golden Valley Counties in west central North Dakota. The project area is located in the Little Missouri Badlands area of the unglaciated Missouri Plateau. Topography is characterized by gently rolling uplands interrupted by buttes and ridges capped by resistant rock types and steep badlands created by the network of small tributaries draining to the Little Missouri River.

The regional geology can be summarized as predominately weathered sandstone, siltstone, and shale (claystone) locally overlain by unconsolidated soil deposits. Unconsolidated deposits at the surface consist of clay, silt, sand, and gravel of irregular thickness within the valleys and typically thin deposits in upland areas. Most of the bedrock exposed at the surface and encountered below the surficial soils consists of relatively flat-lying sedimentary formations. The vast majority of the exposed bedrock consists of the Sentinel Butte and Bullion Creek Formations (Paleocene), which consists of alternating layers of weathered

claystone, siltstone, sandstone, and lignite. The Sentinel Butte Formation is described as fine- to medium-grained, gray to tan and yellowish gray, clay, silt, sand, and lignite. The Bullion Creek Formation is described as fine- to medium-grained, yellow-brown, silt, sand, clay, and lignite.

The Bullion Creek Formation typically forms more rounded, vegetated slopes than the overlying Sentinel Butte Formation. Deposits of bentonitic claystone/shale and their derivative clay soils from the Sentinel Butte Formation are historically susceptible to landslide deformations when slopes approach 25 percent or greater, especially when moisture content increases seasonally due to snowmelt and spring rains. Bentonite typically forms a desiccated “popcorn” structure when dry at the surface.

The project area has the potential for localized subsidence related to collapse of burned out lignite layers, which can be indicated by the presence of clinker beds or chimneys, although available mapping does not indicate any such features in the project area. Karst subsidence is not noted in the area due the small percentage of limestone deposits, although surface runoff can develop localized “pseudo-karst” piping features including small tunnels and caves that are sometimes observed in badland topography. Localized features such as burned out lignite layers and piping features are not mapped and can only be evaluated after identification in the field.

Geologic hazards can be caused by man-made impacts such as road construction, regrading, fill placement, and altering natural drainage patterns. Such activities can contribute to existing areas of slope instability and initiate new landslides.

### 3.2 GEOHAZARD RANKING CRITERIA

Tetra Tech assigned a ranking to each of the six (6) potential slope crossing geohazard locations ranging from very low to very high potential of instability. The geohazard ranking criteria is summarized below in Table 4-1: Slope Geohazard Ranking Criteria.

**Table 4-1. Slope Geohazard Ranking Criteria**

Rank	Ranking Criteria Description
Very Low	Very low potential of slope movement. Typically, gentle (<12 degrees) slopes. Slope has a very low potential for mass movement. Well vegetated (>80%), stable soil type. No obvious erosion or movement features - slope less than 12 degrees.
Low	Low potential of slope movement. Typically, gentle to moderate (12 to 20 degrees) slopes. Low potential for mass movement. Possible minor rills, erosion, and creep. Well vegetated (>80%), stable soil type.
Medium	Moderate potential of slope movement. Typically, moderate (20 to 30 degrees) slopes. Moderate potential for mass movement. Slope has evidence of creep, erosion, minor slumping, or seepage. Sparse vegetation (<50%). Stratigraphy and soil type are favorable for slope movement.
High	High potential of slope movement. Typically, moderate to steep (20 to >45 degrees) slopes. Evidence of slope movement, major erosion, slumping, seepage, etc. Proximal to other areas of mass movement. Stratigraphy and soil type are favorable for slope movement. Area should be evaluated within the next 6-12 months.
Very High <sup>1</sup>	Very high potential of slope movement. Typically, moderate to steep (20 to >45 degrees) slopes. Material is unstable. Visible evidence of recent mass movement. Recommend site specific evaluation. Area may need immediate attention and should be evaluated within 1-2 months.

Note: <sup>1</sup>Slope stability features assigned a hazard rating of high or very high based on specific criteria should be further evaluated by direct field observation. Some rankings were modified based on engineering judgement, with comments provided in the geohazard table.

A geohazard intersect map (Figure 1) is included in the Appendix. Specific slope geohazard points are consecutively numbered by county, generally from west to east then north to south along the proposed pipeline alignment.

## **4 FIELD EVALUATION**

### **4.1 FIELD EVALUATION SUMMARY**

A field evaluation consisting of observation and data gathering was conducted by Tetra Tech for six (6) potential geohazard locations identified and selected by Belle Fourche Pipeline for the proposed South Bend pipeline segment and existing Wilson to Bowline pipeline segment.

Prior to the field work, Tetra Tech prepared an Incident Prevention Plan. The document included anticipated safety issues that the Tetra Tech field team might encounter while performing the field work within the pipeline right-of-way. All project access to the pipeline right-of-way and requisite landowner notifications were performed by Belle Fourche Pipeline personnel or their designated land agents for all locations prior to the field work beginning. A one (1) person Tetra Tech field crew performed the requested field evaluations on July 6<sup>th</sup> and 7<sup>th</sup>, 2020, with mobilization and de-mobilization occurring on July 5<sup>th</sup> and July 8<sup>th</sup>, respectively. The field crew was accompanied by two (2) Belle Fourche Pipeline representatives throughout the duration of the program.

The field evaluations were conducted to determine if remedial measures are necessary to reduce the slope failure potential. Tetra Tech collected site specific information for each potential geohazard location to establish a baseline of current conditions. Site specific information included; geohazard identification, distance of the geohazard from the proposed or existing pipeline, geohazard location (latitude/longitude), location description, soil and/or rock lithology, slope type, slope inclination and dimensions, slope aspect relative to the proposed pipeline direction, erosion potential, surface water (if applicable), vegetation cover, existing pipeline depth of cover (if available), location photos, and comments on the specific geohazard. Field equipment included: Real-Time Kinematic Global Positioning System (RTK GPS), mobile tablet, utility line locator (for depth of cover measurements), and laser rangefinder/inclinometer.

### **4.2 FINDINGS AND CONCLUSIONS**

Slope instability (landsliding) is the most common and frequent type of geologic hazard along the proposed and existing pipeline segments. Landsliding and the other identified hazards have the potential to damage or rupture the existing or proposed pipelines within the evaluated areas. The relationships of geologic unit, slope angle, slope length, and slope aspect are important relative factors for understanding previous landsliding, existing landsliding, and future landsliding potential.

The field geohazard evaluation of the various sites indicates steep slopes with poor vegetation and fine-grained surficial soils are susceptible to slope movement and erosion. Specifically, areas of unconsolidated soils overlying highly weathered sandstone and claystone bedrock of the Bullion Creek and Sentinel Butte Formations are more susceptible to slope instability. Slopes with poorly established vegetation are susceptible to surficial raveling, rilling, gully erosion, and surficial slump failures. Slope failures above the pipeline can continue to load slide mass and debris on to the pipeline alignment adding weight and increasing the potential for slope failure below the pipeline. Slope movements may also start lower on the slope and

propagate head-ward upslope to intersect the pipeline alignment. Historic slope movements may provide information and insight on hazards most likely to affect the pipeline in the future.

Many of the areas which have moved in the past may be temporarily stable but have the potential to reactivate. A previous slide will often remain stable unless a present condition changes. Direct condition changes generally involve construction on or adjacent to a landslide or adjacent slopes. Indirect condition changes generally involve the behavior of surface water, infiltration and groundwater on or near a landslide or slopes prone to landsliding. Recent development near the pipeline, or on-going construction activities can present a potential impact to the pipeline corridor both immediate and ancillary. For these investigations a corridor width of 200 feet total, 100 feet either side of centerline, was considered.

### 4.3 ADDITIONAL ANALYSIS

Based on the findings of this initial geohazard field data collection, Tetra Tech recommends additional geohazard studies be performed on other portions of the proposed South Bend pipeline segment and other portions of the existing pipelines traversing areas of steep topography or water crossings.

## 5 GEOHAZARD SUMMARIES, MITIGATION ALTERNATIVES, AND RECOMMENDATIONS

### 5.1 GEOHAZARD SUMMARIES

Six (6) potential geohazard locations were evaluated in the field on July 6<sup>th</sup> and 7<sup>th</sup>, 2020 and are discussed and described briefly below with the information tabulated in summary tables. Conceptual mitigation alternatives are also summarized should Belle Fourche Pipeline determine it necessary. The slope crossing field forms include detailed data, descriptions, and photos of each evaluated geohazard location and are included in the Appendix.

#### 5.1.1 POTENTIAL SLOPE 1, GOLDEN VALLEY COUNTY, NORTH DAKOTA

The slope is the upper portion of the western side of a local drainage tributary. The slope extends downward to the east for approximately 175 feet at 8 degrees. The slope was well vegetated with grasses and several small sections of sagebrush, with a livestock trail extending along much of the slope. The slope was ranked as a low potential for slope movement due to the relatively shallow slope angle, lack of erosional or slumping features along the slope, no proximal source of water, and its well-vegetated character. The risk for potential impacts to the proposed South Bend pipeline are also low.

Location	Geohazard Rating	Slope (deg)	Down-slope Length (ft)	Distance from Pipeline to Geohazard (ft)	Slope Aspect	USCS Soil Class	Geology
Potential Slope 1, Golden Valley County	Low	8	175	100	E	CL-ML	Bullion Creek Formation

## 5.1.2 POTENTIAL SLOPE 2, GOLDEN VALLEY COUNTY, NORTH DAKOTA

The slope is the lower portion of the western side of a local drainage tributary. The slope is relatively short at approximately 35 feet in length, extending downward to the east at approximately 22 degrees. An approximately 20-foot long gully was observed along a livestock path found on the southern portion of the slope, increasing in dimensions downslope to roughly 6 feet wide and 3 feet deep. Another partially revegetated gully was observed on the north portion of the slope, extending the entire length of the slope. The maximum width of the gully was approximately 15 feet near the toe of the slope and was near 10 feet deep. Additional minor erosion along historic wheel paths and throughout the slope were also observed. This slope was ranked as a medium potential for slope movement due to the moderately steep drainage bank slope and evidence of continued erosion and material loss within the proposed pipeline corridor. In its current state, the risk for potential impacts to the proposed South Bend pipeline is low to moderate. Potential mitigation may include partial regrading in gully and erosion areas and installation of erosion control measures during pipeline construction activities.

Location	Geohazard Rating	Slope (deg)	Down-slope Length (ft)	Distance from Pipeline to Geohazard (ft)	Slope Aspect	USCS Soil Class	Geology
Potential Slope 2, Golden Valley County	Medium	22 – 31	35	40	E	CL-ML	Bullion Creek Formation

## 5.1.3 POTENTIAL SLOPE 4, MCKENZIE COUNTY, NORTH DAKOTA

The proposed South Bend pipeline extends east to west approximately 75 feet beyond the toe of the north facing slope for approximately 400 feet, then continues to the west as the slope toe turns toward the southwest. The slope is a north and northwest facing ridge that extends approximately 165 feet down steep sides averaging 30 degrees. There were multiple smaller landslides and numerous slumps observed along the slope, with most of the movement associated with the north-facing slope. A larger landslide measuring approximately 75 feet across, 15 to 20 feet long, and 3 to 4 feet deep at the head scarp was also observed. Evidence of historic standing water near the toe of the slope was also recorded. Along the north-facing portion of the slope, an approximate 2-foot deep and 1- to 2-foot wide gully extending up to 30 feet down the slope was observed. This slope was ranked as a high potential for slope movement due to general steepness of the slope, the existing slide masses and slumping observed, gullying, as well as indications of previous standing water at the toe of the slope. The risk for potential impacts to the proposed South Bend pipeline is low, however, given that the proximal distance from the proposed pipeline to the toe of the slope is 60 feet or greater.

Location	Geohazard Rating	Slope (deg)	Down-slope Length (ft)	Distance from Pipeline to Geohazard (ft)	Slope Aspect	USCS Soil Class	Geology
Potential Slope 4, McKenzie County	High	30 – 47	165	75	N, NE	CL	Sentinel Butte Formation

## 5.1.4 POTENTIAL SLOPE 5, MCKENZIE COUNTY, NORTH DAKOTA

A drainage with an intermittent stream intersects the proposed South Bend pipeline alignment at the toe of the slope. At the time of assessment, minimal water was observed in the stream. The existing Bicentennial

to Baker pipeline (10-inch) exists approximately 55 feet to the northwest of the proposed South Bend segment at this location. The slope extends down to the northeast at 30 degrees for approximately 40 feet, then flattens to approximate 10 degrees for 65 feet where the intermittent stream defines the toe. The upper, steeper portion of the slope is defined by a knob which extends outward beyond the surrounding slope facies and intersects the proposed pipeline alignment. There was slumping observed approximately one-third of the way up the slope, with approximate dimensions of 20 feet wide, 5 feet long, and extended about 2 feet above the surrounding soil. Multiple small livestock trails merging at one main trail near the top of the slope to the west of the proposed pipeline location extended down the length of the slope. The main trail exhibited minor gullying less than 6 inches deep. Additional surficial erosion was observed at various locations throughout the slope. This slope was ranked as a medium potential for slope movement due to its moderately steep to steep slope and observed slumping, gullying, and erosion features throughout the slope. Due to the proximity of the proposed and existing pipelines to the observed slope features, the risk for potential impacts to the pipeline is moderate.

Location	Geohazard Rating	Slope (deg)	Down-slope Length (ft)	Distance from Pipeline to Geohazard (ft)	Slope Aspect	USCS Soil Class	Geology
Potential Slope 5, McKenzie County	Medium	10 – 30	105	20	NE	CL	Bullion Creek Formation

### 5.1.5 POTENTIAL SLOPE 6, MCKENZIE COUNTY, NORTH DAKOTA

A drainage with an intermittent stream intersects the proposed South Bend pipeline alignment at the toe of the slope. At the time of assessment, there was approximately 3 to 4 inches of water observed in the stream. The existing Bicentennial to Baker pipeline (10-inch) exists approximately 55 feet to the northwest of the proposed South Bend segment at this location. The slope is mostly well vegetated and is part of the southern side of a steep drainage, extending down to the northeast at an average of 37 degrees. The upper 15 feet of the slope is slightly less steep at 30 degrees, while the remaining distance slopes at near 46 degrees. There was gullying observed along the western edge of the corridor with approximate cross-sectional dimensions of 1-foot wide by 1-foot deep. The gullies extended down the slope approximately 40 feet. A deeper gully, or possibly a tension crack, was observed near the top of the slope, extending 25 to 30 feet transversely along the slope, gradually transitioning into the more defined and eroded gullies downslope. The slope was ranked as a high potential for slope movement due to its steepness, observed gullies, and possible tension crack near the crest of the slope. The risk for potential impacts to the proposed South Bend pipeline at this location is also high due to the steepness of the slope and proximity to the observed slope features.

Location	Geohazard Rating	Slope (deg)	Down-slope Length (ft)	Distance from Pipeline to Geohazard (ft)	Slope Aspect	USCS Soil Class	Geology
Potential Slope 6, McKenzie County	High	30 – 46	55	10	NE	CL	Bullion Creek Formation

### 5.1.6 POTENTIAL SLOPE 7, MCKENZIE COUNTY, NORTH DAKOTA

A drainage with an intermittent stream intersects the proposed South Bend pipeline alignment at the toe of the slope. The slope extends down to the northeast for approximately 145 feet at an average angle of 20 degrees. The slope has a convex shape, with the upper 100 feet sloping at 13 degrees and the bottom 45 feet within the drainage channel sloping at 28 degrees. There was minor historic slumping observed near

the toe of the slope and within the drainage channel, and some head cutting of the streambed was observed upstream of the slope location. The observed slumping did not appear to be active at the time of assessment, however. The slope was well vegetated throughout with no apparent erosion observed. This slope was ranked as a medium potential for slope movement due to its moderately steep slope and observed historic slumping near the toe of the slope. Due to the nature of the observed slumping and proximity to other observed features near the slope, the risk for potential impacts to the proposed South Bend pipeline is moderate.

Location	Geohazard Rating	Slope (deg)	Down-slope Length (ft)	Distance from Pipeline to Geohazard (ft)	Slope Aspect	USCS Soil Class	Geology
Potential Slope 7, McKenzie County	Medium	13 – 28	145	15	NE	CL	Sentinel Butte Formation

## 5.2 MITIGATION ALTERNATIVES SUMMARY

Should erosion and slope movement continue to occur at the locations above and Belle Fourche Pipeline determines that mitigation is necessary, potential mitigation alternatives are presented and discussed in more detail below for further consideration. All slope stabilization methods include one or more of the following goals; reduce driving forces, increase resisting forces, or avoid the failure area.

Typically, mitigation alternatives fall into three primary categories: avoidance, slope modification (reduce the driving forces/increase the resisting forces), and slope reinforcement (increase the resisting forces).

**Avoidance** consists of avoiding areas of potential or existing hazards. Avoidance can be accomplished by re-routing around the hazard area, trenching or horizontal directional drilling to a depth sufficiently below the hazard, or spanning over the hazard area.

**Slope Modification** includes; slope re-grading (slope flattening, benching, toe berm/buttress), removal and replacement of unstable material (may include shear key trench or light-weight fill material), surficial reinforcement (re-vegetation, erosion control fabric, geocell, rip rap), and surface water controls (interception ditches, BMP berms). Slope flattening is often the simplest method for improving the stability.

**Drainage Improvements** includes; surface water diversion, interception, and collection ditches or berms, subsurface drainage galleries, horizontal drains, and dewatering wells.

**Slope Reinforcement** can include a wide variety of reinforcement types or combinations of different types. Ground anchors, tieback walls, micropiles, soil nails, retaining walls, soldier piles, sheet piles, and reinforced soil slopes are examples of the types of reinforcement techniques typically used to repair unstable slopes.

Slope modification and structural reinforcement are often combined to some degree to optimize the slope mitigation method. Slope modification and structural slope reinforcement techniques typically include measures to address surface and ground water drainage, such as underdrains, cut-off drains, horizontal drains, diversion and interception ditches, de-watering wells, and impermeable membranes. A more complete and detailed list of possible mitigation alternatives are summarized in the following table.

Mitigation Alternative	Effectiveness	Cost	Brief Description
<b>Earthworks</b>			
Slope Re-grading	High	Low to High	Improves stability by flattening or benching slope to uniform and stable geometry. Often includes cutting material from top of slope and placing it as fill at toe of slope.
Toe Buttress	High	Low to High	Construction of soil berm at toe of slope to resist driving forces of slide mass. Typically benched into the slope and keyed into the toe area.
Shear Key Trench	High	Low to High	Excavation or large trench or series of trenches into slope to intercept the failure plane. Replace native materials with compacted higher strength, free-draining, granular material. Typically included in conjunction with re-grading or buttressing.
Rip Rap Armoring	Moderate	Low	Placing large cobbles and boulders or engineered hard armor products along stream bank or across slope to provide erosion and provide surface protection.
Lightweight Fill	Medium	High	Replacement of native soils with light-weight material to reduce weight of slide mass and reduce driving forces in slide area. Lightweight material can consist of geofam, polystyrene blocks, wood fiber, shredded rubber tires, or other materials.
Ground Improvement (stone columns, jet grouting, etc.)	High	High	Replacing or strengthening existing soil within the slide area or across the slide plane by drilling and replacement or mixing soil with cement to increase shear strength.
<b>Surface Protection</b>			
Geocell	High	Low to Moderate	Shallow cellular confinement system used to prevent erosion on slopes up to 45 degrees. Permeable and allows water to flow between cells, improving drainage and promoting vegetation growth for erosion control.
Erosion Control Fabric	Moderate	Low	Prevent erosion by protecting surface and promoting vegetation.
<b>Drainage Improvement</b>			
French Drains	Moderate	Low	Excavated trenches perpendicular to slope and filled with gravel wrapped in filter fabric. Improves stability by draining near surface soils and reducing pore pressures.
Horizontal Drains	Moderate	Moderate	Drilling into slope at low angle and installation of drain pipe. Improves stability by lowering groundwater levels and decreasing pore pressure. Can be susceptible to freezing or clogging, which may require periodic maintenance. Can be damaged by slide movement and become inoperative.
Dewatering Wells	High	Moderate	Drilling vertical wells and pumping to lower groundwater levels and decrease pore pressures. Requires electricity to run pumps and outfall system.
BMP ditches and Interception ditches	Low to Moderate	Low	Construction of berms and/or ditches to collect and divert surface water flow away from failure area. Controls surface water flow to reduce infiltration and erosion.
<b>Structural Reinforcement</b>			
MSE Wall	Low to Moderate	Moderate	Construction of reinforced retaining wall on slope below pipeline. Welded wire mesh, gabions, and geogrid wrapped faces are typical applications.
Soil Nails	High	High	Installation of steel bars grouted into place with a steel mesh and shotcrete slope facing. Provides additional shearing resistance along failure plane and surface protection.
Ground Anchors	High	High	Installation of anchor strands or bars grouted into place and pre-tensioned against a reaction block at the slope face. Provides additional shearing resistance and normal force across the failure plan.

Mitigation Alternative	Effectiveness	Cost	Brief Description
Micropiles	High	High	Installation of small diameter steel and grout piles through slide mass to provide additional shearing resistance across failure plane. Often installed in 'A-frame' type pattern with a concrete pile cap.

Geohazard locations with a 'high' or 'very high' potential for slope movement with potential to affect the pipeline can be monitored and instrumented to provide observation and characterization of factors that may contribute to slope instability (precipitation, groundwater elevation, stream flow), and slope movement (magnitude and direction of movement, and depth of shear zone). This information can be useful as an 'early-warning' system indicating impending pipeline damage and for design of a long-term mitigation design. The simplest method of monitoring consists of periodic field inspection and documentation of basic site conditions.

Additional monitoring techniques include topographic survey, fixed survey points, rain gauges, stream gages, crack monitoring, piezometers, extensometers, inclinometers, and aerial and terrestrial photography. These techniques can be utilized at specific locations on a case by case basis.

A significant factor to consider for improving slope stability is subsurface water, surface run-off, and infiltration control. Saturated soil conditions can reduce soil strengths and contribute to slope instability. To minimize these conditions, surface water runoff must be controlled both during construction and after construction of any mitigation system. Mitigation methods will perform more effectively with a drainage system installed to intercept and control surface water flow.

The mitigation alternatives summarized above are general "tried and true" methods for slowing or arresting slope movement within slide areas and have proven effective on similar projects. However, given the relatively unknown subsurface conditions, the overall lifespan and the effectiveness to arrest movement through mitigation is not completely predictable without additional geotechnical investigation, slope monitoring, and analysis. New or existing slides can be reactivated due to many factors beyond the geotechnical engineer's control such as seismic activity and vibration, relaxation of the mitigation system, or increased infiltration due to 'above normal' precipitation. Other factors include variations in subsurface soil or rock properties and groundwater elevations not encountered during the limited field investigation.

### **5.3 GENERAL RECOMMENDATIONS**

The following recommendations are based on information obtained from the data review, geohazard mapping, and geohazard description. The recommendations below are for general consideration at high instability, erosion potential, and/or active geohazard locations along the proposed pipeline corridor.

The intent of a monitoring program is to identify slope movements before the pipeline is affected. The monitoring program should consist of both visual monitoring, and movement monitoring if deemed necessary. Four (4) of the six (6) potential geohazard locations in Golden Valley and McKenzie Counties of North Dakota evaluated during the July 2020 field evaluations were observed to have slope movement or erosional features with potential to encroach toward and pose risk to the proposed or existing pipeline. At a minimum, geohazard locations ranked as 'high' or 'very high' with potential to affect the pipeline should be monitored to observe, document, and characterize factors that may contribute to slope instability and movement. Monitoring should include measuring the physical dimensions of the failure areas to determine movement over time. Consideration should be given to adjusting the proposed pipeline alignment around these geohazard locations or providing regrading and erosion control to decrease the potential for future slope instability.

Movement monitoring could be performed by in-situ instruments or surveyed movement monitoring. Systematic visual monitoring could be performed by Tetra Tech's geotechnical staff. The program would monitor active and pre-existing landslides and slopes with high potential for instability that would affect the pipeline, if deemed necessary by Belle Fourche Pipeline. The program would be structured similar to the initial field inspections completed as part of this evaluation. Each visual monitoring event would be recorded and evaluated so monitoring events can be compared through time. In-situ movement and movement surveys would also be recorded and evaluated. This monitoring information will also be useful for design of a long-term mitigation design. If subsequent monitoring indicates the slope failure is active and encroaching on the pipeline, a geotechnical investigation is recommended to provide full mitigation recommendations.

The slope movements and movement susceptible slopes along the project segment are most directly affected by water. Future monitoring should focus on recording water features on or near the slopes, as well as any loading, erosion, or moving at susceptible slopes.

In unstable slopes and landslides, it is critical to understand the failure mechanism before making recommendations for mitigation and stabilization. Otherwise, construction activities can often be ineffective or further instigate additional instability. Survey monitoring points can be installed within slope movement areas to monitor and document magnitude, rate, and direction of future movement. In areas where seepage or groundwater appears to affect stability, temporary piezometers can be installed in boreholes and monitored to document groundwater levels and identify the shear plane depth in the event of future movement. Geotechnical evaluation/investigation may be necessary for geohazard locations where ongoing active slope movement occurs with the potential to damage the pipeline. Geotechnical evaluation/investigation may include a combination of the following elements; field inspection, field monitoring, geophysical exploration, subsurface exploration (boreholes and/or test pits/trenches), laboratory testing, slope stability analysis, and slope mitigation design alternatives.

Stabilization measures can be extensive and repairs costly depending on the mechanism of failure, combinations of slope geometry, slide size, access, and location of the failure plane. Therefore, it is important to recognize that based on actual slope and subsurface conditions, recommendations for slope stabilization measures may be too extensive or cost prohibitive to implement. In such a case, other less-conservative alternatives can be considered that would be less costly, but also less certain to provide long-term stabilization.

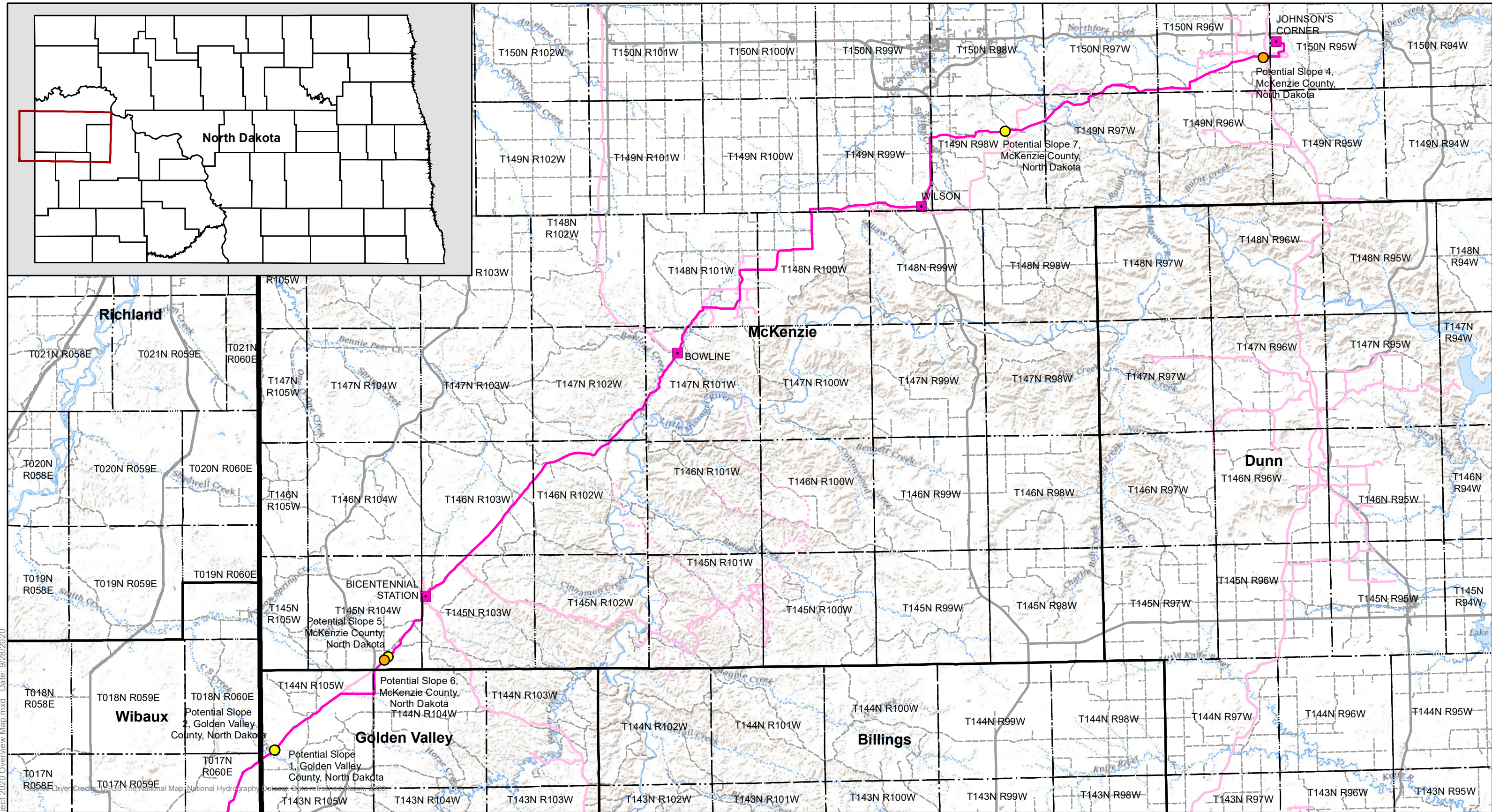
## **6 LIMITATIONS**

This assessment has been conducted in accordance with generally accepted geotechnical engineering practices in the region where the work was conducted; however, no guarantees or warranties are provided or implied. The conclusions and preliminary recommendations submitted in this report are based upon project information provided to Tetra Tech, and data obtained from the desktop assessment.

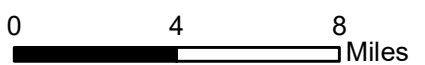
This report has been prepared exclusively for our client. This report and the data included herein shall not be used by any third party without the express written consent of both the client and Tetra Tech. Tetra Tech is not responsible for technical interpretations by others. As the project evolves, Tetra Tech should provide continued consultation and field services to review and monitor the implementation of our recommendations and verify that our recommendations have been appropriately interpreted.

## APPENDIX A

South Bend - Overview and Slope Crossing Map (Figure 1) & Field Forms



E:\Bridger Pipeline\South Bend Project 2020 Overview Map.mxd Date: 9/28/2020



**2020 South Bend Project Slope Inspection Locations**  
*Belle Fourche - South Bend Project*

**FIGURE 1**



2020 Belle Fourche Slope Crossing Field Form

# Potential Slope 1, Golden Valley County, North Dakota

### *Crossing Summary*

**Proposed Pipeline at Crossing:** South Bend Project

**Mass Failure Potential:**

Low

**Narrative Summary:**

The slope is shallow and well vegetated. This slope is the upper portion of "Potential Slope 2, Golden Valley County, North Dakota". A livestock trail exists along the slope and extends down most of the slope. No apparent indications of instabilities or erosion were noted along the slope.

### *Action Items*

**Suggested Action Items:**

None

### *Location, Date, and Time*

**Target Crossing Coordinates:** 47.269246, -104.02882

<b>Region:</b> Belle Fourche	<b>Inspection Date:</b> Jul 7, 2020
<b>State:</b> North Dakota	<b>Time Arrived:</b> 12:04
<b>County:</b> Golden Valley	<b>Time Departed:</b> 12:13

### *Access and Parking*

**Access Coordinates:** 47.26066, -104.02812

**Parking Coordinates:** 47.26066, -104.02812

**Access and Parking Comments:** Parked at abandoned house north of the main gravel road (Cs Creek Road) and walked north to proposed pipeline corridor location.

**Field Crew:**

Andrew Warren (team lead, Tetra Tech)

Kyle Koppinger (Belle Fourche)

Kevin Peña (Belle Fourche)

**Access Method:** Walk

**Access Difficulty:** Moderate

### *Assessment Area*



**Start Coordinates:** 47.26875, -104.02934

**End Coordinates:** 47.26903, -104.02901

---

***Evidence of Mass Failure***

None

---

***Bedrock Geology***

**Exposed Bedrock:** No

---

***Soil Conditions***

**USCS Soil Category:** CL (lean clay) with Silt

**Soil Condition Comments:** Lean clay with silt and sand to silty clay with sand.

---

***Water Conditions***

No proximate water source with potential to affect the slope.

---

***Site Topography/Landforms***

**Landform Type:** Valley

**Slope Profile:** Linear

**General Slope Aspect:** East

**Crossing Angle:** Diagonal

**Crossing Angle Description:** Proposed pipeline will be diagonal to slope.

**Average Slope Angle:** 8 degrees

**Maximum Slope Angle:** 8 degrees

**Length of Entire Slope:** 175 ft (53.3 m)

**Length of Slope at Maximum Slope Angle:** 175 ft (53.3 m)

**Topography Landform Comments:** The slope is the upper portion of "Potential Slope 2, Golden Valley County, North Dakota".

---

***Vegetation Cover***

5% shrubs

90% forbs/groundcover

5% bare

**Tree Fall Evidence:** No

---

**Potential Slope 1, Golden Valley County, North Dakota Photo Log**



**Photo Type:** Looking downslope | **Photo Bearing:** 55 degrees

---

**Photo #1**



**Photo Type:** Looking across slope | **Photo Bearing:** 98 degrees

---

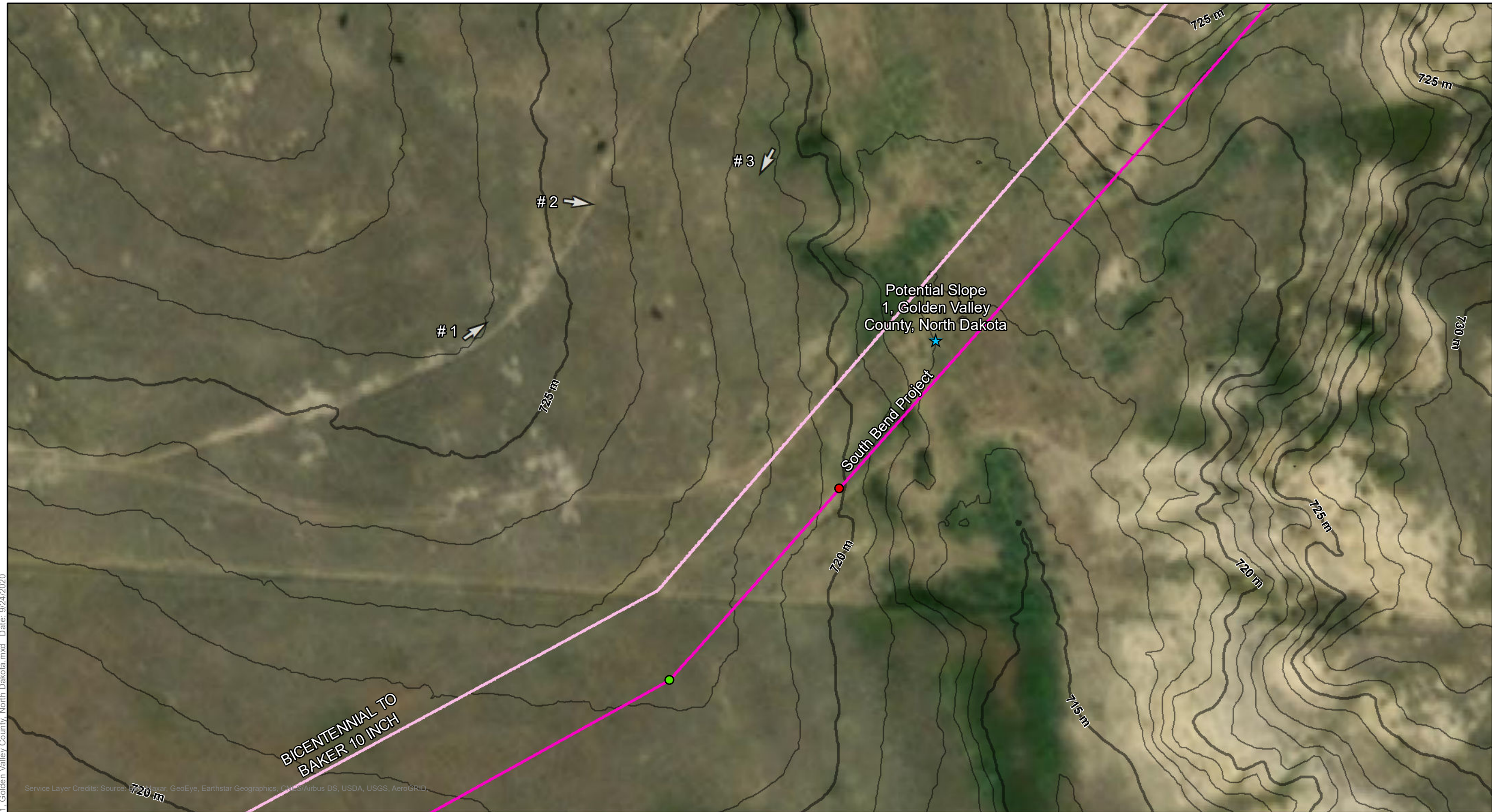
**Photo #2**



**Photo Type:** Looking upslope | **Photo Bearing:** 209 degrees

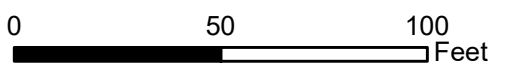
---

**Photo #3**



E:\Bridger Pipeline\Pipeline\Potential Slope 1 - Golden Valley County, North Dakota.mxd Date: 9/24/2020

Service Layer Credits: Source: Esri, DeLorme, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, Esri, Mapbox



- DOC Measurement Location
- Slope Start Point
- Slope End Point
- ★ Slope Crossing Coordinates Provided

Photo Location and Direction

- South Bend Project (Proposed)
- Other Active Line
- ⋯ Other Inactive Line
- 5m Contour
- 1m Contour

**2020 South Bend Project**  
**Potential Slope 1, Golden Valley**  
**County, North Dakota**  
*Belle Fourche - South Bend Project*  
**FIGURE 1**



2020 Belle Fourche Slope Crossing Field Form

Potential Slope 2, Golden Valley County, North Dakota

Crossing Summary

Proposed Pipeline at Crossing: South Bend Project

Mass Failure Potential:

Medium

Narrative Summary:

The slope is moderate in steepness and relatively short in length. The slope is well vegetated but did exhibit some erosion and gullying at two main locations along the slope within the proposed pipeline corridor. There is also a well-defined drainage area at the toe of the slope. The slope appeared stable with no apparent signs of recent erosion at the time of assessment.

Action Items

Suggested Action Items:

Other (see comments)

Action Item Comments:

During future site visits, observe erosional features and gully areas for signs of change.

Location, Date, and Time

Target Crossing Coordinates: 47.269229, -104.029326

<b>Region:</b> Belle Fourche	<b>Inspection Date:</b> Jul 7, 2020
<b>State:</b> North Dakota	<b>Time Arrived:</b> 11:41
<b>County:</b> Golden Valley	<b>Time Departed:</b> 12:02

Access and Parking

Access Coordinates: 47.26067, -104.02812

Parking Coordinates: 47.26067, -104.02812

Access and Parking Comments: Parked near abandoned house located north of the main gravel road (Cs Creek Road) and walked north to the potential slope location.

Field Crew:

Andrew Warren (team lead, Tetra Tech)

Kyle Koppinger (Belle Fourche)

Kevin Peña (Belle Fourche)

Access Method: Walk

Access Difficulty: Moderate



---

**Assessment Area**

**Start Coordinates:** 47.26903, -104.02901

**End Coordinates:** 47.26917, -104.02884

---

**Evidence of Mass Failure**

Gullying

**Description:** A gully was observed within a livestock path on southern end of the slope, extending approximately 20 feet down the slope, and was approximately 6 feet wide at its widest point and approximately 3 feet deep. Another larger gully with associated erosion was observed on the north edge of slope extending down the length of the slope. The maximum width of this gully was approximately 15 feet wide near the toe of the slope, with an approximate maximum depth near 10 feet.

---

**Bedrock Geology**

**Exposed Bedrock:** No

---

**Soil Conditions**

**USCS Soil Category:** CL (lean clay) with Silt

**Soil Condition Comments:** Lean clay with silt to silty clay

---

**Water Conditions**

No proximate water source with potential to affect the slope.

---

**Site Topography/Landforms**

**Landform Type:** Valley

**Slope Profile:** Linear

**General Slope Aspect:** East

**Crossing Angle:** Diagonal

**Crossing Angle Description:** The proposed pipeline will be diagonal to the slope face.

**Average Slope Angle:** 22 degrees

**Maximum Slope Angle:** 31 degrees

**Length of Entire Slope:** 35 ft (10.7 m)

**Length of Slope at Maximum Slope Angle:** 15 ft (4.6 m)

**Topography Landform Comments:** The maximum slope angle and length is in the area of the gully on north side of slope.



---

***Vegetation Cover***

10% shrubs  
85% forbs/groundcover  
5% bare

**Tree Fall Evidence: No**

---

**Potential Slope 2, Golden Valley County, North Dakota Photo Log**



**Photo Type:** Looking upslope | **Photo Bearing:** 253 degrees

---

**Photo #1**



**Photo Type:** Looking across slope | **Photo Bearing:** 149 degrees

---

**Photo #2**



**Photo Type:** Slope documentation | **Photo Bearing:** 227 degrees

**Photo Description:** Looking upslope at historic vehicle wheel paths and minor associated erosion and gullyng.

---

**Photo #3**



**Photo Type:** Looking across slope | **Photo Bearing:** 319 degrees

---

**Photo #4**



**Photo Type:** Slope documentation | **Photo Bearing:** 197 degrees

**Photo Description:** Looking up slope at livestock trail and minor gullying within, and nearby surficial erosion.

---

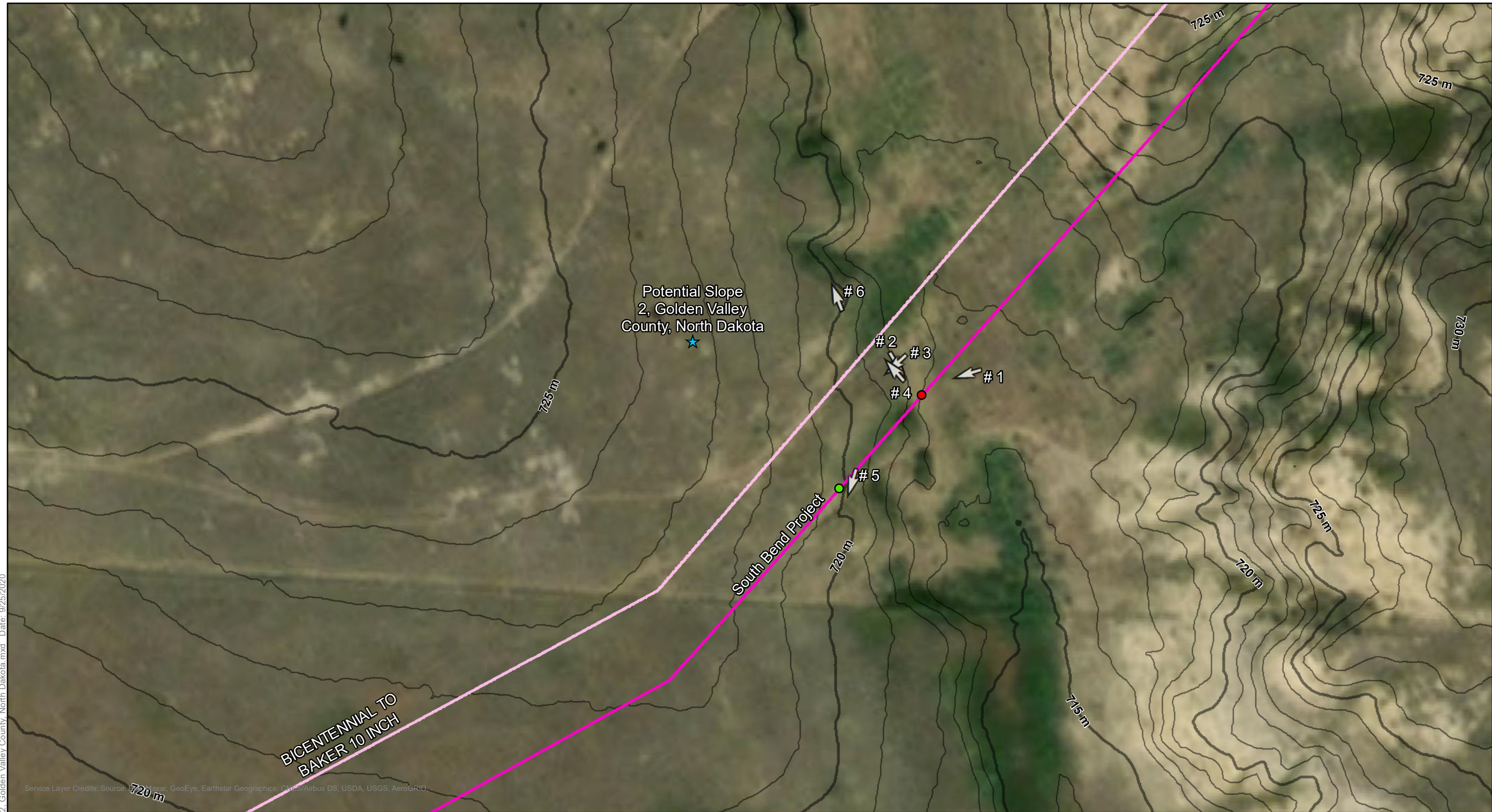
**Photo #5**



**Photo Type:** Slope documentation | **Photo Bearing:** 339 degrees  
**Photo Description:** Erosion and gullying on north edge of slope.

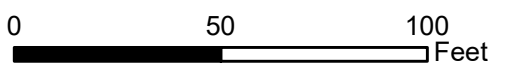
---

**Photo #6**



E:\Bridger Pipeline\Pipeline\Potential Slope 2, Golden Valley County, North Dakota.mxd Date: 9/25/2020

Service Layer Credits: Source: Esri, DeLorme, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, Esri, Mapbox



- DOC Measurement Location
- Slope Start Point
- Slope End Point
- ★ Slope Crossing Coordinates Provided

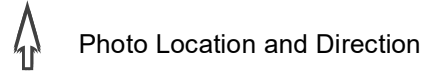


Photo Location and Direction

- South Bend Project (Proposed)
- Other Active Line
- ⋯ Other Inactive Line
- 5m Contour
- 1m Contour

**2020 South Bend Project**  
**Potential Slope 2, Golden Valley**  
**County, North Dakota**  
*Belle Fourche - South Bend Project*  
**FIGURE 1**



2020 Belle Fourche Slope Crossing Field Form

Potential Slope 4, McKenzie County, North Dakota

Crossing Summary

Proposed Pipeline at Crossing: South Bend Project

Mass Failure Potential:

High

Narrative Summary:

The slope is moderately steep to very steep and well vegetated throughout. Multiple historic slides were observed throughout the slope, mostly on the north facing portion of the slope. The largest slide observed was approximately 75 feet across, 15 to 20 feet in height, and 3 to 4 feet deep at the head scarp. Rooting depths of roughly similar depths (3 to 4 feet) were observed at the head scarp. Numerous slumps were observed, mostly near the toe of the slope. Evidence of historic standing water was observed near toe of slope. No active slope movement was observed. The proposed South Bend pipeline will be located a minimum of 60 feet beyond the toe of the slope.

Action Items

Suggested Action Items:

Regrade, Install Erosion Control Measures

Action Item Comments:

Regrade the slope to remove multiple slide masses and slumps with proper site drainage and re vegetate the area. Additionally, regular monitoring and assessments of the slope should be conducted to assess for changing slope conditions.

Location, Date, and Time

Target Crossing Coordinates: 47.785839, -102.906472

Region: Belle Fourche Inspection Date: Jul 6, 2020
State: North Dakota Time Arrived: 11:14
County: McKenzie Time Departed: 12:17

Access and Parking

Access Coordinates: 47.78794, -102.90505
Parking Coordinates: 47.78843, -102.90363

Access and Parking Comments: Walked across access road and to corridor from parking area.

Field Crew:



Andrew Warren (team lead, Tetra Tech)  
 Kyle Koppinger (Belle Fourche)  
 Kevin Peña (Belle Fourche)

**Access Method:** Walk

**Access Difficulty:** Easy

**Pipeline Corridor Comments:** The proposed South Bend pipeline will be located a minimum of 60 feet beyond the toe of the slope.

***Assessment Area***

**Start Coordinates:** 47.78647, -102.90756

**End Coordinates:** 47.78666, -102.90528

***Evidence of Mass Failure***

Slides

**Description:** Multiple slides along the slope were observed, with the largest slide located on the north-facing portion of the slope. Dimensions of that slide were approximately 75 feet across, 15 to 20 feet in height, and roughly 3 to 4 ft deep at the head scarp.

Slumping

**Description:** Numerous slumps were observed throughout the slope, many of which were located on the north-facing portion of the slope. Many of the slumps observed appear to be associated with larger slide masses as secondary movement.

Gullying

**Description:** A gully was observed on the north facing portion of slope and was approximately 2 feet deep and 1 to 2 feet across, extending roughly 20 to 30 feet in length near the bottom of the slope.

**Other Mass Failure Comments:** The observed slides and slumps did not appear to be actively moving at the time of assessment.

***Bedrock Geology***

**Exposed Bedrock:** No

***Soil Conditions***

**USCS Soil Category:** CL (lean clay) with Silt

**Soil Condition Comments:** Lean clay with silt and gravel. Numerous boulders found at top of the slope and at the bottom of the slope.

***Water Conditions***

No proximate water source with potential to affect the slope.



---

### ***Site Topography/Landforms***

**Landform Type:** Ridge

**Slope Profile:** Linear

**General Slope Aspect:** North, Northwest

**Crossing Angle:** Perpendicular

**Crossing Angle Description:** The proposed pipeline will generally be perpendicular to the slope.

**Average Slope Angle:** 30 degrees

**Maximum Slope Angle:** 47 degrees

**Length of Entire Slope:** 165 ft (50.3 m)

**Length of Slope at Maximum Slope Angle:** 15 ft (4.6 m)

**Topography Landform Comments:** There are generally two slope aspects: north and northwest, with a gentle curved transition between the two slope aspects. The slope is generally linear, but there are multiple oversteepened sections along the slope from historic slide activity. The northwest slope aspect was measured at an average angle of 23 degrees and 180 ft in length. The north facing slope aspect was generally steeper with a closer proximity to the proposed pipeline. Measured lengths and angles of the north facing slope aspect are detailed above.

---

### ***Vegetation Cover***

40% trees

20% shrubs

30% forbs/groundcover

10% bare

**Tree Fall Evidence:** No

**Vegetation Cover Comments:** No apparent indications of gravitropism, however, rooting depths of up to approximately 3 to 4 feet were observed at historic scarp locations along the north facing slope.

---

**Potential Slope 4, McKenzie County, North Dakota Photo Log**



**Photo Type:** Looking upslope | **Photo Bearing:** 150 degrees

**Photo Description:** Looking up slope at the north-facing slope from near the proposed pipeline corridor.

---

**Photo #1**



**Photo Type:** Slope movement evidence | **Photo Bearing:** 160 degrees  
**Photo Description:** Historic slide/slumping mass at toe of the north-facing slope.  
-----

**Photo #2**



**Photo Type:** Slope documentation | **Photo Bearing:** 195 degrees

**Photo Description:** Area of historic standing water just above the toe of the north-facing slope.-

---

**Photo #3**



**Photo Type:** Slope documentation | **Photo Bearing:** 141 degrees

**Photo Description:** Oversteepened section of the north-facing slope at historic slide head scarp.

---

**Photo #4**



**Photo Type:** Slope documentation | **Photo Bearing:** 265 degrees  
**Photo Description:** Oversteepened section of the north-facing slope at historic slide head scarp.

---

**Photo #5**



**Photo Type:** Looking downslope | **Photo Bearing:** 304 degrees

**Photo Description:** Looking downslope toward proposed pipeline corridor from the crest of the north-facing slope.

---

**Photo #6**



**Photo Type:** Looking downslope | **Photo Bearing:** 351 degrees

**Photo Description:** Looking downslope toward proposed pipeline corridor from the crest of the northwest-facing slope.

---

**Photo #7**



**Photo Type:** Looking upslope | **Photo Bearing:** 114 degrees  
**Photo Description:** Looking upslope toward the northwest-facing slope.  
-----

**Photo #8**



**Photo Type:** Looking across slope | **Photo Bearing:** 53 degrees  
**Photo Description:** Looking across the toe of the northwest-facing slope.  
-----

**Photo #9**



**Photo Type:** Looking upslope | **Photo Bearing:** 124 degrees

**Photo Description:** Looking upslope near the convergence of the north-facing and northwest-facing slopes.

---

**Photo #10**



**Photo Type:** Slope documentation | **Photo Bearing:** 241 degrees

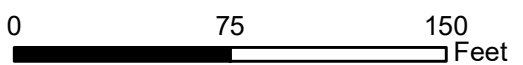
**Photo Description:** Looking at historic scarp on the east edge of the north-facing slope.  
-----

**Photo #11**



E:\Bridger Pipeline\Pipeline\Potential Slope 4 - McKenzie County, North Dakota.mxd Date: 9/28/2020

Source Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID,



- DOC Measurement Location
- Slope Start Point
- Slope End Point
- ★ Slope Crossing Coordinates Provided
- Photo Location and Direction
- South Bend Project (Proposed)
- - - Other Inactive Line
- 15 ft Contour
- 3 ft Contour

**2020 South Bend Project**  
**Potential Slope 4, McKenzie**  
**County, North Dakota**  
*Belle Fourche - South Bend Project*  
**FIGURE 1**



2020 Belle Fourche Slope Crossing Field Form

Potential Slope 5, McKenzie County, North Dakota

Crossing Summary

Proposed Pipeline at Crossing: South Bend Project

Mass Failure Potential:

Medium

Narrative Summary:

The slope is moderate in steepness and generally well vegetated. The slope is more thickly vegetated along the lower portion of the slope and the upper portion. There is an intermittent stream located at the toe of the slope. Minor slumping was observed approximately one-third up the slope with no apparent recent movement activity. A livestock path was observed along the western edge of the slope and exhibited minor gullying from precipitation events. Minor surficial erosion was observed throughout the slope. The slope appeared to be stable at the time of assessment.

Action Items

Suggested Action Items:

None

Location, Date, and Time

Target Crossing Coordinates: 47.339739, -103.901176

<b>Region:</b> Belle Fourche	<b>Inspection Date:</b> Jul 7, 2020
<b>State:</b> North Dakota	<b>Time Arrived:</b> 08:24
<b>County:</b> McKenzie	<b>Time Departed:</b> 09:06

Access and Parking

**Access Coordinates:** 47.34423, -103.90612  
**Parking Coordinates:** 47.34423, -103.90612

**Access and Parking Comments:** Parked just off the edge of Prairie Dog Road and walked south to corridor across drainage.

Field Crew:

- Andrew Warren (team lead, Tetra Tech)
- Kyle Koppinger (Belle Fourche)
- Kevin Peña (Belle Fourche)

**Access Method:** Walk



**Access Difficulty:** Moderate

---

***Assessment Area***

**Start Coordinates:** 47.33958, -103.90135

**End Coordinates:** 47.33974, -103.90111

---

***Evidence of Mass Failure***

Slumping

**Description:** Minor slumping was observed approximately one-third up the slope below the oversteepened section of the slope. The observed slump mass was approximately 20 feet wide and 5 feet long with a height of roughly 2 feet above adjacent ground. No apparent recent movement was observed.

Gullying

**Description:** A livestock trail exhibiting signs of minor gullying less than 6 inches deep was observed on westernmost edge of topographical knob.

**Other Mass Failure Comments:** Minor surficial erosion and bare areas were observed throughout the slope.

---

***Bedrock Geology***

**Exposed Bedrock:** No

---

***Soil Conditions***

**USCS Soil Category:** CL (lean clay) with Sand

**Soil Condition Comments:** Lean clay with sand and silt, occasional gravel.

---

***Water Conditions***

**Proximate water source(s) with potential to affect the slope:**

Intermittent Waterways

**Description:** Drainage with an intermittent stream is located at the toe of the slope. Minimal water in the stream channel was observed at the time of assessment.

---

***Site Topography/Landforms***

**Landform Type:** Valley

**Slope Profile:** Concave

**General Slope Aspect:** Northeast

**Crossing Angle:** Parallel

**Crossing Angle Description:** Proposed pipeline will be parallel to slope.



**Average Slope Angle:** 20 degrees  
**Maximum Slope Angle:** 30 degrees  
**Upper Slope Angle:** 30 degrees  
**Lower Slope Angle:** 10 degrees

**Length of Entire Slope:** 105 ft (32 m)  
**Length of Slope at Maximum Slope Angle:** 40 ft (12.2 m)  
**Length of Upper Slope:** 40 ft (12.2 m)  
**Length of Lower Slope:** 65 ft (19.8 m)

**Topography Landform Comments:** The proposed pipeline crossing location intersects a small knob along the drainage channel valley representing the maximum slope and length.

---

***Vegetation Cover***

10% trees  
15% shrubs  
60% forbs/groundcover  
15% bare

**Tree Fall Evidence:** No

**Vegetation Cover Comments:** Substantially more trees to the east of the proposed pipeline corridor.

---

**Potential Slope 5, McKenzie County, North Dakota Photo Log**



**Photo Type:** Looking upslope | **Photo Bearing:** 204 degrees  
**Photo Description:** Looking at slope from opposite drainage bank.

---

**Photo #1**



**Photo Type:** Looking upslope | **Photo Bearing:** 227 degrees

---

**Photo #2**



**Photo Type:** Slope documentation | **Photo Bearing:** 119 degrees  
**Photo Description:** Looking at small slump and cattle trail.

---

**Photo #3**



**Photo Type:** Looking downslope | **Photo Bearing:** 22 degrees

---

**Photo #4**



**Photo Type:** Slope documentation | **Photo Bearing:** 20 degrees  
**Photo Description:** Minor gullying and livestock trail.

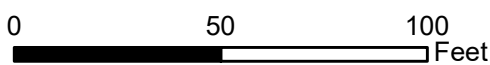
---

**Photo #5**



E:\Bridger Pipeline\Pipeline\Potential Slope 5, McKenzie County, North Dakota.mxd Date: 9/28/2020

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID,



- DOC Measurement Location
- Slope Start Point
- Slope End Point
- ★ Slope Crossing Coordinates Provided

Photo Location and Direction

- South Bend Project (Proposed)
- Other Active Line
- ⋯ Other Inactive Line
- 15 ft Contour
- 3 ft Contour

**2020 South Bend Project**  
**Potential Slope 5, McKenzie**  
**County, North Dakota**  
*Belle Fourche - South Bend Project*  
**FIGURE 1**



2020 Belle Fourche Slope Crossing Field Form

Potential Slope 6, McKenzie County, North Dakota

Crossing Summary

Proposed Pipeline at Crossing: South Bend Project

Mass Failure Potential:

High

Narrative Summary:

The slope is very steep and well vegetated with thick brush throughout much of the slope, mixed with grasses. The slope forms part of the southern bank of a long drainage with an intermittent stream at the toe. There was approximately 3 inches of water at the time of assessment. Gullying was observed on the western edge of the corridor and was approximately 1 foot deep and 1 foot wide, extending approximately 40 feet along the slope. A deeper gully or possible tension crack was observed near the top of the slope, extending roughly 25 to 30 feet transversely along the slope. The deeper gully or possible tension crack was approximately 2 feet deep and 2 feet wide and transitioned into the more defined and eroded gullies downslope. No apparent recent movement was observed on the slope at the time of assessment.

Action Items

Suggested Action Items:

Clear Corridor, Regrade

Action Item Comments:

Regrade the slope to improve the oversteepened and vulnerable slope and remove the thick brush along the slope to better view potential instabilities. Revegetate the slope with low lying forbs and grasses for erosion protection.

Location, Date, and Time

Target Crossing Coordinates: 47.336974, -103.905431

Region: Belle Fourche Inspection Date: Jul 7, 2020
State: North Dakota Time Arrived: 09:08
County: McKenzie Time Departed: 09:43

Access and Parking

Access Coordinates: 47.34414, -103.90614
Parking Coordinates: 47.34414, -103.90614



**Access and Parking Comments:** Parked just off Prairie Dog Road and accessed the proposed pipeline corridor from the same location as for Potential Slope 5, McKenzie County.

**Field Crew:**

- Andrew Warren (team lead, Tetra Tech)
- Kyle Koppinger (Belle Fourche)
- Kevin Peña (Belle Fourche)

**Access Method:** Walk

**Access Difficulty:** Moderate

---

***Assessment Area***

**Start Coordinates:** 47.33698, -103.90549

**End Coordinates:** 47.33706, -103.90536

---

***Evidence of Mass Failure***

Surface Tension Cracks

**Description:** A possible tension crack was observed near the top of the eastern side of the slope and was approximately 2 feet wide and 2 feet deep. The possible tension crack extended approximately 25 to 30 feet transversely along slope and then transitioned into more defined gully areas downslope. There was also minimal erosion observed in vicinity of the possible tension crack.

Gullying

**Description:** Gullying was observed on eastern edge of corridor with dimensions of approximately 1 foot deep by 1 foot wide, extending approximately 40 feet along the slope. Several gully channels along the slope face were observed.

---

***Bedrock Geology***

**Exposed Bedrock:** No

---

***Soil Conditions***

**USCS Soil Category:** CL (lean clay) with Sand

**Soil Condition Comments:** Lean clay with sand and silt, occasional gravel.

---

***Water Conditions***

**Proximate water source(s) with potential to affect the slope:**

Intermittent Waterways

**Description:** Long drainage with an intermittent stream is located at the toe of the slope. Roughly 3 inches of water were observed in the intermittent stream channel at the time of assessment.



---

**Site Topography/Landforms**

**Landform Type:** Valley

**Slope Profile:** Linear

**General Slope Aspect:** Northeast

**Crossing Angle:** Parallel

**Crossing Angle Description:** The proposed pipeline will be parallel to the slope.

**Average Slope Angle:** 37 degrees

**Maximum Slope Angle:** 46 degrees

**Length of Entire Slope:** 55 ft (16.8 m)

**Length of Slope at Maximum Slope Angle:** 40 ft (12.2 m)

**Topography Landform Comments:** Small slope break located at the top of the slope. Area is roughly 15 feet long and 30 degrees. There is also an area approximately 5 feet long of slightly lower gradient than the maximum slope angle near toe of slope.

---

**Vegetation Cover**

5% trees

50% shrubs

35% forbs/groundcover

10% bare

**Tree Fall Evidence:** No

---

**Potential Slope 6, McKenzie County, North Dakota Photo Log**



**Photo Type:** Looking upslope | **Photo Bearing:** 212 degrees  
**Photo Description:** Looking at the slope face from opposite drainage bank.  
-----

**Photo #1**



**Photo Type:** Looking upslope | **Photo Bearing:** 208 degrees

---

**Photo #2**



**Photo Type:** Slope documentation | **Photo Bearing:** 229 degrees  
**Photo Description:** Looking at gullying on eastern portion of the slope.

---

**Photo #3**



**Photo Type:** Looking across slope | **Photo Bearing:** 133 degrees

---

**Photo #4**



**Photo Type:** Looking downslope | **Photo Bearing:** 46 degrees

---

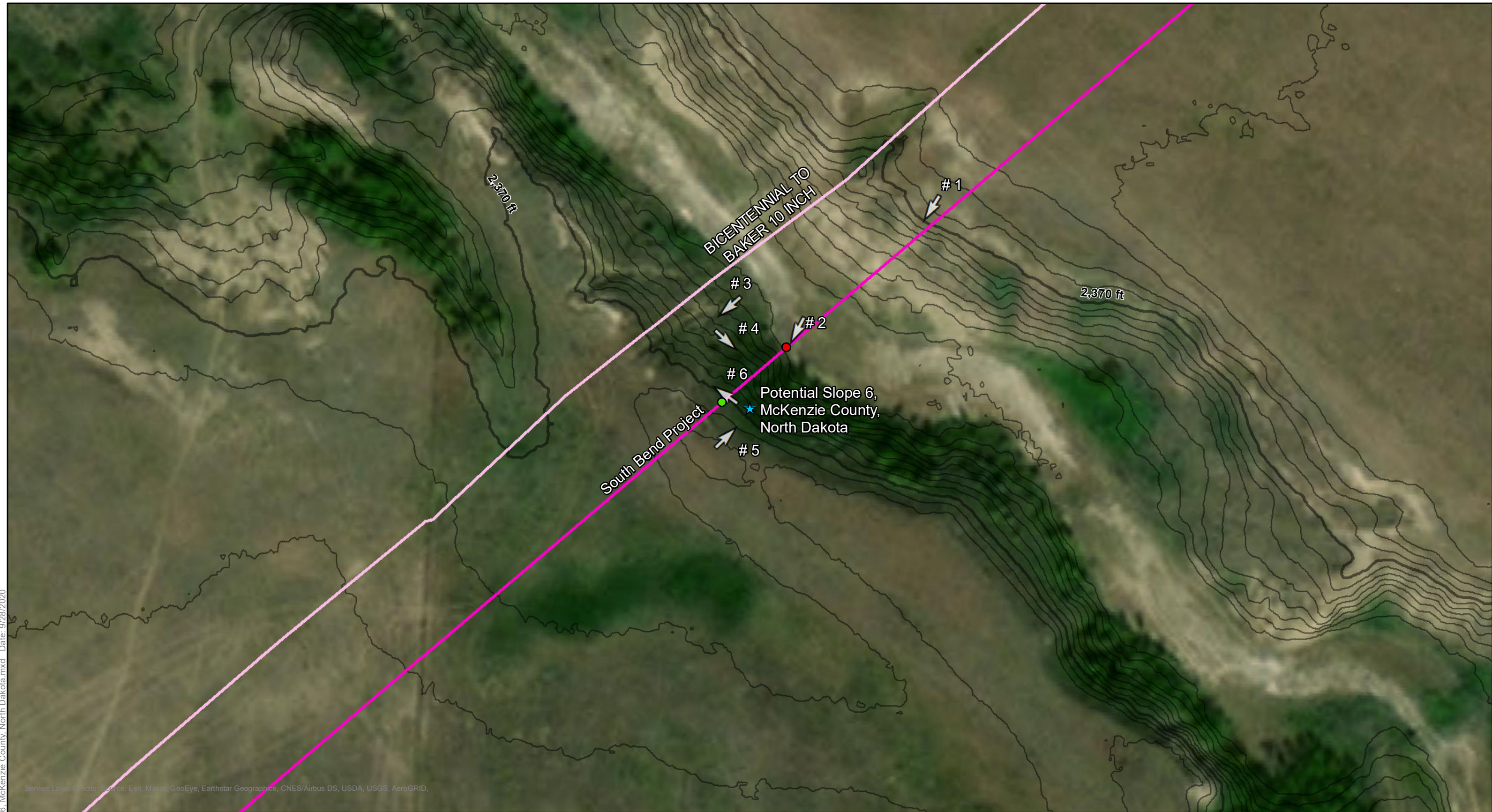
**Photo #5**



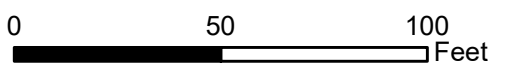
**Photo Type:** Slope movement evidence | **Photo Bearing:** 306 degrees  
**Photo Description:** Looking at a possible tension crack near top of slope.

---

**Photo #6**



E:\Bridger Pipeline\Pipeline\Potential Slope 6 - McKenzie County, North Dakota.mxd Date: 9/28/2020



- DOC Measurement Location
- Slope Start Point
- Slope End Point
- ★ Slope Crossing Coordinates Provided

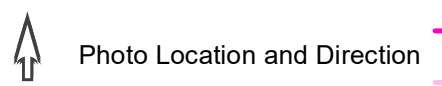


Photo Location and Direction

- South Bend Project (Proposed)
- Other Active Line
- ⋯ Other Inactive Line
- 15 ft Contour
- 3 ft Contour

**2020 South Bend Project**  
**Potential Slope 6, McKenzie**  
**County, North Dakota**  
*Belle Fourche - South Bend Project*  
**FIGURE 1**



2020 Belle Fourche Slope Crossing Field Form

Potential Slope 7, McKenzie County, North Dakota

Crossing Summary

Proposed Pipeline at Crossing: South Bend Project

Mass Failure Potential:

Medium

Narrative Summary:

The slope is moderate to steep and well vegetated. There is a small drainage with an intermittent stream located at the toe of the slope which has caused some historical erosion; however, the area has revegetated and appears to have stabilized at the time of assessment. Several small slumps were also observed near the toe of the slope within the drainage channel. No recent movement was apparent at the time of assessment. Overall, the slope appeared to be stable at the time of assessment with no signs of active movement or instability.

Action Items

Suggested Action Items:

Other (see comments)

Action Item Comments:

Periodically assess the slope for indications of slope movement associated with historic slumping and erosion near the toe of the slope.

Location, Date, and Time

Target Crossing Coordinates: 47.733506, -103.199639

<b>Region:</b> Belle Fourche	<b>Inspection Date:</b>	Jul 6, 2020
<b>State:</b> North Dakota	<b>Time Arrived:</b>	13:06
<b>County:</b> McKenzie	<b>Time Departed:</b>	13:48

Access and Parking

Access Coordinates: 47.73307, -103.19769
Parking Coordinates: 47.73307, -103.19769

Access and Parking Comments: Parked on the side of 122nd Ave NW and walked to the proposed pipeline corridor.

Field Crew:

Andrew Warren (team lead, Tetra Tech)
Kyle Koppinger (Belle Fourche)



Kevin Peña (Belle Fourche)

**Access Method:** Walk

**Access Difficulty:** Easy

---

### ***Assessment Area***

**Start Coordinates:** 47.73410, -103.20131

**End Coordinates:** 47.73421, -103.20083

---

### ***Evidence of Mass Failure***

#### Slumping

**Description:** Minor historic slumping observed near the toe of the slope within the drainage channel. Additional slumping and minor sliding were observed along the opposite drainage bank.

---

### ***Bedrock Geology***

**Exposed Bedrock:** No

**Other Bedrock/Surficial Geology Comments:** Exposed boulder-sized sandstone blocks observed along opposite drainage bank.

---

### ***Soil Conditions***

**USCS Soil Category:** CL (lean clay) with Sand

**Soil Condition Comments:** Sandy lean clay with silt and occasional gravel.

---

### ***Water Conditions***

**Proximate water source(s) with potential to affect the slope:**

#### Intermittent Waterways

**Description:** Local drainage with an intermittent stream located at the toe of the slope. Stream bed is approximately 1 to 2 feet wide and 1 foot deep. Some headcutting of the stream bed was observed upstream of the slope.

---

### ***Site Topography/Landforms***

**Landform Type:** Valley

**Slope Profile:** Convex

**General Slope Aspect:** Northeast

**Crossing Angle:** Parallel

**Crossing Angle Description:** The proposed pipeline will be parallel to slope.

**Average Slope Angle:** 20 degrees



**Maximum Slope Angle:** 28 degrees

**Upper Slope Angle:** 13 degrees

**Lower Slope Angle:** 28 degrees

**Length of Entire Slope:** 145 ft (44.2 m)

**Length of Slope at Maximum Slope Angle:** 45 ft (13.7 m)

**Length of Upper Slope:** 100 ft (30.5 m)

**Length of Lower Slope:** 45 ft (13.7 m)

**Topography Landform Comments:** Site is a drainage valley.

---

***Vegetation Cover***

25% trees

20% shrubs

50% forbs/groundcover

5% bare

**Tree Fall Evidence:** Yes

**Rooting Depth:** 2.0 ft (0.6 m)

**Vegetation Cover Comments:** A fallen mature cottonwood tree was observed with exposed roots at the toe of the slope. The tree appears to have fallen many years ago and has continued to grow since falling.

---

**Potential Slope 7, McKenzie County, North Dakota Photo Log**



**Photo Type:** Looking downslope | **Photo Bearing:** 20 degrees

---

**Photo #1**



**Photo Type:** Looking across slope | **Photo Bearing:** 335 degrees

---

**Photo #2**



**Photo Type:** Looking upslope | **Photo Bearing:** 207 degrees

---

**Photo #3**



**Photo Type:** Looking upslope | **Photo Bearing:** 239 degrees

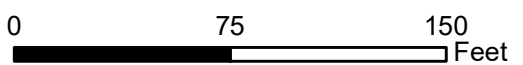
---

**Photo #4**



E:\Bridger Pipeline\Pipeline\Potential Slope 7 - McKenzie County, North Dakota.mxd Date: 9/28/2020

Map Data Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID,



- DOC Measurement Location
- Slope Start Point
- Slope End Point
- ★ Slope Crossing Coordinates Provided

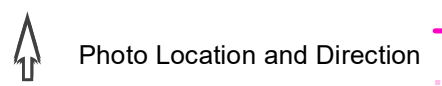


Photo Location and Direction

- South Bend Project (Proposed)
- ⋯ Other Inactive Line

- 15 ft Contour
- 3 ft Contour

**2020 South Bend Project**  
**Potential Slope 7, McKenzie**  
**County, North Dakota**  
*Belle Fourche - South Bend Project*  
**FIGURE 1**