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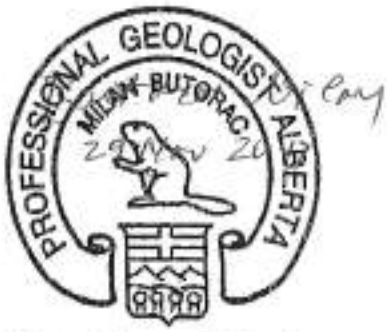
HIGH LEVEL BANK STABILITY REVIEW
PEMBINA RIVER VALLEY
ENTWISTLE, ALBERTA
REVISION 1

Report

to

Parkland County



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Date November 29 2017
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The Association of Professional Engineers and Geoscientists of Alberta

Date: November 29, 2017
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Review Engineer

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1. INTRODUCTION

1.1 General

This report provides the results of a high level stability review for the east side of the Pembina River Valley adjacent to the Hamlet of Entwistle in Parkland County, Alberta.

The work was carried out in general accordance with our proposal letter to Ms. Amanda Soetaert, E.I.T. of Parkland County (County) dated May 4, 2017. Notice to proceed was given in an email communication on May 24, 2017. The work has been carried out in accordance with the terms of the Consulting Service Agreement (Contract No. C170524EN) between the County and Thurber Engineering Ltd. (Thurber).

It is a condition of this report that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

1.2 Project Background

It is understood that the County desired to complete a slope stability review along the east side of the Pembina River in the Hamlet of Entwistle, located approximately 100 km east of Edmonton on Highway 16.

The defined study area extends from Township Road (TR) 532 northward to TR 534, approximately 3.2 km, as illustrated on Drawing No. 18683-1, Appendix A.

At this location, the Pembina River is characterized by deep (approximately 60 m in height) slopes. The southern half of the study area (TR 532 to TR 533) is less developed, while the north half of the study area (TR533 to TR 534) is more developed and includes the central area of Entwistle itself. It is understood that with the ongoing development in the area, the County has concerns with possible slope failures in the area and potential future impacts of slope failure on existing infrastructure. In addition, the County is concerned with the impacts upon any new development along the bank.

Considering the above, the County required a slope stability review to: evaluate the slope stability conditions; identify and assess the risks and effects of the slope conditions on the public, infrastructure, land, structures, etc.; determine the potential causes and mechanisms of slope instability; evaluate any solutions to instability issues; and identify areas for future study.

The following sections present Thurber's work to complete this assessment.

1.3 Scope of Work

Thurber proceeded with a defined scope of work, as outlined in our proposal dated May 4, 2017, and consisted of the following:

- Desktop Study – Thurber has conducted a review of existing subsurface information and terrain analysis. This study involved the review of available geotechnical reports, topographic maps, geological maps and reports, aerial photographs, and available LIDAR imagery.

- Site Reconnaissance – Thurber has conducted a site reconnaissance to assess the general geotechnical conditions in the project area, focusing on key sites where landslide activity was observed to have occurred in the past. This task also included the capturing of photographic and video imagery of current conditions using a remote-controlled drone.

- Slope Stability Analysis – Thurber used the collected data and observations to complete preliminary stability analyses on three representative sections of the river valley.

- Preparation of this report outlining the above work stages and providing a general geotechnical evaluation, analysis, and recommendations for potential mitigation measures and future study.

The approved scope of work for this assessment did not include borehole drilling or soil sampling/testing.

2. DESKTOP STUDY

2.1 Site Investigation Review

As part the desktop study, Thurber has reviewed available reports and plans that contained geotechnical information for the area. In general, the geotechnical information for the area is rather limited, and confined to the sources of information provided below, with locations illustrated on Drawing No. 18683-1, Appendix A.

- Design and As-Built Drawings for the Entwistle Bridge on Highway 16 (BF75014) over the Pembina River, Alberta Transportation, 1959.

- Alberta Municipal Affairs, Entwistle Infrastructure Inventory and Assessment, Section 6 Storm Drainage System, Associated Engineering, 2000.

- Hamlet of Entwistle, Wastewater Treatment Facilities, GPEC Consulting, 2001.
- Parkland County Sewage Lagoon Expansion, Stantec, 2010.
- Groundwater Monitoring, Parkland County Sewage Lagoon Expansion, EBA, 2011.
- Design and As-Built Drawings for Pembina River Bridge on Highway 16A:08 at Entwistle, Stantec/Alberta Infrastructure, 2002.
- Geotechnical Site Investigation, Proposed Guyed Communication Tower, SW-28-53-7-W5, Sabatini Earth Technologies, 2010.
- Trans Mountain Expansion Project, Geotechnical HDD Feasibility Assessment, Pembina River Crossing, BGC Engineering, 2015.
- Pinnacle Renewable Energy, Draft Geotechnical Investigation Report, Proposed Pellet Plant, NW-21-53-7-W5, Englobe, 2017.

Following is a summary of the subsurface and drainage information collected from the reviewed sources.

Design and As-Built Drawings for the Entwistle Bridge on Highway 16 (BF75014) over the Pembina River, Alberta Transportation, 1959

Thurber acquired these drawings from Alberta Transportation (AT) and reviewed them for collected geotechnical information. Drawing 2785-C, Appendix B indicates that three test holes were drilled on the east bank (and toe) of the Pembina River for the design of this bridge structure.

One test hole was drilled at the crest of the valley, near the east abutment location, and indicated a subsoil stratigraphy consisting of overburden soils (top soil, sandy till, clay till, silt, and clay (in descending order) to a depth of 11 m below the crest elevation. Underlying the overburden soils bedrock was encountered. The bedrock consists of alternating layers of sandstone, clay shale, and siltstone. These layers were described in the test hole logs as hard to very hard, presumably in soil mechanics terms. The test hole extended to an approximate depth of 35 m below crest elevation, about half the height of the river valley at the bridge location. Some bentonite seams were observed in the lower depths of the test hole.

Two test holes were drilled at the toe of the river valley for the eastern bridge pier. The depths of these holes ranged from 19 m to 23 m below the bottom elevation of the Pembina River. Both

test holes encountered a top 1 m to 2 m thick layer of river sediments (sand and sandy silt), overlying the same bedrock formation encountered at the crest (alternating layers of clay shale, sandstone, and siltstone).

Alberta Municipal Affairs, Entwistle Infrastructure Inventory and Assessment, Section 6 Storm Drainage System, Associated Engineering, 2000

In 2000, Alberta Municipal Affairs engaged Associated Engineering to perform an assessment of Entwistle's storm drainage system. As described in the report, as of 2000, Entwistle contained minimal storm drainage infrastructure, and is divided into four drainage basins with six identified locations where runoff is discharged over the top of bank into the Pembina River Valley.

Five of these locations (48, 50 – two locations, 51, and 53 Avenues) are located north of Highway 16 in the defined Northwest Drainage Basin and one location (47 Avenue) is located south of Highway 16 in the Southwest Drainage Basin. These locations are illustrated on Figure 6.1 taken from the report, provided in Appendix B, as well as Drawing Nos. 18683-8A in Appendix A.

All of the drainage basins feature minimal infrastructure to handle surface runoff, consisting primarily of some gutters, culverts, ditches, and swales. Of particular interest to the bank stability are the Northwest and Southwest Basins immediately adjacent to the river banks.

As mentioned, the Northwest Basin is the most developed of the four basins, corresponding to the most developed residential area of Entwistle. However, as observed in the report, despite the construction of some ditch and culvert infrastructure, the drainage is described as poor, resulting in numerous areas of ponding, typically at intersection corners, but some river discharge locations do provide some conveyance of flow.

For the Southwest Basin, the majority of the runoff flow follows the roadways and gutters intercepted by some ditches and culverts. With discharge moving to the south. Ponding is also observed in this area at intersections.

The report further provided recommendations for upgrading the storm drainage infrastructure recognizing that major regrading of the existing roadways was not feasible. The proposed upgrades were presented in Figure 6.2, provided in Appendix B. In the Northwest Basin, a network of storm sewers with defined discharge points on the bank of the river valley was proposed. In the Southwest Basin, it was recommended that catch basin and culvert upgrades be undertaken.

The report illustrated that the overland discharge locations in the Northwest Basin are susceptible to surface erosion and could be impacting the stability of the river valley slopes in these locations.

It is understood that the recommended storm sewer has not been installed, nor will it be installed as it is cost prohibitive. There have been some minor improvements to drainage in Entwistle since 2000, none of which have served to improve or reduce the effects of discharge over the bank of the river valley.

Hamlet of Entwistle, Wastewater Treatment Facilities, GPEC Consulting, 2001/Parkland County Sewage Lagoon Expansion, Stantec, 2010/Groundwater Monitoring, Parkland County Sewage Lagoon Expansion, EBA, 2011.

The County provided Thurber with three geotechnical reports pertaining to the development and subsequent expansion of the Entwistle Sewage Lagoon, located in SW-28-53-7-W5, located northeast of the residential area of Entwistle. Three subsurface investigations have been undertaken on this property in 2001, 2010, and 2011.

The initial investigation undertaken in 2001 consisted of five test holes advanced to a maximum depth of 13 m. Surficial clay and clay till extended to a maximum depth of 12 m, with underlying sand and gravel.

For the expansion project in 2010, the investigation consisted of three test holes advanced to a maximum depth of 9.1 m. Surficial clay and clay till extended to a maximum depth of 7 m, overlying sand and gravel. Bedrock was encountered in one test hole at a depth of approximately 8 m.

Further monitoring wells were installed in six locations in 2011. The test holes for these will extended to a maximum depth of 9.9 m. Surficial clay and clay till extended to a maximum depth of 9 m with underlying sand and gravel. Bedrock was encountered at a depth of 5.5 m in two test holes.

Test hole locations and logs are provided in Appendix B for all three investigations.

Design and As-Built Drawings for Pembina River Bridge on Highway 16A:08 at Entwistle, Stantec/Alberta Infrastructure, 2002.

Parkland County provided Thurber with the design and as-built drawings for the Highway 16A bridge over the Pembina River towards the north end of the study area, northwest of the residential area of Entwistle.

Thurber reviewed them for collected geotechnical information. Drawing RD-11189-P, Appendix B indicates that a total of nine test holes were drilled on the valley slopes and river banks, at various elevations for the design of the bridge structure. The maximum depth of these test holes was 8.5 m below ground surface.

For the most part, these test holes encountered clay shale bedrock within 2 m of depth, with overlying sand and gravel. In some locations, bedrock was encountered at the surface. It is expected that the encountered sand and gravel layers are either colluvial slope or alluvial stream deposits, depending on where they are located within the river valley.

Geotechnical Site Investigation, Proposed Guyed Communication Tower, SW-28-53-7-W5, Sabatini Earth Technologies, 2010

The county furnished Thurber with the geotechnical report for a proposed guyed communication tower, to be located in SW-28-53-7-W5, located northeast of the residential area of Entwistle. This geotechnical investigation consisted of four test holes, advanced to a maximum depth of 5 m below ground surface.

The encountered stratigraphy consists of a thin layer of surficial topsoil, overlying sandy, very stiff clay till extending to a depth of 3.5 m. Beneath the clay till, silty and clayey gravel was encountered. Test hole locations and logs are provided in Appendix B.

Trans Mountain Expansion Project, Geotechnical HDD Feasibility Assessment, Pembina River Crossing, BGC Engineering, 2015

The county also provided Thurber with a copy of Trans Mountain Pipeline's (TMP) geotechnical feasibility assessment report for the horizontal directional drilling (HDD) crossing of their pipeline beneath the Pembina River. This report provides a detailed description of the subsurface conditions along their proposed alignment, south of Highway 16. The test holes range in depth from 59 m to 99 m below ground surface.

Two of the test holes were drilled from valley crest elevations, south of residential Entwistle itself. At the PR-02 location, the subsurface consisted of approximately 3.8 m of high plastic clay at the subsurface, overlying "good quality" sandstone, mudstone, and siltstone bedrock. This bedrock continued until the terminal depth of 59 m. At the PR-04 location, the subsurface

consisted of 7.0 m of overburden soils (thin topsoil, over 1.1 m of sand, over 1.8 m of clay, over 4.1 m of silt) overlying interbedded “poor quality” sandstone, mudstone, and siltstone. In general, the quality of the bedrock increased with depth and continued to the terminal depth of 71 m.

The bedrock in both test holes consists of the Paskapoo formation overlying the Scollard formation, which is discussed in more detail in Section 2.2. Test hole logs, as well as stratigraphic cross-sections developed from geotechnical and geophysical data are provided in Appendix B.

Pinnacle Renewable Energy, Draft Geotechnical Investigation Report, Proposed Pellet Plant, NW-21-53-7-W5, Englobe, 2017

The final geotechnical report provided by the County, was a geotechnical investigation report prepared by Englobe in 2017 for the design and construction of a proposed pellet plant, to be located in NW-21-53-7-W5, located northeast of the residential area of Entwistle. The geotechnical investigation consisted of 11 test holes, advanced to depths between 3.5 m and 9.5 m below ground surface.

In general, the encountered stratigraphy consisted of a surficial topsoil (ranging from 200 mm to 900 mm in thickness), overlying clayey silt, overlying sandy silty clay, overlying sand extending to terminal depth. In some test holes peat was observed missed with the clayey silt layers. Test hole logs for this investigation are provided in Appendix B.

2.2 Site Topography Geology Review

Thurber has reviewed available geological mapping, reports, and LIDAR and aerial photo imagery for the study area. The following information was reviewed as part of the site geological review, in addition to above reviewed reports:

- I. Withers. Bedrock Topography of the Wabamun Lake Map-Area, NTS 83G, Alberta. Department of Energy, Mines and Resources, Ottawa. Published 1971.
- L.D. Andriashek and M.M. Fenton. Surficial Geology Wabamun Lake, Alberta. NTS 83G. Alberta Geological Survey. 1979.
- D.J. Glass. Lexicon of Canadian Stratigraphy. Volume 4. Western Canada. Canadian Society of Petroleum Geologists. Calgary, Alberta. 1990 and 1997.

- S. Lyster and L.D. Andriashek. Geostatistical Rendering of the Architecture of Hydrostratigraphic Units within the Paskapoo Formation, Central Alberta. ERCB/AGS Bulletin 66. 2012.
- S. Lyster and L.D. Andriashek. Twentieth Percentile Modelled Base of the Paskapoo Formation. Alberta Geological Survey. 2011.
- N. Atkinson and S. Lyster. Thickness and Distribution of Quaternary and Neogene Sediments in Alberta, (Canada). Alberta Geological Survey. 2012.
- Alberta Energy Regulator/ Alberta Geological Survey. Bedrock Geology of Alberta. Map 600. Published 2013.
- Alberta Energy Regulator/ Alberta Geological Survey. Surficial Geology of Alberta. Map 601. 2013.
- L.A. Atkinson and K.E. MacCormack. Sylvan Lake Sub-Basin Hydrostratigraphic Model – Top of the Scollard Formation, Central Alberta. Alberta Geological Survey. 2013.
- Alberta Government. Alberta Environment and Parks. Alberta Water Well Information Database. www.groundwater.alberta.ca/WaterWells/d/ Accessed 2017.
- LiDAR and Aerial Photography Provided by Parkland County.

2.2.1 Topography

As illustrated on Drawing No. 18683-2, Appendix A, the study area is located within a relatively flat area surrounding the Pembina River, located approximately 80 km west of Edmonton, Alberta. The area surrounding Entwistle is generally used as agricultural land. The flat plateau is located south of the buried Beverly Valley that connects the Chip Lake and Wabamun Lake depressions.

The residential areas of Entwistle are located where this flat plain terminates on the eastern side of the Pembina River Valley. The hamlet is bisected by the generally east-west running Highway 16.

The depth of the river valley from the crest (Elevation 780 m), where Entwistle is situated, is on the order of 60 m to 70 m, depending on the location. The slopes of the river valley on the east side are generally between 20 degrees and 45 degrees, as shown on Drawing No. 18683-3, Appendix A. However, some localized steeper slopes (greater that 45 degrees) are evident at

some higher elevation locations, and localized shallower slopes (less than 20 degrees) are evident at lower elevations within river valley plateaus.

The Pembina River was formed initially as a meltwater channel during the Laurentide Glacial Ice Sheet retreat. The river is incised through glacial surficial deposits and Paskapoo Formation in to the Upper Scollard Formation. Within the river, the bedrock formations are exposed at the ground surface.

The following sections further present the geology of the study area.

2.2.2 Surficial Geology

There are four major surficial deposit units present within the study area, as illustrated on Drawing No. 18683-4, Appendix A. Those units are defined as: stagnant ice moraine and glaciolacustrine deposits, located east of the river valley crest where Entwistle is situated; and colluvium and alluvium located within the river valley.

The total thickness of the glacial surficial deposits at the valley crest elevations vary between 5 m and 25 m, as shown on Drawing No. 18683-5, Appendix A. The thickness of surficial deposits within the river valley vary within a large range. In some locations, where landsliding has occurred, colluvium could be tens of meters thick. However, in general alluvium and colluvium within the river valley are present as a thin veneer covering bedrock formations.

Stagnant ice moraine is present on the east side of the Pembina River Valley at crest elevations. These deposits are composed of till which is a mixture of the clay, sand and silt with boulders and some inclusions of glaciolacustrine and glaciofluvial deposits.

Glaciolacustrine deposits are present overlaying the moraine deposits, and they are present mostly as a top layer on the west side of the Pembina River Valley. The glaciolacustrine deposits are composed of bedded silt and clay with minor sand inclusions and some pockets of sand and gravel.

Alluvium deposits are generally present as a thin layer (veneer) deposited by the Pembina River and tributary creeks, during the river incision. Alluvium is composed of gravel, sand, silt, and some clay.

Colluvium deposits are a gravitationally moved material originated from bedrock or other surficial geology units. The colluvium is located at the river and creeks banks and it is composed

of mixture of clay, silt, sand and pieces of bedrock formations. Some portions of the colluvium in the river valley are unstable and moving in the form of recently active landslides.

2.2.3 Bedrock Geology

The bedrock beneath the surficial deposits consists of two formations: the uppermost portion of which consists of deposits of the Tertiary period, Paskapoo Formation; underlain by the Upper Cretaceous period Scollard Formation. The limits of these formation are presented on Drawing No. 18683-6, Appendix A.

The Paskapoo Formation consists of deltaic and fluvial deposits of interbedded and interlensed fresh water sandstone, siltstone and shale. Typical sediments within the formation consist of interbedded hard to soft sandstone, siltstone and mudstone with subordinate coal, pebble conglomerate and bentonite. The base of the Paskapoo Formation is marked by a thick sandstone layer which is situated on top of the uppermost coal seam of the Ardley Coal Zone of the Upper Scollard Formation.

The Paskapoo Formation can range up to 800 m in thickness in the Rocky Mountain foothills, west of the study area. But in the Entwistle area, only the lowest portion of Paskapoo is present with up to 30 m of thickness, as shown on Drawing No. 16983-7, Appendix A.

The lowest portion of the formation is named as the Haynes Member and it is typically composed of thick medium to coarse-grained sandstone that forms prominent cliffs at outcrops, as visually evident on the slopes of the Pembina River Valley.

The Scollard Formation is present in the study area underling the Paskapoo Formation. The border between the formations is erosional, what means that the uppermost portion of the Scollard Formation is eroded. The Scollard Formation is descriptively separated into two portions: the Upper Scollard and the Lower Scollard.

As present at within the study area, the Upper Scollard is incised by the Pembina River and is mainly composed of interbedded mudstone, sandstone and siltstone with coal zones. As mentioned above, the Ardley Coal Zone is located in the upper portion of the Upper Scollard and this coal is mined in the Wabamun Lake coal mines, east of the study area.

2.2.4 Pembina River Valley Slopes

As previously discussed, the river valley is incised approximately 60 m to 70 m from the surrounding plateau, forming a meandering river. The bottom of the river valley and most of the

river terraces are developed within Scollard Formation deposits. Steep escarpments (cliffs) are formed by Paskapoo Formation sandstones. In the uppermost portion of the valley slopes, glacial deposits of thicknesses between 5 m and 10 m can be observed.

The Pembina River is providing intensive and continual vertical and horizontal erosional forces on the valley, providing ongoing incision. Based on aerial photography from the years 2004 and 2015, we can estimate that total average river bed shifting is 2.9 m in the intervening 11 years, resulting in a shifting rate of approximately 0.25 m/year. This shifting is the result of both river erosion and deposition.

Drawing Nos. 18683-8A and – 8B, Appendix A, illustrates zones with significant river erosion. These zones are within concave banks where the river is eroding mostly bedrock deposits and some thin alluvial or colluvial terraces. In these high erosion zones, river bed shifting could be as much as 8 m in the 11 year observation period (approximately 0.72 m/year).

Shifting of the river due to deposition is evident at concave banks where alluvial terraces and deposits are illustrated.

Major erosion of the river valley slopes is the result of weathering and crumbling of the bedrock formations, primarily the Paskapoo Formation sandstone in form of the rockfalls. Deeper within the valley, rockfall debris and washout material form colluvial materials which mostly cover the Scollard Formation deposits. Colluvium is primarily material that has been mobilized as landslides. Drawing Nos. 18683-8A and -8B, Appendix A, illustrates the four identified major landslide zones (Sites 1 to 4) within the Pembina River Valley study area on the east bank. The available data indicates that most of the colluvial slopes and landslides occurred prior to 2004 and most likely even decades before then. The depositional rate of these downslope sliding areas is unknown.

Landslide areas and erosion patterns were developed and delineated using a combination of air photo interpretation and LiDAR survey imagery.

3. SITE RECONNAISSANCE

3.1 Primary Site Reconnaissance

Following the completion of the desktop study, a primary engineering and geology site reconnaissance was undertaken by Mr. Stephen Coulter, P. Eng., P.E. and Mr. Niels Rasmussen, P.Geo. of Thurber on September 29, 2017. Permission to enter private property was arranged for by Ms. Amanda Soetart, E.I.T. of Parkland County.

Due to the large size of the site, the difficulty to access various locations along the length of the study area, and the high level nature of this study, it was decided that the reconnaissance would focus on the four identified possible landslide sites discussed in Section 2.2.4, as well as the general conditions of the river valley slopes and surrounding areas. The site visits also evaluated possible locations for remote-control drone flights that would allow for aerial observation of the river valley slopes.

3.1.1 Site 1

The river valley banks at Site 1 are situated towards the south end of the study area, directly west of the Pembina River Tubing business parking lot and facilities. The area at the crest of the river valley is relatively undeveloped and consists of agricultural fields with mature forest vegetation along the valley slopes and immediate crest area. The LiDAR survey indicates that the typical slope angles are in the range of 20 to 40 degrees, with a small portion of the slopes over 45 degrees.

The site could be accessed via a foot trail from the Pembina River Tubing parking area that leads down the valley to the river shore. Along this path the slope was vegetated with mature trees. Some of the trees were observed to have bent trunks at their bases and mature straight trunks for the rest of their height (Photos 1 and 2, Appendix C). This type of growth is typical of trees that experienced some downslope movement when they were young but have not significantly moved in the years since, which is most likely on the order of decades.

The slopes were steep enough and heavily wooded in most areas that they could not be easily traversed by foot (Photos 3, 4, and 5, Appendix C), which prohibited accessing a great deal of the river's edge and the associated slopes. These conditions are also not favourable for future aerial drone flights as the west bank of the river could not be easily accessed either.

Overall, the slopes in the area appeared relatively stable due to the presence of heavy mature vegetation and little encroachment by human activities. The stability of the slopes in this area are also most likely aided by the presence of very shallow bedrock. At numerous locations along the walking trails that descend from the crest, sandstone outcrops of the Paskapoo formation (Photo 6, Appendix C) could be seen.

3.1.2 Site 2

The river valley in the vicinity of Site 2 is situated west of 55 Street (Range Road 74B) and south of 46 Avenue. The area at the crest, east of 55 Street is developed with some housing,

but is generally the edge of town with some mixed agricultural land. The immediate upland area of the identified landslide area is vegetated with mature trees and used as agricultural land.

The available LiDAR survey indicates that slopes in this area are generally between 20 and 45 degrees, with some of the upper slopes where sloughing has occurred being over 45 degrees. In general, these steeper slopes are located towards the south of the identified site where the river is more concave in route (Photos 7 and 8, Appendix C). Along some of these southern slopes, near vertical walls have been exposed near the crest of the slopes with colluvial material collecting at the toe. The contact between overburden soils to bedrock is visually observable as a relatively horizontal line at approximately 10 m depth from the crest (Photos 9 and 10, Appendix C). Some midslope seepage was also observed along these slopes. These slides appear to be relatively historic in nature, as the colluvial slopes at the toe have some mature vegetation growing on them.

The valley slope along the north portion of this area is where the more recent slope movement was identified in the desktop study. These slopes show some exposed overburden and sandstone outcrops, but are much shorter in height compared to the northern portion, due to more gradual upper slopes in this area (Photos 11, 12, and 13, Appendix C). The colluvium in this area at the toe of the slope features more recently started vegetation. The failure in this area appears to be a retrogressive one that in time has moved back from the crest. However, the vegetation that is on the slopes is vertical, indicating that the movement has not occurred in the very recent past, confirming the result of the desktop study where it was suggested that these slope movements have occurred decades in the past.

This site is accessible from the toe for future aerial reconnaissance with a remote controlled drone to give further visual assessment higher on the slope that cannot be observed from the river edge.

3.1.3 Site 3

The valley slopes in the Site 3 area are located west of 55 Street and roughly north of 46 Avenue and south of Highway 16. This location is beginning to encroach upon the more developed area of Entwistle where more densely situated residences and business are located. At the crest of the valley slope a narrow band (5 m to 25 m) of mature vegetation is situated.

LiDAR data indicates that the majority of slopes in this area are in the range of 20 to 45 degrees with some of the upper slopes greater than 45 degrees. Towards the south end of the site, an exposed slope could be observed (Photo 14, Appendix C) where a possible landslide zone

could be situated (Photo 17, Appendix C). Aerial drone reconnaissance was highly recommended for this site at this time to understand the state of the upper slopes at this south end.

In the middle of the area the slopes appeared to be more stable with no visible outcrops and uniform mature vertical vegetation (Photo 15, Appendix C). This area also featured some colluvial slopes of previously mobilized material with mature vegetation growing on it (Photos 18 and 19, Appendix C). However, there is also a small amount of tree deadfall on these slopes that appears to indicate that some movement has occurred in the past and some trees have fallen as a result of it.

Towards the north end of Site 3, some exposed outcrops could be observed, with some visible erosion channels running through them (Photo 16, Appendix C). This is consistent with reports from Parkland County that the landowner in that area is concerned with the overland flow he can observe from the west side of his property.

3.1.4 Site 4

The valley slopes in the Site 4 area are located southwest of the end of Township Road 534 at the north end of the defined study area. This zone is located at the northern reaches of the developed residential area on Entwistle that is north of Highway 16. The area can be considered as heavily forested with mature vegetation as the townsite transitions to the lands within Pembina River Provincial Park. Most of this vegetation as viewed from the crest area appears to be vertical in growth pattern (Photos 20 and 21, Appendix C).

The LiDAR data indicates the lower slopes in this area are generally less than 20 degrees, with midslopes between 20 and 45 degrees and some of the upper slopes greater than 45 degrees.

The exposed vertical walls indicated by the LiDAR survey are visually evident along the southern, middle, and northern portions of this site. Colluvial slopes of previously mobilized material is quite consistent across the entire length of the site (Photos 23, 24, 25, and 26, Appendix C). These colluvial slopes generally feature large mature tree vegetation that is relatively vertical in growth. These slopes appear to have moved in the past, possibly decades ago, and the exposed sandstone vertical faces appear to be stable and relatively shallow (approximately 5 m below the crest elevation).

A drainage channel was also observed about in the middle of the site, and is also evident from topography and LiDAR data (Photo 27, Appendix C). From the toe of the valley slope it does not

appear that this channel discharges a great volume of water as the vegetation in this area is dense and mature.

This site is accessible for a remote controlled drone flight from the west bank of the river and was recommended to observe the condition of the transition from the exposed bedrock faces to the colluvial slopes below.

3.1.5 Runoff Discharge Locations

The previously identified runoff locations identified in the Alberta Municipal Affairs (2000) study at 48, 50, 51, and 53 Avenues were also observed. In general, these locations were found in the same condition as they were in the previous study with the erosion continuing to erode the overburden soils at the crest of the river valley, and to some degree, can be identified on the LiDAR images and surface slope maps (Drawing Nos. 18683-2 and 18683-3).

It is expected that over time the overburden soils will continue to erode down to the bedrock contact, which is expected to be approximately 5 m or less from the plateau elevation. As this continues it will pull vegetation into the eroded channel and retrogress back as unprotected overland flows are continued to be allowed to run into the areas.

3.1.6 General Slope Assessment

In general, the Pembina River Valley, situated immediately along the western edge of the Hamlet or Entwistle appeared to be marginally stable to stable in condition. The marginally stable areas appeared to be localized to concave portions of the river route where higher flow velocities can be expected.

Bedrock was observed to relatively shallow along the entire reach of the study area, typically a depth of 5 m to 10 m from the valley crest, leading to a high tolerance for near vertical slopes in most locations.

Colluvial slopes have formed at various locations along the study area, below the exposed upper slopes. For the most part the slopes appear to be stable in the recent past, due to the visual observation of vertical mature vegetation on them.

Some areas of observed overland flow are occurring (Site 3 as well as the 4 previously identified locations). These may be occurring at other sites, but a comprehensive inventory of these locations was beyond the scope of this report.

Visually, there appears to be no immediate threat of imminent slope failure to any existing development within the Hamlet of Entwistle, due to the observed conditions of the slopes and what is known about the shallow bedrock geology. However, river action may lead to some of these slopes destabilizing in the future. No immediately active landsliding areas were observed during the primary reconnaissance, but one was positively identified at Site 3 during the secondary reconnaissance, as discussed in Section 3.2. It is important to note that the scope was limited to observing highlighted sites identified during the desktop study, and other localized areas of instability that were not directly observed, may exist at some location along the study area.

From the accessible vantage points it is difficult to assess the condition of the lower colluvial slopes where they interact with the upper exposed vertical bedrock zones. As was observed at Site 2, some seepage out of the slopes was being experienced. Following the completion of this primary reconnaissance it was decided to proceed with a secondary reconnaissance using a remote controlled aerial drone fitted with a video camera to observe the condition of the upper slopes, where access can be gained (Sites 2, 3, and 4). Secondary reconnaissance of Site 1 was deemed unnecessary due the access difficulty, as well as its lack of proximity to development.

3.2 Secondary Site Reconnaissance

As mentioned above, a secondary site reconnaissance using a remote controlled aerial drone was recommended to be undertaken following the primary site reconnaissance for Sites 2, 3, and 4.

This reconnaissance was undertaken on October 19, 2017 by Mr. Niels Rasmussen, P.Geo. of Thurber using a drone fitted with a video camera. A series of drone flights were undertaken for each of these sites. The recording of four selected flights is saved on an attached DVD in Appendix D for future reference. One recorded flight has been provided for each of: Site 2 (South), Site 2 (North), Site 3, and Site 4.

The main target of these flights was to observe the condition of the lower colluvial slopes and the upper exposed bedrock walls above the tree lines on the colluvial slopes themselves. During the primary reconnaissance, most of the visual observation was undertaken from the river elevation. Due to the steep slope of the river valley, direct observation of these areas was difficult.

To aid in the discussion of this secondary reconnaissance, Thurber has produced panoramic photo mosaics of multiple single frame images obtained from the drone flight films. These images are attached as Plates D1 through D4 in Appendix D. The following sections provide discussions of these observations.

3.2.1 Site 2

Plates D1 and D2, Appendix D illustrate the observed conditions from Site 2. In general, the lower colluvial slopes feature mature vertical vegetation with some bare areas that may be experiencing current minor surface erosion. The slide area does appear to be retrogressing slightly at the crest with the loss of some overburden material. There appears to be some trees that are leaning over the crest and/or have fallen over due to this relatively recent loss of overburden material.

3.2.2 Site 3

Plate D3, Appendix D illustrates the observed conditions towards the south end of Site 3. The erosion patterns observed in the primary reconnaissance towards the north end of the site could not be captured with the drone due to range concerns.

The most striking feature is that there is indeed an active landslide occurring towards the south end of Site 3, which would be located immediately west of the area between 46 and 47 Avenue. This corresponds to the disturbed toe conditions from the primary visit (Photo 17, Appendix C).

The plate clearly shows that an active scarp is present with overburden material flowing over the crest and bedrock outcrops and continues downslope. Relatively green mature vegetation in the form of knocked down trees in the slide zone indicates that this slide is recent and possibly ongoing. Surface erosion runnels are also an indication of this being a relatively recent event.

3.2.3 Site 4

Plate D4, Appendix D shows the upper slope conditions observed at Site 4 and shows that the lower colluvial slopes are relatively populated with mature vertical tree vegetation. There are some localized areas where trees have fallen, most likely to localized disturbances. The indications are that this colluvial zone has not moved in quite some time and has been relatively stable for the recent past.

4. SLOPE STABILITY ANALYSIS

Slope stability analyses were carried out to provide a preliminary assessment of the current overall slope stability at three selected locations, generally corresponding to the three more critical identified previous landslide locations; Site 2 (Section A-A'), Site 3 (Section B-B'), Site 4 (Section C-C'). The locations of these selected sections are illustrated on Drawing Nos. 18683-8A and -8B, Appendix A.

The analyses were carried out using the Limit Equilibrium Software Slope/W (version 7.21). The slope stability model was based on the subsurface information collected in the previous investigation review, topography and geology review, primary and secondary site reconnaissances, as well as Thurber's experience in the area on similar projects. The slope geometry was based on the LiDAR data provided by the County to Thurber.

The first step of the analysis was to use Site 3 (Section B-B') to perform a back-analysis to determine the material properties that result in a post failure condition. This was undertaken, knowing that this section is actively failing and therefore indicating a factor of safety (FOS) of approximately 1.0 or lower.

The material parameters used in the stability analyses were based on the back-analysis as well as previously reviewed information and similar soils from other case studies, as summarized in Table 4.1.

TABLE 4.1
SOIL PARAMETERS USED IN SLOPE STABILITY ANALYSIS

SOIL TYPE	BULK UNIT WEIGHT (kN/m^3)	EFFECTIVE COHESION, c' (kPa)	EFFECTIVE FRICTION ANGLE, ϕ' (Degrees)
Clay Till/Sand/Silt (Overburden Soils)	19	2	25
Weathered Sandstone Bedrock (Paskapoo)	24	50	45
Competent Sandstone Bedrock (Scollard)	Impenetrable		

Referring to Figure E1, Appendix E, the material properties were varied to obtain a FOS of approximately 0.9 for Site 3. These materials were then used as inputs to evaluate Sites 2 and 4. For all of the sites the depth of the overburden was varied to reflect what is known from adjacent geotechnical studies and observations from the site visits. Due to the shallow bedrock surface, it is expected that the failures are generally confined to the overburden layer and some of the shallower weathered sandstone bedrock.

The calculated FOS for Sites 2 and 4 were 1.2 (Figure E2, Appendix E) and 1.4 (Figure E3, Appendix E), respectively, indicating that these slopes are most likely in the marginally stable to stable range, which is reflective of the visual assessment during the site reconnaissance.

It should be noted that these analyses should be considered very preliminary and not to provide guidance for future top of bank development. They are conducted with very limited subsurface information on stratigraphy and material strength properties. However, they can serve as a guide to inform general conditions of the valley slopes in critically identified areas.

5. GEOTECHNICAL EVALUATION AND RECOMMENDATIONS

As discussed in the desktop study, and confirmed within the site reconnaissance visits, the stratigraphy along the east side of the Pembina River Valley within the study area consists of a relatively thin (5 m to 10 m thick) layer of overburden soils overlying weathered bedrock of the Paskapoo Formation) overlying more competent bedrock (of the lower Paskapoo and upper Scollard Formations), which extends to the bottom of the river valley.

The slopes of the valley generally range from 20 to 45 degrees, with some localized steeper sections in the upper slopes, and some localized shallower sections in the lower slopes. These slope configurations have been formed by the oversteepening of the overburden soils and eventual downslope failure overtop of the exposed bedrock formations. The mobilized overburden and upper weathered bedrock then collects at the toe of the valley slopes in the form of shallow slope colluvial deposits. Some seepage was observed along the exposed bedrock (near Site 2). This seepage is not expected to be a major concern and is most likely occurring at either a horizontal fissure in the bedrock or the daylighting of a highly contrasting permeability contact within the bedrock formations, possibly at an interaction between the Paskapoo and Scollard formations.

The desktop study had identified four sites where historical (or current) landslide events have occurred. These four sites were further investigated during two subsequent site visits. For the most part, the site reconnaissance has confirmed that the majority of the landslides have not happened in recent time and the banks are marginally stable to stable, as confirmed by the slope stability analysis.

However, one location was identified as experiencing either fairly recent and/or continuing landslide activity, the southern end of Site 3.

None of the landslide areas, either historic or current, appear to pose an existing imminent risk to existing developments or infrastructure along the study area. However, it is important to

recognize that the scope of this report is limited to a high level assessment, and not all of the banks were observed or analyzed for slope stability, and localized slope conditions and continuing river action erosion may lead to other unidentified localized failures. Through air photo interpretation and LiDAR analysis no other historical landslides were observed. The presence of competent bedrock in the lower and midslopes is a large contributing factor in the stability of the study area.

Site 3 is located approximately 100 m away from the nearest structure, on the west side of 55 Street (Range Road 74B). It is understood that most residential development is on the east side of 55 Street and therefore, no habitable structures should be immediately affected. This location should be periodically monitored using a more thorough visual inspection. This monitoring should be undertaken at semi-annual intervals. This inspection should place in the early summer following spring runoff season and again prior to the winter. If the failure is observed to be ongoing, remedial measures may be required to address possible property owners concerns at this location. Remediation may include installing slope reinforcement, erosion blankets, bio-engineering methods (wattle construction, live staking etc.), re-vegetating the area, and/or some combination of the above. Unabated, this failure may continue to retrogress through the overburden soils eastward and begin to encroach on the agricultural land west of 55 Street.

In addition to these slope failure zones, it is understood, and it was observed that there are several identified locations along the banks where overland surface water discharge is occurring. It is not known if any of the storm water collection upgrades proposed in the Alberta Municipal Affairs (2000) report were implemented. However, it appears that the overland discharge drainage issues that were discussed in that report have continued at locations both south and north of Highway 16. This erosion will continue during future surface runoff events and will over time, remove overburden soils down to the exposed bedrock contact. It is not expected to be likely that this erosion down to the bedrock will cause overall instability to the valley slope. However, it is possible that the erosion of overburden soils in these areas could progress back eastward from the crest of the slope, destabilizing some of the near crest aras. It is recommended that erosion control measures be employed in these areas to minimize erosion effects. This may require some regrading, as well as armoring the crest and upper banks with riprap, erosion control blankets, or a similar engineered method. Controlling this erosion will promote greater bank stability in these areas.

Channel erosion at the direct river banks is occurring along the outside bank of oxbow bends in the Pembina River. For the most part, this erosion is mobilizing previously deposited colluvial material. The very steep high bedrock valley walls that were observed in the area do not appear

to be highly susceptible to toe erosion and show an ability to stand up at an almost vertical angle in some locations. It is not expected that the identified erosion in these areas would have a significant impact on the stability of the top of bank areas.

If there were local zones that the County wished to protect at the toes of the slope for other reasons, this would most likely be accomplished by providing heavy rip rap armouring. Due to the primarily granular composition of the colluvial slopes, bio-engineering methods may be unfeasible at these locations.

Additionally, future development in the Entwistle area should take the conditions discussed in this report into consideration. Future surface discharge points should be adequately planned and protected so as not to promote additional erosion in critical areas.

It is further recommended that the future site specific geotechnical investigations be undertaken for any future development within 100 m (corresponding to 1.5 times the approximate valley height) of the crest of the valley. These types of investigations should include test hole drilling in order to obtain stratigraphy and soil and rock strength properties in order to adequately analyze the slopes and determine an adequate development setback distance.

Finally, the County should consider developing a periodic visual monitoring program (possibly every 5 years, or sooner depending on any observations of changes brought to the County's attention by residents). This program would ensure that ongoing movement and/or erosion are at a level that are not to be expected to be of concern. Preferably, this monitoring program would include site visits in conjunction with some LiDAR analysis to determine if the river, valley slopes, or river crest is shifting over time and if it is having impacts on the conditions of the slopes.

A comparison of photographs in key areas would also be useful in assessing any changes to the slopes over time. The cost of this periodic monitoring would be anticipated to be in the range of $15,000 to $20,000 (per monitoring period) plus any costs of acquiring updated air photos and LiDAR data. This program could be commenced 5 years from now, unless any notable further events or changes in the slope conditions are brought to the County's attention.

Additional, more sophisticated investigation and monitoring programs (test hole drilling, slope inclinometers, surface marker monitoring, etc.) may be suggested as a result of the observations from the visual monitoring program in the future.

6. LIMITATION AND USE OF THIS REPORT

There is a possibility that this report may form part of future design and construction documents for information purposes. This report was issued before any final design or construction details have been prepared or issued for any development in the area. Therefore, differences may exist between the report recommendations and the final design, the contract documents, or as observed during construction. In such instances, Thurber Engineering Ltd. should be contacted immediately to address these differences.

Designers and contractors undertaking or bidding of future work should examine the factual results of the investigation, satisfy themselves to the adequacy of the information for design and construction, and make their own interpretation of the data as it may affect their proposed scope of work, cost, schedules, safety and equipment capabilities.

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STATEMENT OF LIMITATIONS AND CONDITIONS

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This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

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5. INTERPRETATION OF THE REPORT

a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.

c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.

d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

7. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

APPENDIX A

Drawing No. 18683-1 – Study Area Location Plan
Drawing No. 18683-2 – Study Area Topography Map
Drawing No. 18683-3 – Study Area Ground Surface Slope Map
Drawing No. 18683-4 – Study Area Surficial Geology Map
Drawing No. 18683-5 – Study Area Glacial Deposits Thickness Map
Drawing No. 18683-6 – Study Area Bedrock Geology Map
Drawing No. 18683-7 – Study Area Paskapoo Formation Thickness Map
Drawing No. 18683-8A – Study Area Geology Summary Map – North Part
Drawing No. 18683-8B – Study Area Geology Summary Map – South Part

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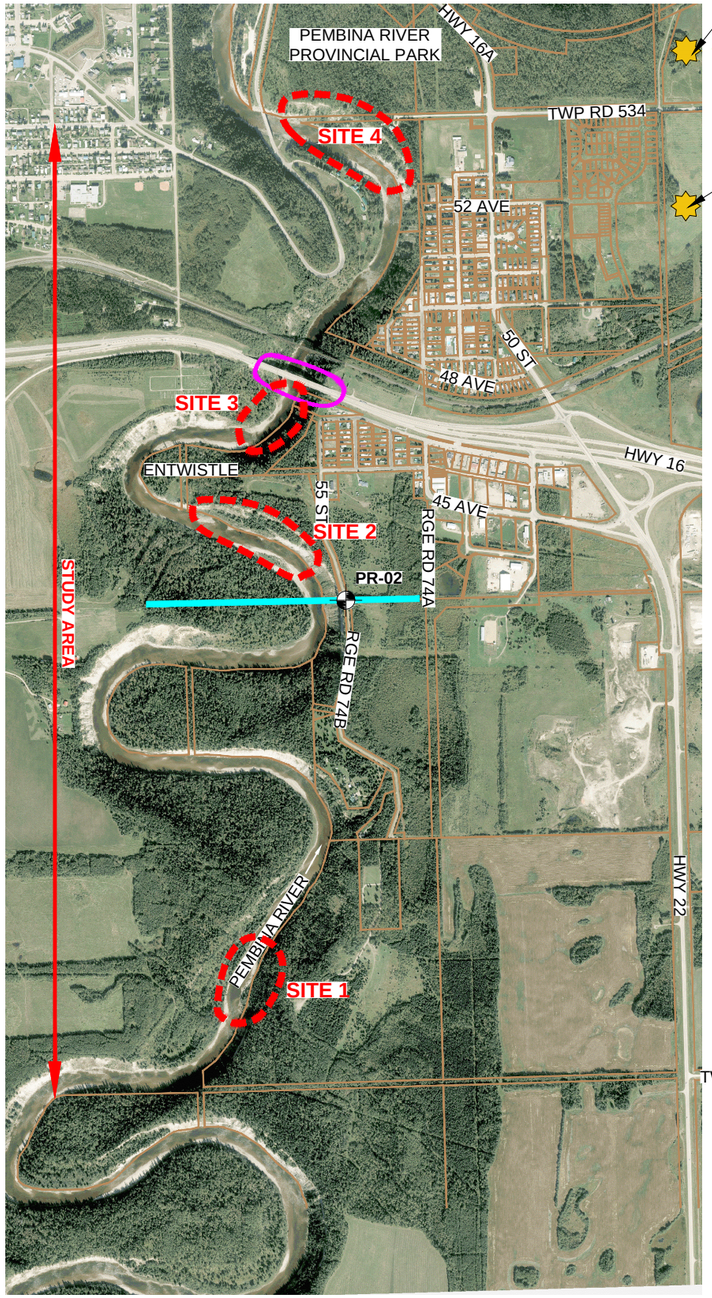

PROPOSED GUYED COMMUNICATION TOWER (2010)

ENTWISTLE SEWAGE LAGOON (2001 / 2010 / 2011)

PROPOSED PELLET PLANT (2017)

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- APPROXIMATE LOCATION OF PREVIOUS SUBSURFACE INVESTIGATIONS
- TRANS MOUNTAIN PIPELINE CROSSING SUBSURFACE INVESTIGATION (2015)
- APPROXIMATE LOCATION OF TEST HOLE PR-02 (2015)
- HIGHWAY 16 BRIDGE SUBSURFACE INVESTIGATION (1959)

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BASE PLAN PROVIDED BY ESRI WORLD IMAGERY

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HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

STUDY AREA LOCATION PLAN

DWG No. 18683-1

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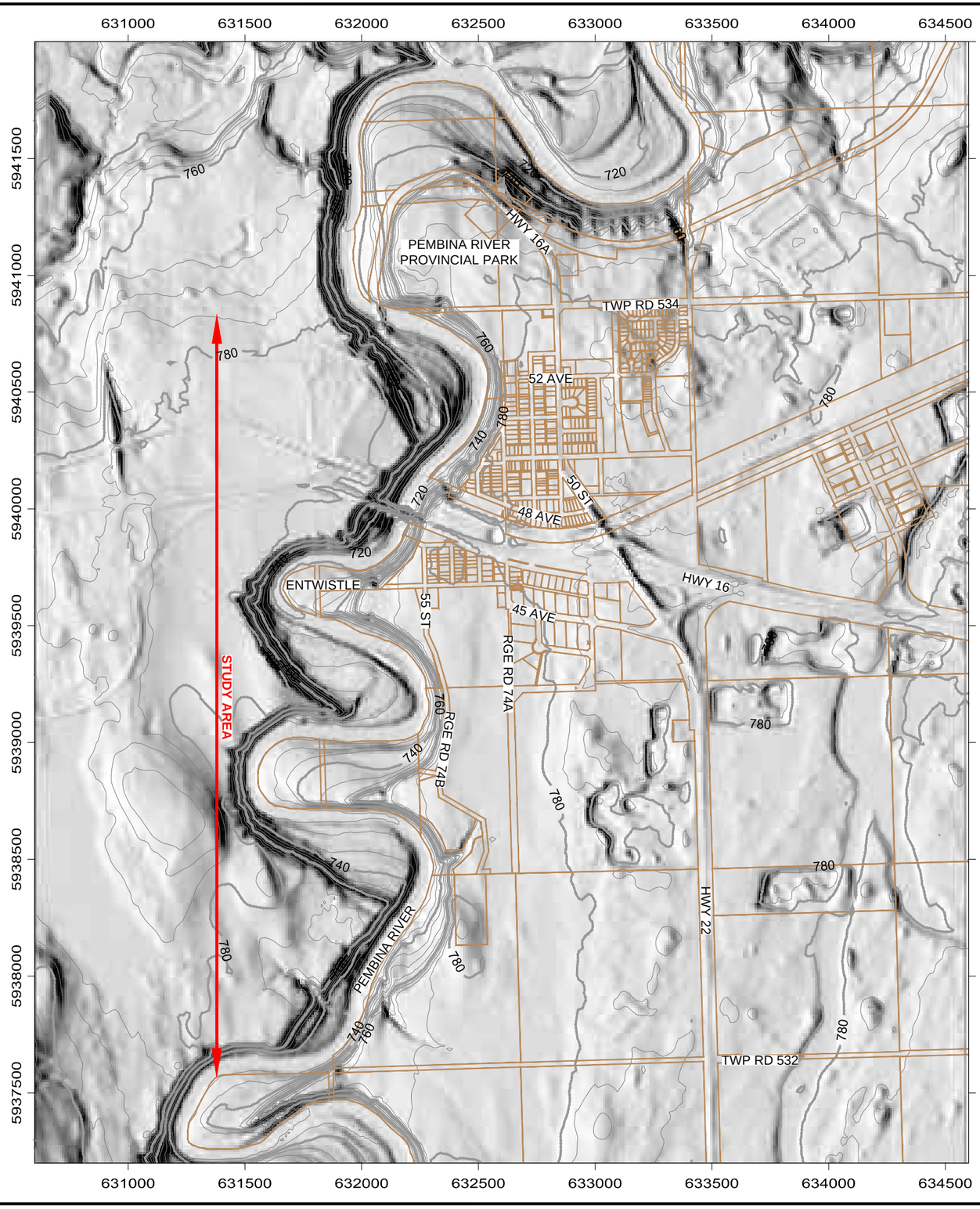

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HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

STUDY AREA TOPOGRAPHY MAP

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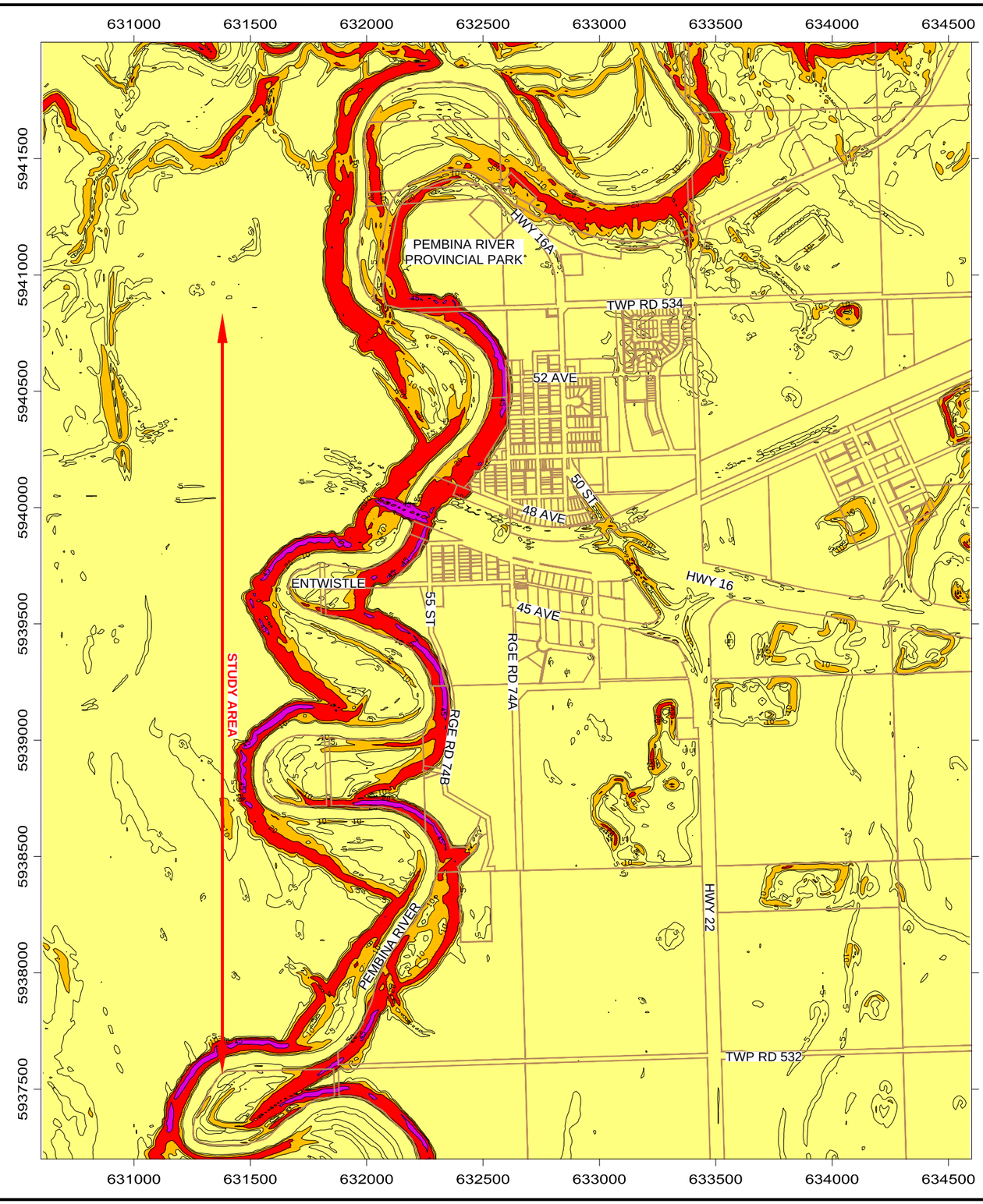

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HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

STUDY AREA GROUND SURFACE SLOPE MAP

DWG No. 18683-3

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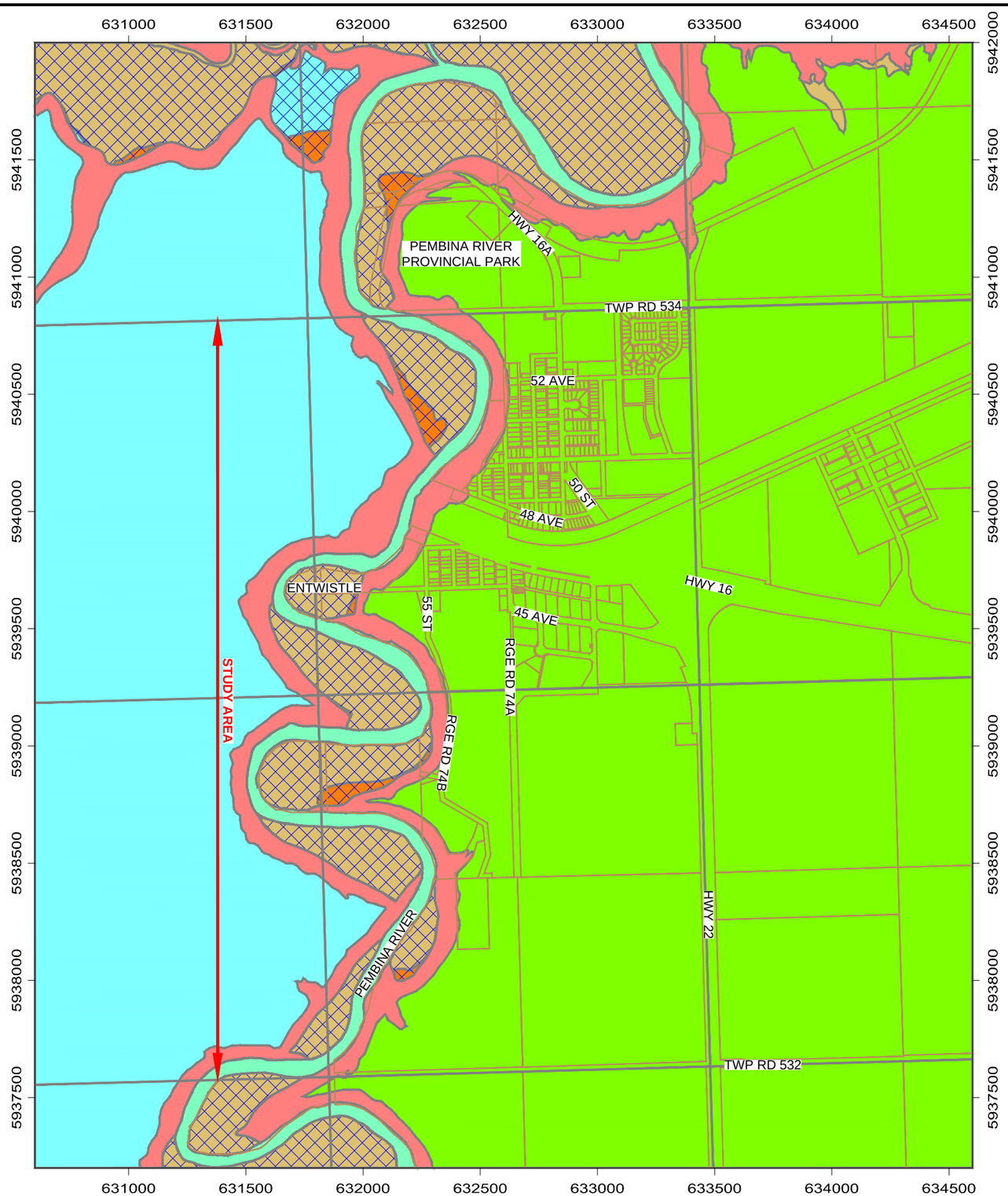

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- ALLUVIUM; VENEER OF SAND, GRAVEL AND SILT OVER BEDROCK AND GLACIAL DEPOSITS
- COLLUVIUM: GRAVITATIONALY MOVED GLACIAL DEPOSITS AND BEDROCK DEPOSITS
- GLACIOLACUSTRINE DEPOSITS: LAMINATED TO MASSIVE FINE SAND, SILT AND CLAY.
- STAGNANT ICE MORAINE: MAINLY TILL WITH LOCALY INCLUDED STRATIFIED GLACIOLACUSTRINE OR GLACIOFLUVIAL DEPOSITS.
- PASKAPOO FORMATION: ALLUVIAL SANDSTONE, SILTSTONE AND MUDSTONE WITH SOME COAL LAYERS.
- SCOLLARD FORMATION: MUDSTONE, SILTSTONE AND SANDSTONE
- RIVER

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HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

STUDY AREA SURFICIAL GEOLOGY MAP

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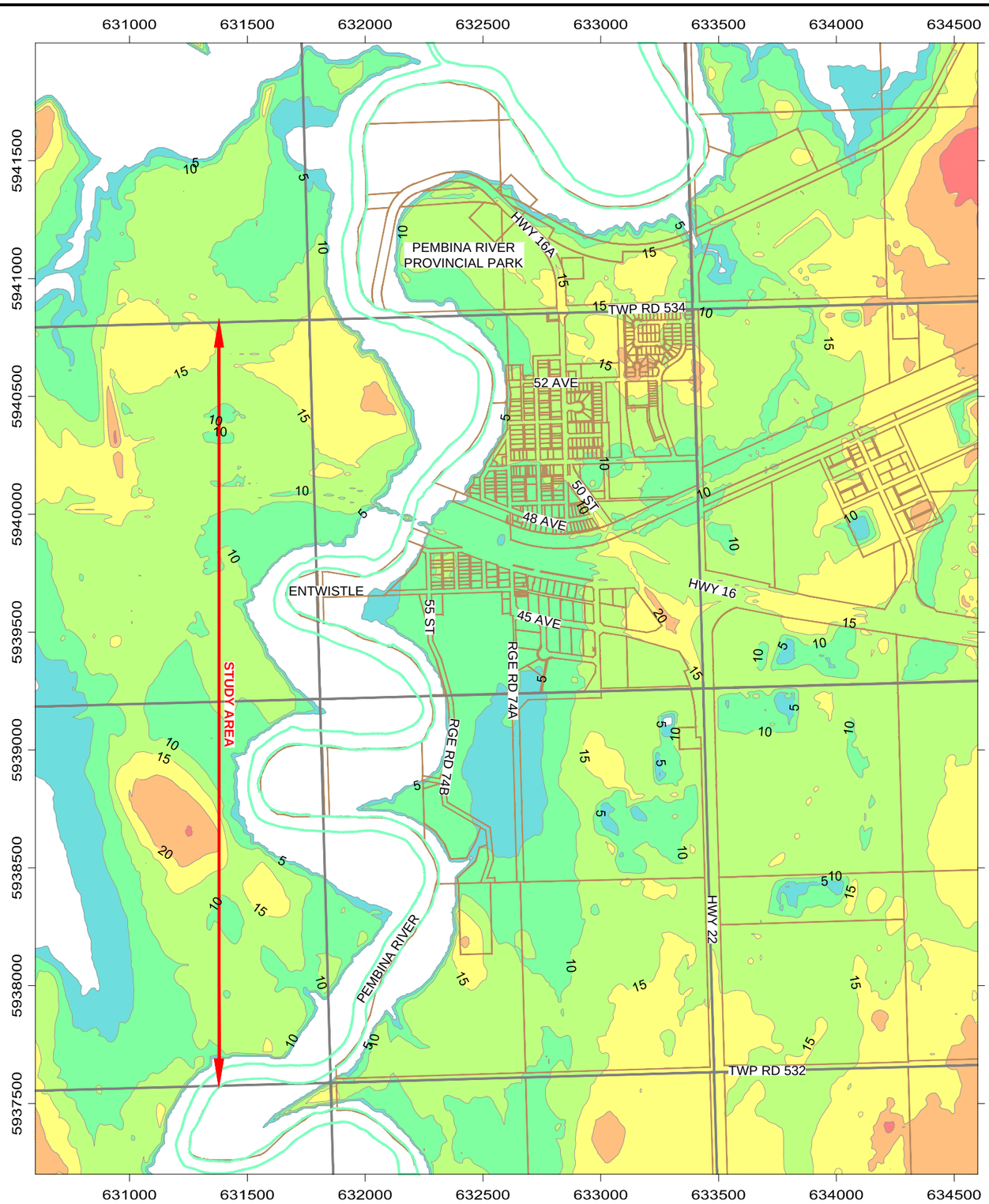

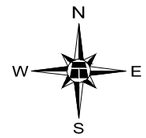

Reference Maps:
M.M. Fenton and others. Surficial Geology of Alberta. Alberta Geological Survey Map 601. 2013. G.J. Prior and others. Bedrock Geology of Alberta. Albeta Geological Survey Map 600. 2013.

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HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

STUDY AREA GLACIAL DEPOSITS THICKNESS MAP

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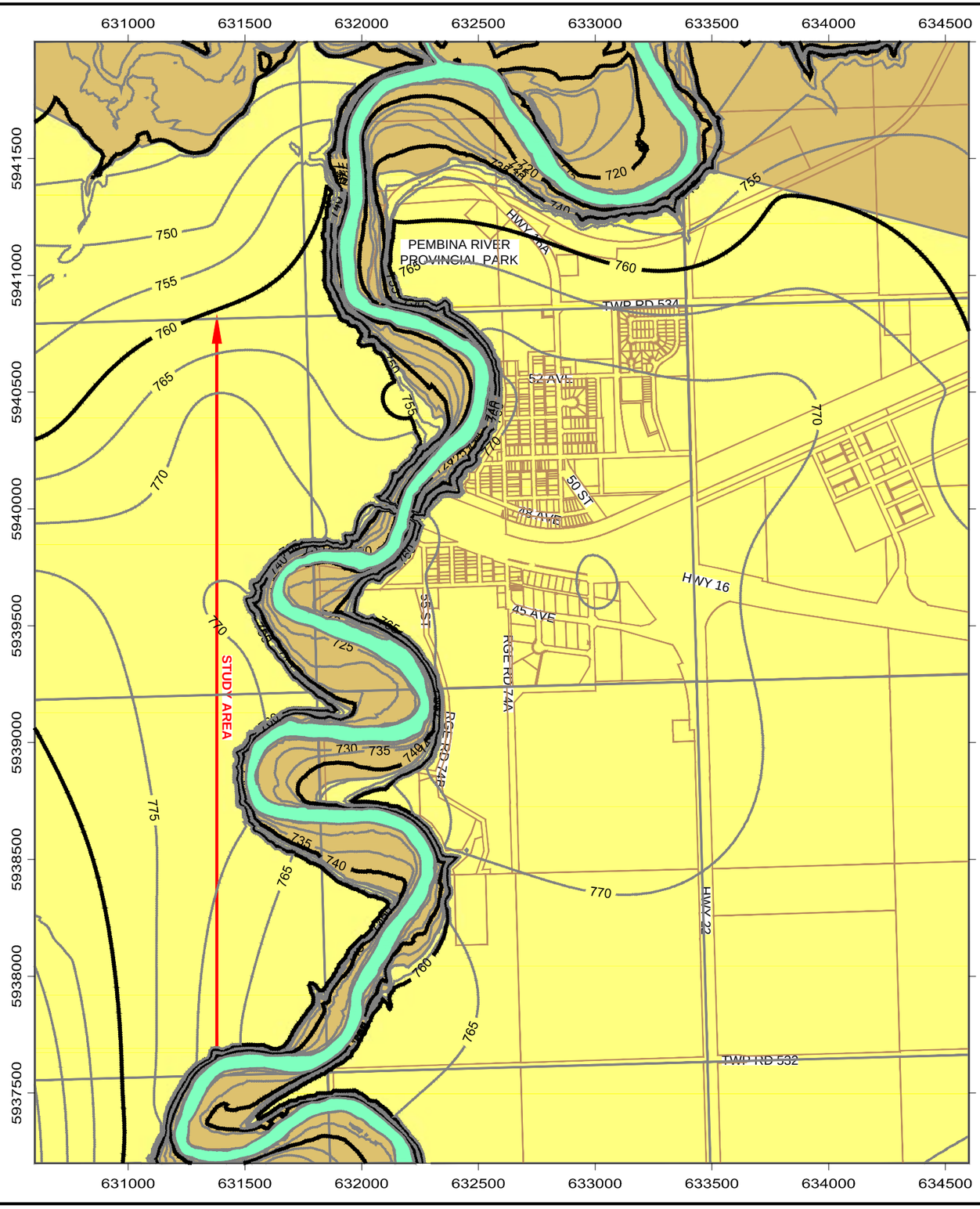

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PASKAPOO FORMATION: ALLUVIAL SANDSTONE, SILTSTONE AND MUDSTONE WITH SOME COAL LAYERS.

SCOLLARD FORMATION: MUDSTONE, SILTSTONE AND SANDSTONE

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parkland county

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

STUDY AREA BEDROCK GEOLOGY MAP

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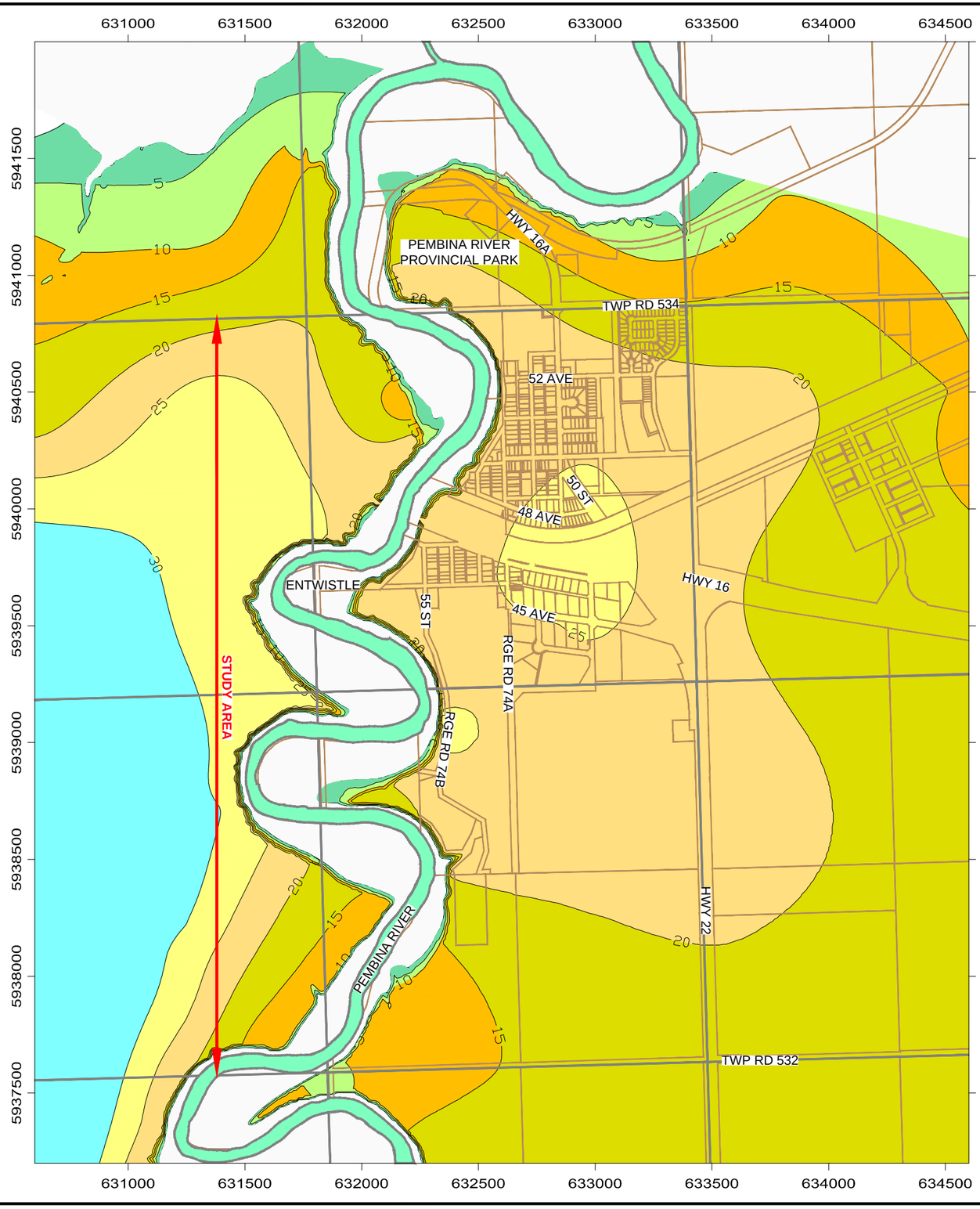

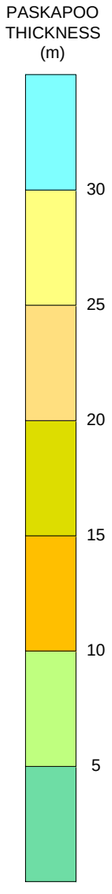

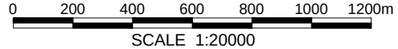

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HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

STUDY AREA PASKAPOO FORMATION THICKNESS MAP

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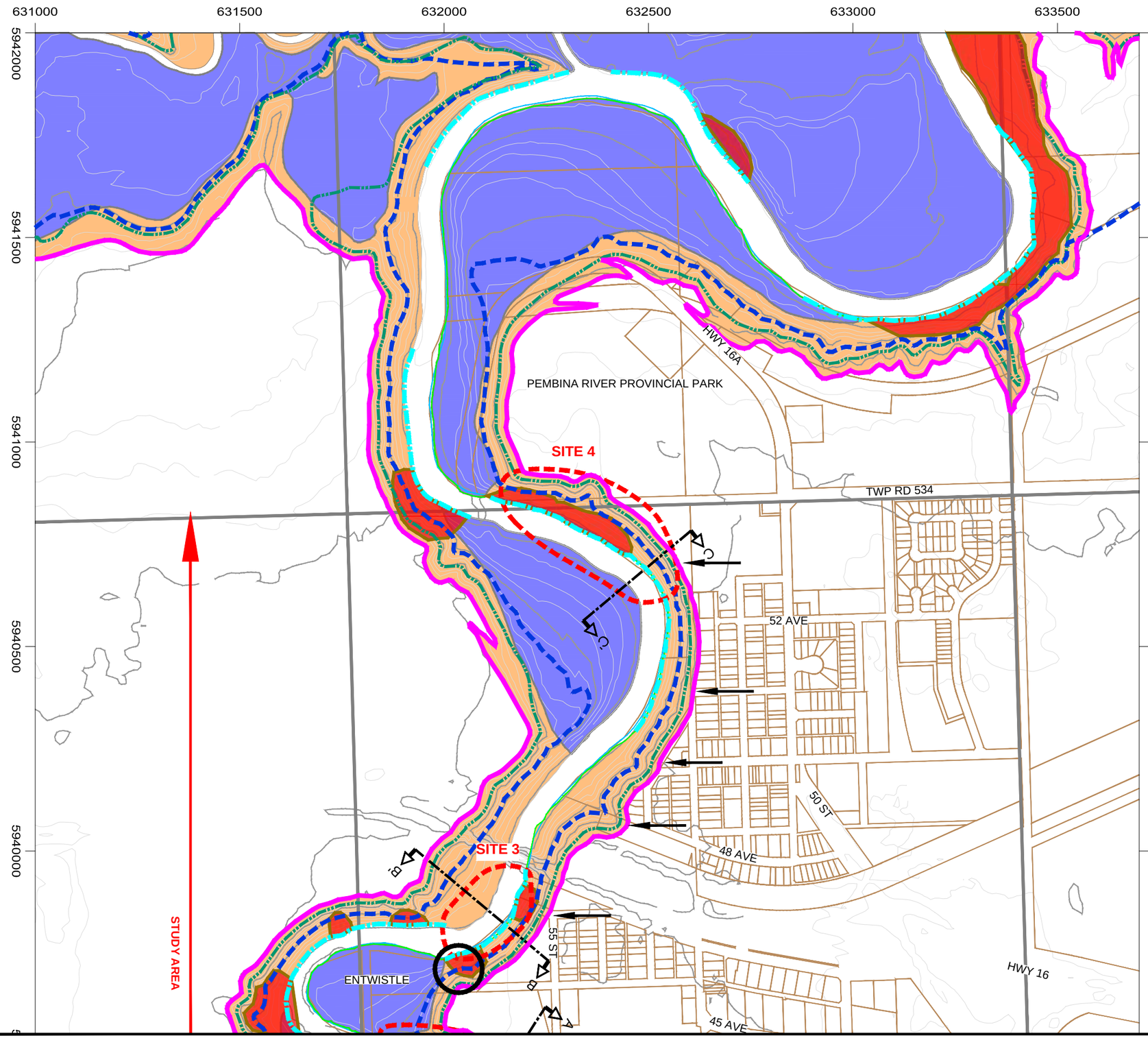
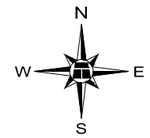




LEGEND

- GROUND SURFACE (CONTOURS 5m)
- LANDSLIDES
- COLLUVIUM
- ALLUVIUM
- TOP SCARP
- HIGH EROSION RIVER BED
- TOP OF BEDROCK
- TOP OF SCOLLARD FORMATION
- IDENTIFIED HISTORICAL LANDSLIDE LOCATIONS
- A A' CROSS - SECTION LOCATION
- ACTIVE LANDSLIDE LOCATION
- IDENTIFIED SURFACE RUNOFF LOCATION

0 100 200 300 400 500 600m

SCALE 1:10000

parkland county

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

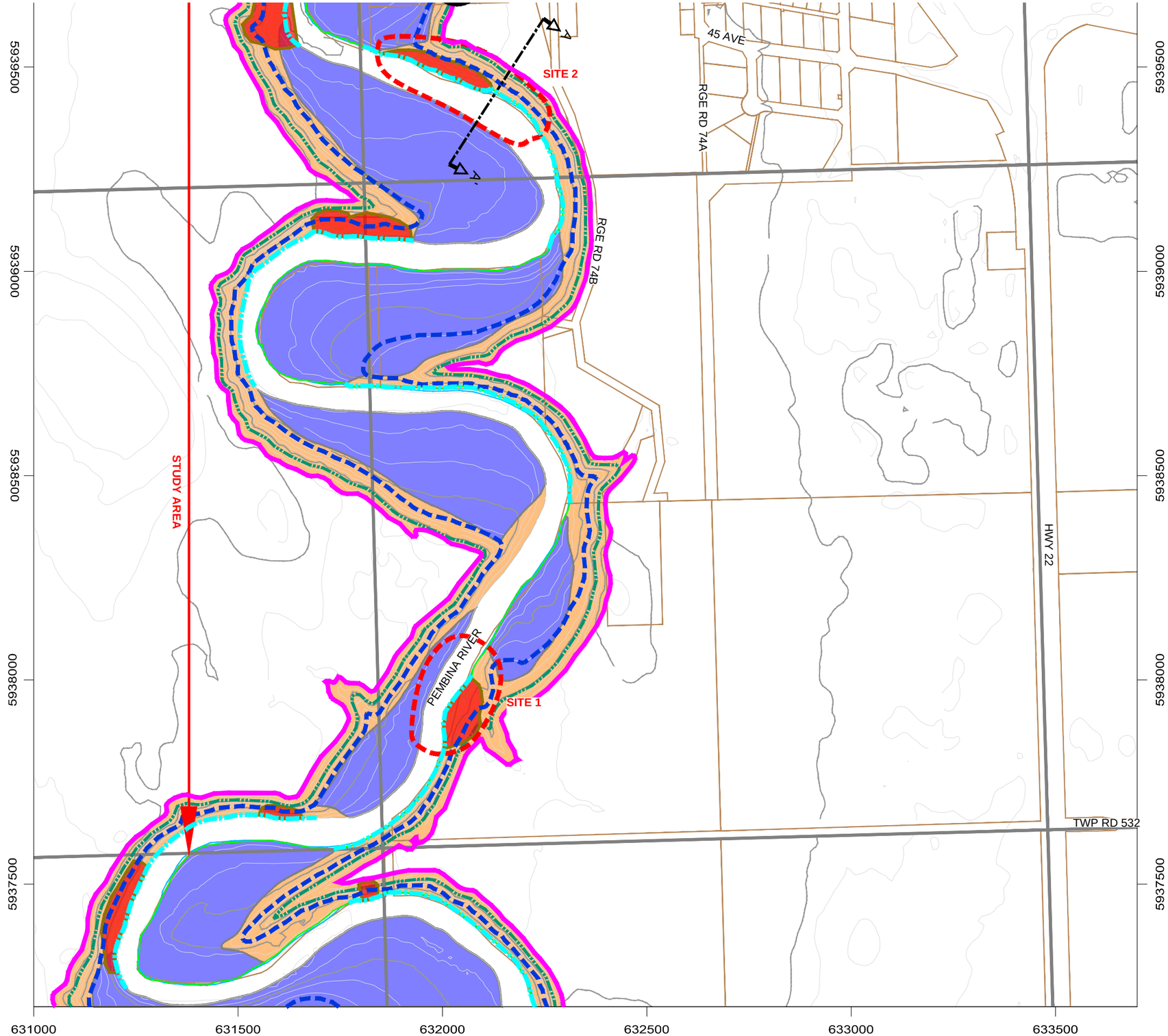
STUDY AREA GEOLOGY SUMMARY MAP
NORTH PART

DWG No. 18683-8A

DRAWN BY	ML
DESIGNED BY	SEC
APPROVED BY	RVC
SCALE	1:10000
DATE	NOVEMBER 2017
FILE No.	18683

THURBER ENGINEERING LTD.

H:\18000\18683 Entwistle High Level Bank Stability Review\Drafting\18683-8.dwg - 8B - Nov. 24, 2017



N
W E
S

LEGEND

- GROUND SURFACE (CONTOURS 5m)
- LANDSLIDES
- COLLUVIUM
- ALLUVIUM
- TOP SCARP
- HIGH EROSION RIVER BED
- TOP OF BEDROCK
- TOP OF SCOLLARD FORMATION
- IDENTIFIED HISTORICAL LANDSLIDE LOCATIONS
- A A' CROSS - SECTION LOCATION

0 100 200 300 400 500 600m

SCALE 1:10000

parkland county

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

STUDY AREA GEOLOGY SUMMARY MAP
SOUTH PART

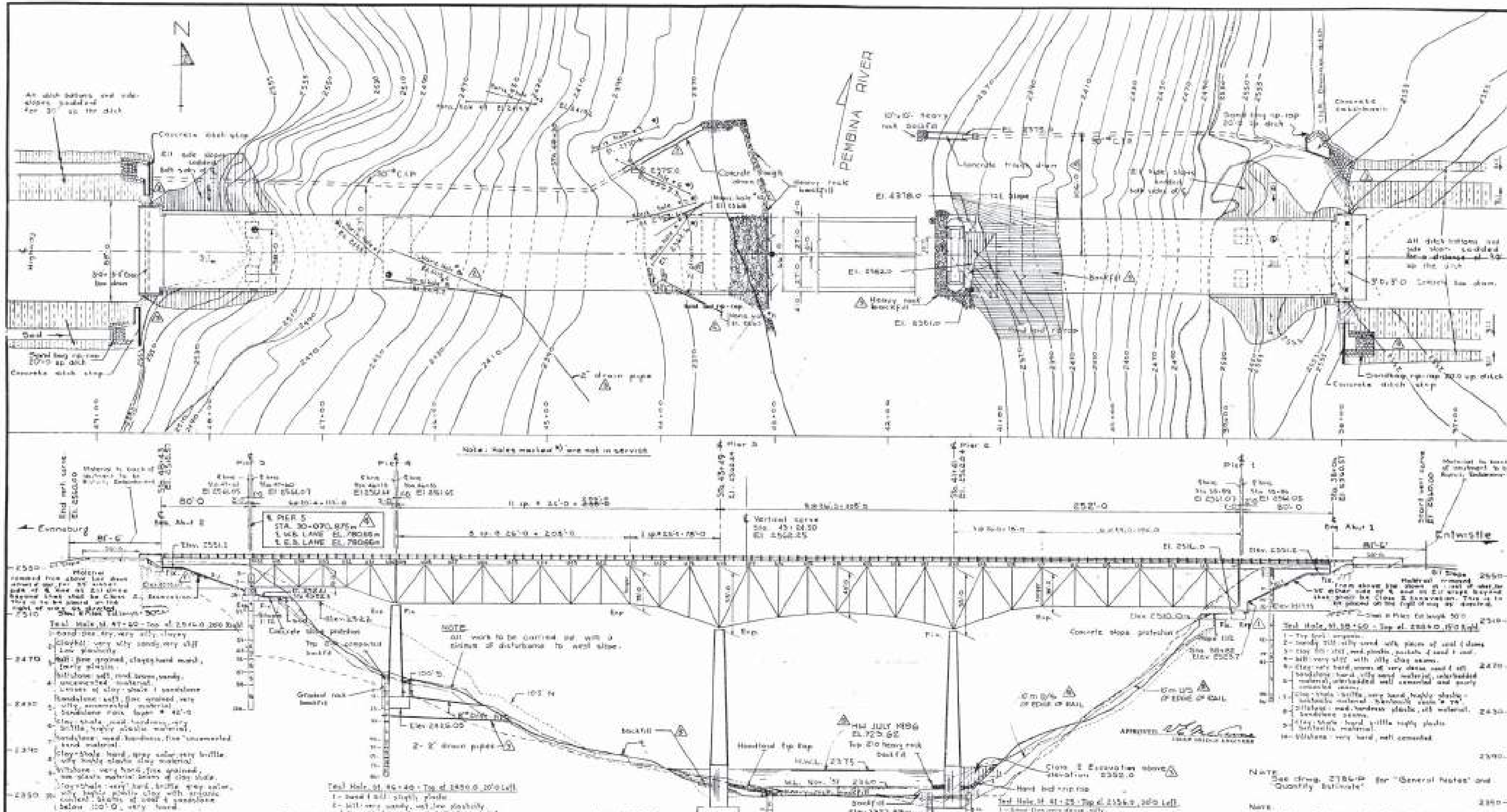
DWG No. 18683-8B

DRAWN BY	ML
DESIGNED BY	SEC
APPROVED BY	RVC
SCALE	1:10000
DATE	NOVEMBER 2017
FILE No.	18683

THURBER ENGINEERING LTD.

APPENDIX B

Historical Site Data



No.	TITLE	Dwg. No.
1	General Layout	2785-C
2	Site Map & Profile	2786-C
3	Pier 1 & 5 Details	2787-C
4	Pier 2 & 3 Details	2788-C
5	Pier 2 & 3 Sections	2789-C
6	Pier 4 Details	2790-C
7	Abutment 1 & 2 Details	[illegible]
8	Drainage Details	[illegible]
9	Miscellaneous Details	2793-C
	East bank drainage details	2792-6C
	West bank drainage details	2792-6C
	West bank drainage profile	2792-2C

NO.	DATE	DESCRIPTION	BY
5	10-07-89	1986 HW EL/DESIGN PROFILE ADDED	A.J.
4	30-04-84	1984 SURVEY	G.W.E.
3	[illegible]	As constructed	R.M.
2	[illegible]	[illegible]	[illegible]
1	[illegible]	Changed "Lagomarsino" to "Ford"?	[illegible]

REVISIONS

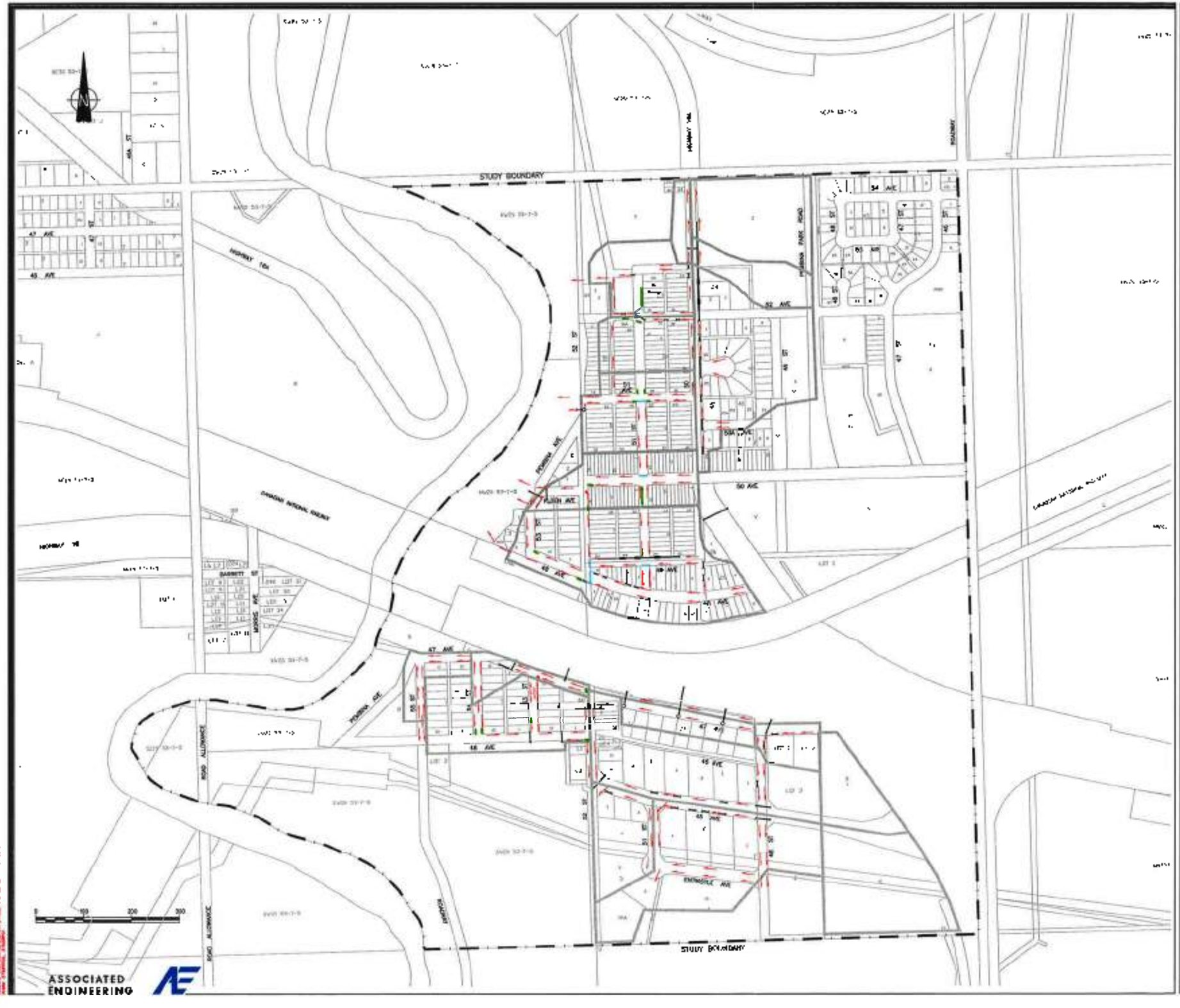
ENTWISTLE BRIDGE GENERAL LAYOUT

GOVERNMENT OF THE PROVINCE OF ALBERTA
DEPARTMENT OF HIGHWAYS
BRIDGE BRANCH, EDMONTON

FILE NO. 13014
HWY. NO. 16
LOCATION 26-26-53-7-5?
SCALE 1" = 40'
STREAM Pembina River
SHEET 1 OF 9
DWG. NO. 2785-C

ALBERTA MUNICIPAL AFFAIRS
VILLAGE OF ENTWISTLE
INFRASTRUCTURE INVENTORY AND ASSESSMENT

EXISTING STORM SEWER SYSTEM DRAINAGE FEATURES



LEGEND

- EXISTING SURFACE DRAINAGE
- EXISTING SUB-CATCHMENT BOUNDARY
- EXISTING CULVERT
- EXISTING CONCRETE SWALE
- EXISTING PROBLEM AREA

SCALE 1 : 8,000

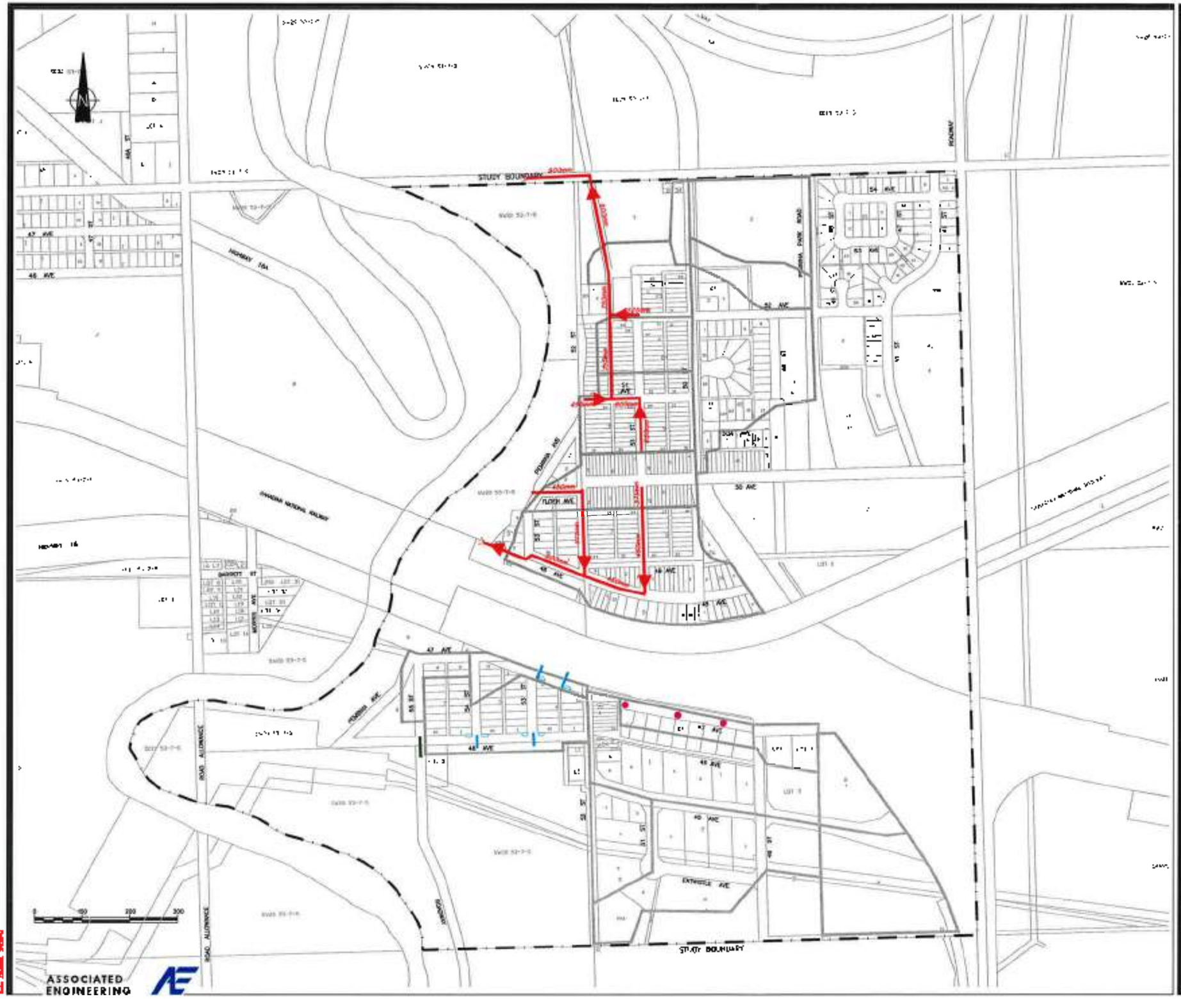
OCTOBER, 2000

ASSOCIATED ENGINEERING

FIGURE 6.1

ALBERTA MUNICIPAL AFFAIRS
VILLAGE OF ENTWISTLE
INFRASTRUCTURE INVENTORY AND ASSESSMENT

PROPOSED STORM SEWER SYSTEM UPGRADES



LEGEND

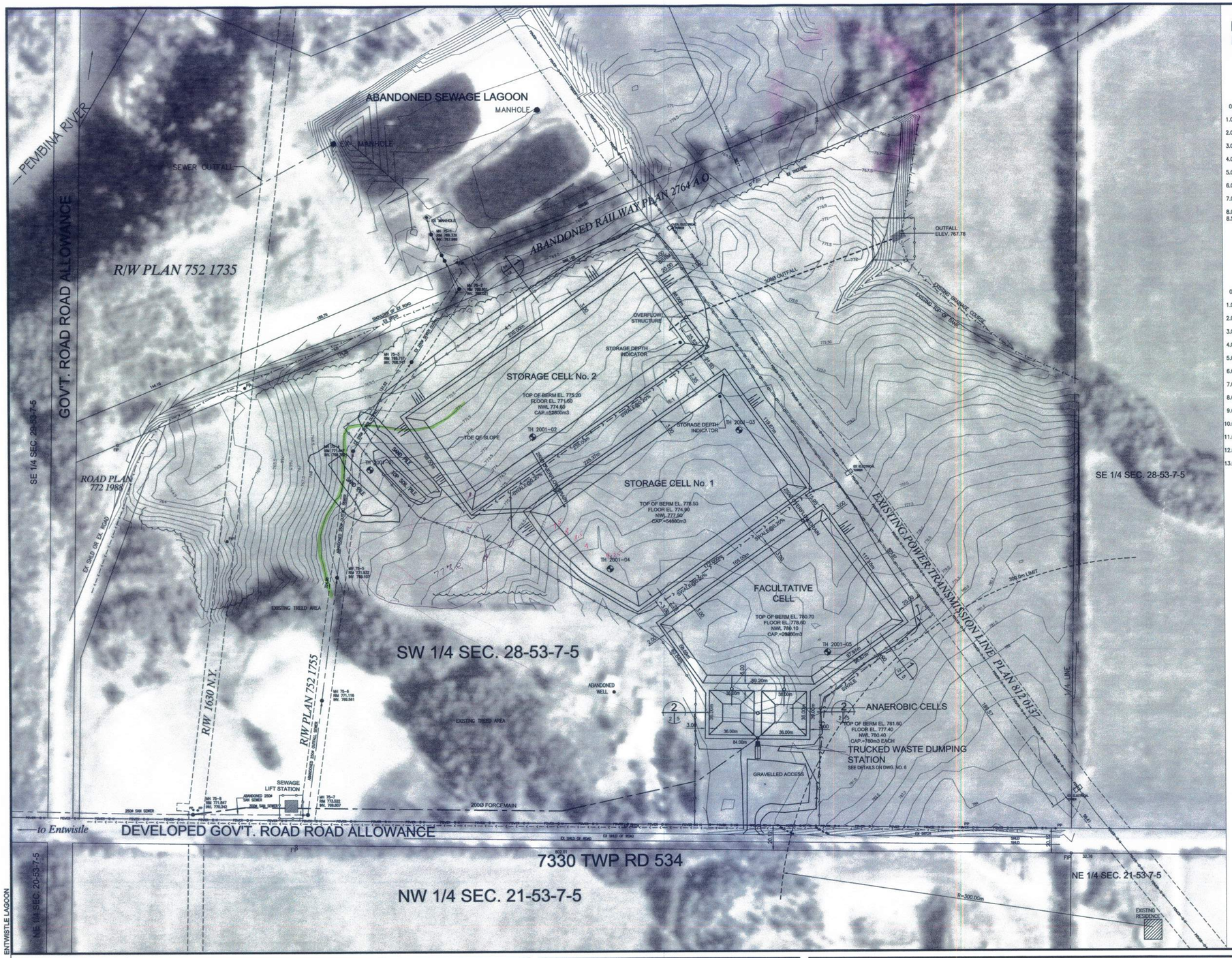
- PROPOSED STORM SEWER
- PROPOSED CULVERT UPGRADING
- UPGRADE EXISTING CATCH BASINS
- CATCH BASINS C/W DISCHARGE TO DITCH

SCALE 1 : 8,000

OCTOBER, 2000

ASSOCIATED ENGINEERING

FIGURE 6.2



TESTHOLE 2001-01

0 - topsoil, silty, dark brown, damp
1.0 - clay, silty, high plastic, very stiff to hard, medium, moist
2.0 - below 1.8m: transition to clay till
3.0 - 2.4m
4.0 - clay (TILL), silty, sandy, medium plastic, stiff to very stiff, mottled medium brown/grey, moist, frequent coal and gravel, occasional clay shale pieces and oxides
5.0 - 5.0m
6.0 - sand, very silty, clayey, medium to fine grained,dense, medium brown, saturated
7.0 - below 5.9m: grey, hard, possible weathered sandstone
8.0 - below 8.4m: trace silt, medium to coarse grained
8.5 - 8.5m
End of test hole at 8.5m
slough material and free water to 7.5m depth at completion of drilling. Standpipe installed to 8.4m. Testhole backfilled with cuttings. water level at 3.4m when monitored 28days after completion of drilling

TESTHOLE 2001-02

0 - topsoil, silty, dark brown
1.0 - clay, silty, high plastic, very stiff to hard, medium, moist
1.5m
2.0 - clay (TILL) silty, very sandy, medium plastic, very stiff, mottled medium brown/grey, moist, frequent coal and gravel oxides
3.0 -
4.0 - below 4.6m: medium to high plastic, grey, frequent gravel and coal, occasional claystone pieces
5.0 - 5.6m
6.0 - sand, silty, clayey, medium to fine grained,dense, medium brown, saturated
7.0 - below 6.9m: grey, very dense, possible weathered sandstone, free water
8.0 - 8.5m
8.5 - End of test hole at 8.5m
slough material and free water to 8.2m depth at completion of drilling. Standpipe installed to 8.4m. Testhole backfilled with cuttings. Water level at 4.9m when monitored 28 days after completion of drilling

TESTHOLE 2001-03

0 - topsoil, silty, dry, dark brown
1.0 - clay, very sandy, low plastic, stiff light brown, damp
2.0 - 0.9m
3.0 - clay (TILL), silty, sandy, medium plastic, very stiff, mottled medium brown/grey, moist, occasional gravel, coal & oxides occasional thin sand lense
4.0 - 2.1m
5.0 - sand, silty, clayey, fine medium grain medium dense, medium brown, moist occasional thin clay till zones
6.0 - 3.1m
7.0 - clay, (TILL), very sandy, silty, medium plastic, very stiff, dark brown, moist occasional gravel, oxides and coal
8.0 - below 4.6m: medium to high plastic, very moist
9.0 - below 4.9m: grey
10.0 - below 5.3m: sandy zone, saturated, occasionally claystone pieces
11.0 - below 7.3m: frequent gravel and cobble
12.0 - 12.5m
13.0 - sand, silty, clayey, fine medium grained dense, grey/brown, saturated
End of test hole at 13.0m
Slight slough material ,no free water at completion of drilling. Standpipe installed to 9.1m. Testhole backfilled with cuttings. Standpipe dry when monitored 28 days after completion of drilling

TESTHOLE 2001-04

0 - topsoil, silty, dry, dark brown
1.0 - clay, very sandy, very silty, low plastic, light brown, damp
2.0 - 0.45m
3.0 - clay , silty, high plastic,very stiff mottled medium brown/grey moist
4.0 - 1.2m
5.0 - clay, (TILL), sandy, silty, medium to high plastic, very stiff, mottled medium/dark brown, moist, occasional gravel, coal and oxides
6.0 - below 2.3m: very sandy
7.0 - below 3.8m: sandy
8.0 - below 4.3m: stiff, grey, very moist, no oxides
8.4 - below 7.0m: occasional coarse grained gravel layers and frequent gravel and cobble zones
- below 7.3m: frequent gravel and cobble
- 8.4m
End of test hole at 8.4m
No slough material ,no free water at completion of drilling. Standpipe installed to 8.4m. Testhole backfilled with cuttings. Water level at 7.6m when monitored 28 days after completion of drilling

TESTHOLE 2001-05

0 - topsoil, silty, dark brown
1.0 - clay, silty, medium to high plastic, very stiff
2.0 - medium brown, moist
3.0 - 0.6m
4.0 - clay (TILL), silty, sandy, medium plastic, very stiff, mottled medium brown / grey, moist, occasionally coal and gravel, oxides
5.0 - below 1.5m: frequently thin grey stringers, possible sulfates
6.0 - below 2.3m: very sandy, occasional thin, medium to fine grained sand lenses
7.0 - below 4.6m: medium to high plastic grey, very moist, occasional claystone pieces
8.0 - below 6.9m: grey, very dense, possible weathered sandstone, free water
8.5 - 8.1m
gravel and cobble, within sandy clay till matrix, fine to coarse grained, dense, light brown / grey, saturated
8.5m
End of test hole at 8.5m
Slough material and free water to 87.6m depth at completion of drilling. Standpipe installed to 8.4m. Testhole backfilled with cuttings. Water level at 6.1m when monitored 28 days after completion of drilling

AS BUILT		
IMPROVEMENT	CONTRACTOR	DATE
STRUCTURE WORKS	ICHTON CONSTRUCTING LTD. (GENERAL)	SEPT-OCT., 2001
EARTHWORKS	KOSIK CONSTRUCTION LTD.	SEPT-OCT., 2001

NO.	NATURE OF REVISION	DATE	ENG.	BY
1	AS BUILT	25/12/02	D.S.	E.A.
2	REVISED	1/04/02	D.S.	E.A.

PERMIT TO PRACTICE
GPEC CONSULTING LTD.
Signature
Date 15/04/02
PERMIT NUMBER: P 3926
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

PROFESSIONAL ENGINEERS ALBERTA

DWG-S-1642-003-SITE.DWG 1=1

SCALE	DESIGN BY	DRAWN BY
1:1500	K.H./D.C.S.	M.L.G.
DATE	CHECKED BY	PROJECT NO.
JULY, 2001	D.C.S.	1642-003-40

PARKLAND COUNTY

HAMLET OF ENTWISTLE

WASTEWATER TREATMENT FACILITIES

SITE PLAN

gpec consulting ltd.

Proposed Entwistle Sewage Lagoon	Client: County of Parkland C/O GPEC	TEST HOLE NO: 2001-01
NW corner of site	Solid-Stem Auger, Travel Mount, MS-61	PROJECT NO: 2396-152
Entwistle, Alberta		ELEVATION:

SAMPLE TYPE: Disturbed | Shelby Tube | SPT | Bulk

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

SOIL DESCRIPTION

TOPSOIL, silty, dark brown, damp 100 mm

CLAY, silty, high plastic, very stiff to hard, medium brown, moist

- below 1.8 m, transition to clay till

2.4 m

CLAY (TILL), silty, sandy, medium plastic, stiff to very stiff, mottled medium brown/grey, moist, frequent coal and gravel, occasional claystone pieces and oxides

SAND, very silty, clayey, medium to fine grained, dense, medium brown, saturated

- below 6.9 m: fine to coarse grained

- below 7.6 m: grey, hard, possible weathered sandstone

Below 8.4 m: trace silt, medium to coarse grained

End of Test Hole at 8.5 m
Slough material and free water to 7.6 m depth at completion of drilling
Standpipe installed to 8.4 m
Testhole backfilled with cuttings
Water level at 4.4 m when monitored at completion of drilling

SPT (N): 19, 14, 32, 5, 50/100

▲ Pocket Pen. (kPa) ▲ 100 200 300 400

PLASTIC | MC. | LIQUID

20 40 60 80

TEST RESULTS

Soil Sulphates: Negligible

Tube: DD: n/a
Qu: n/a

J.R. Paine & Associates
Edmonton, Alberta

LOGGED BY: RVW
REVIEWED BY: RE
Fig. No: 2

COMPLETION DEPTH: 8.5 m
COMPLETE: 07/06/22

Proposed Sewage Lagoon
North middle of site
Entwistle, Alberta

Client: County of Parkland C/O GPEC
Solid -Stem Auger, Truck Mount, MS-61

TEST HOLE NO: 2001-02
PROJECT NO: 2393-152
ELEVATION:

SAMPLE TYPE: Disturbed | Shelby Tube | SPT | Bulk
BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH(m) | USC | SOIL SYMBOL

SOIL DESCRIPTION

SAMPLE TYPE | SPT(N)

Pocket Pen. (kPa) ▲ 100 200 300 400

PLASTIC | N.C. | LIQUID
20 40 60 80

TEST RESULTS

DEPTH(m)

0.0 TOPSOIL, silty, dark brown, damp — 150 mm
CLAY, silty, high plastic, very stiff, dark brown, moist

1.5 m
CLAY (TILL), very sandy, silty, medium plastic, very stiff, mottled medium brown/grey, moist, occasional coal, gravel and oxides

- below 4.6 m: medium to high plastic, grey, frequent gravel and coal, occasional claystone pieces

SAND, silty, clayey, medium to fine grained, dense, medium brown, saturated

- below 6.9 m: grey, very dense, possible weathered sandstone, free water

End of Test Hole at 8.5 m
Slough material and free water to 8.2 m depth at completion of drilling
Standpipe installed to 8.4 m
Testhole backfilled with cuttings
Water level at 4.4 m when monitored at completion of drilling

SPT(N): 23, 20, 31, 50/125, 50/15

Soil Sulphates: Negligible

Tube: OD: n/a
Qu: n/a

DRAFT

J R. Paine & Associates
Edmonton, Alberta

LOGGED BY: RWN
REVIEWED BY: RE
Fig. No: 3

COMPLETION DEPTH: 8.5 m
COMPLETED: 07/30/22

Proposed Fmlwistle Sewage Lagoon	Client: Parkland County C/O GPEC	TEST HOLE NO: 2001-03
Middle of site	Solid-Stem Auger, Truck Mount, MS 61	PROJECT NO: 2396-152
Lmlwistle, AB		ELEVATION:

SAMPLE TYPE: Disturbed | Shelby Tube | SPT | Bulk
BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH(m) | USC | SOIL SYMBOL

SOIL DESCRIPTION

SAMPLE TYPE | SPT(N)

Pocket Pen. (kPa): 100 200 300 400
PLASTIC | M.C. | LIQUID
20 40 60 80

TEST RESULTS

DEPTH(m)

TOPSOIL, silty, dry, dark brown — 125 mm

CLAY, very sandy, low plastic, stiff, light brown, damp

– at 0.8 m: thin, fine sand lense — 0.9 m

CLAY (TILL), silty, sandy, medium plastic, very stiff, mottled medium brown/grey, moist, occasional gravel, coal and oxides, occasional thin sand lenses — 2.1 m

SAND, silty, clayey, fine to medium grained, medium dense, medium brown, moist, occasional thin clay silt zones — 3.1 m

CLAY (TILL), very sandy, silty, medium plastic, very stiff, dark brown, moist, occasional gravel, oxides and coal

– below 4.6 m: medium to high plastic, very moist

– below 4.9 m: grey

– below 5.3 m: sandy zone, saturated, occasional clayshale pieces

– below 7.3 m: frequent gravel and cobble

SAND, silty, clayey, fine to medium grained, dense, grey/brown, saturated

End of Test Hole at 13.0 m

Slight slough material, no free water at completion of drilling

Standpipe installed to 9.1 m

Testhole backfilled with cuttings

Standpipe dry when monitored at completion

SPT(N): 16, 21, 15, 10, 15

Soil Sulphates: Negligible

Tube: OD: n/a
Qu: n/a

DEPTH(m)

J.R. Paine & Associates
Edmonton, Alberta

LOGGED BY: RWW
REVIEWED BY: RE
Fig. No: 4

COMPLETION DEPTH: 13.0 m
COMPLETED: 01/06/22
Page 1 of 1

Proposed Twinstle Sewage Lagoon	Client: County of Parkland C/O GPEC	TEST HOLE NO: 2001-04
East middle of site, near power tower	Solid: Stem Auger, Truck Mount, MS-61	PROJECT NO: 2396-152
Entwistle, Alberta		ELEVATION:

SAMPLE TYPE: Undisturbed; Shelby Tube; SPT; Bulk

BACKFILL TYPE: BENTONITE; PEA GRAVEL; SLOUGH; GROUT; DRILL CUTTINGS; SAND

DEPTH (m)	USC	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SPT (N)
0.0			TOPSOIL, silty, dark brown, damp 100 mm		
			CLAY, very silty, very sandy, low plastic, friable, firm, light brown, damp 450 mm		
			CLAY, silty, high plastic, very stiff, mottles medium brown/grey, moist 2 m		
2.0			CLAY (TILL), silty, sandy, medium to high plastic, very stiff, mottled medium/dark brown, moist, occasional gravel, coal and oxides		14
			- below 2.3 m: very sandy		
4.0			- below 3.8 m: sandy		15
			- below 4.3 m: stiff, grey, very moist, no oxides		
7.0			- below 7.0 m: occasional coarse grained gravel layers and frequent gravel and cobble zones		50/100
8.0			End of Test Hole at 8.4 m No slough material or free water at completion of drilling Standpipe installed to 8.4 m Testhole backfilled with cuttings Standpipe dry when monitored at completion of drilling		
15.0					

▲ Pocket Pen. (kPa) ▲ 100 200 300 400

PLASTIC N.C. LIQUID

20 40 60 80

TEST RESULTS

Soil Sulphates: Negligible

Tube: DD: n/a
Qu: n/a

DRAFT

DEPTH (m)

J.R. Paine & Associates
Edmonton, Alberta

LOGGED BY: RWH
REVIEWED BY: RE
Fig. No: 5

COMPLETION DEPTH: 8.4 m
COMPLETED: 02/06/22

Proposed Enhwistle Sewage Lagoon	Client: County of Parkland C/O GNTC	TEST HOLE NO: 2001 05
South end of site	Solid-Stem Auger, Truck Mount, MS-61	PROJECT NO: 2396 152
Entwistle, Alberta		ELEVATION:

SAMPLE TYPE: Disturbed | Shelby Tube | SPT | Bulk

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

DEPTH (m)	LOG	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SPT (N)	Pocket Pen. (kPa) 100 200 300 400	PLASTIC / M.C. / LIQUID 20 40 60 80	TEST RESULTS	DEPTH (m)
0.0			TOPSOIL, silty, dark brown, damp 75 mm						0.0
1.0			CLAY, silty, medium to high plastic, very stiff, medium brown, moist 0.6 m		11				1.0
2.0			CLAY (TILL), silty, sandy, medium plastic, very stiff, mottled medium brown/grey, moist, occasional gravel, coal and oxides - below 1.5 m: frequent thin, grey stringers, possible sulphates		15				2.0
3.0			- below 2.3 m: very sandy, occasional thin, medium to fine grained sand lenses					Soil Sulphates: Negligible	3.0
4.0								Tube: DO: n/a Su: n/a	4.0
5.0			- below 4.6 m: medium to high plastic, grey, very moist, occasional clayshale pieces		19				5.0
6.0									6.0
7.0					38				7.0
8.0			8.1 m GRAVEL AND COBBLE, within sandy clay till matrix, fine to coarse grained, dense, light brown/grey, saturated						8.0
9.0			End of Test Hole at 8.5 m Slough material and free water to 7.6 m depth at completion of drilling Standpipe installed to 8.4 m Testhole backfilled with cuttings Standpipe dry when monitored at completion of drilling						9.0
10.0									10.0
11.0									11.0
12.0									12.0
13.0									13.0
14.0									14.0
15.0									15.0

DRAFT

J.R. Paine & Associates
Edmonton, Alberta

LOGGED BY: HWW
REVIEWED BY: RE
Fig No: 6

COMPLETION DEPTH: 8.4 m
COMPLETED: 02/06/22

Jan 19, 2010

Legend

B-1 BOREHOLE LOCATION (By Stantec)

EXISTING TEST HOLE

Scale

0 30 60 120m

1:2000

Stantec

Gen/Regd

Parkland County

Parkland County Sewage Lagoon Expansion

Dwg No

2.0

Title

BOREHOLE LOCATION PLAN

Stantec

BOREHOLE RECORD

BH1

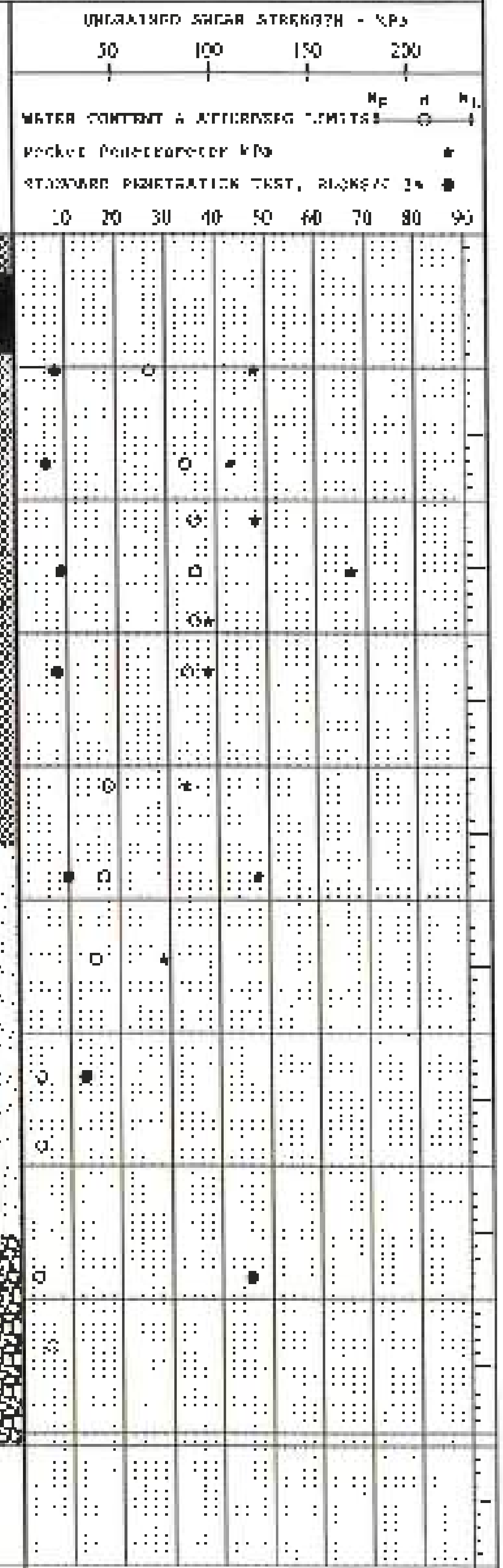
CLIENT: Parkland County
PROJECT No.: 110126007
LOCATION: Proposed Sewage Lagoon & Buildings, Parkland County, AB
BH SIZE: 150 mm
DATES (mm/dd/yy): BORING 12/4/09
WATER LEVEL: Dry (Jan 20, 2010)
DATUM: Assumed

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION
0	780	Firm to stiff light brown and grey CLAY (CH) - sandy, trace pebbles - high plastic - frozen to approx. 0.6 m - no sand or pebbles below 2.0 m
4	776.00	Stiff dark brown clay TILL (CL) - sandy with occasional gravel, occasional coal fragments, frequent rust staining - low plastic - coarse grained sand seam at 4.7 m
5.2	774.80	Compact to dense brown SAND (SW) - medium to coarse grained - dry to damp - becomes dense brown poorly graded SAND (SP) with gravel, occasional clay pockets at 7.9 m
9.1	770.90	End of borehole at 9.1 m. Upon completion borehole open with slough at 7.5 m. - 25 mm standpipe installed to 7.5 m.

SAMPLES

TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD %
SS	1	355	8
SS	2	460	6
BS	3		
SS	4	460	9
BS	5		
SS	6	460	8
BS	7		
SS	8	460	10
BS	9		
SS	10	460	13
BS	11		
SS	12	460	46
BS	13		

STRATA PLOT — MONITOR WELL/PIEZOMETER



Groundwater table ▽

App'd ________ Feb 2 2010 12:5:40

Stantec

BOREHOLE RECORD

BH1

CLIENT: Parkland County

LOCATION: Proposed Sewage Lagoon & Buildings, Parkland County, AB

DATE(S) (mm/dd/yy): BORING: 12/4/09

WATER LEVEL: Dry (Jan 20, 2010)

PROJECT No: 110126007

DRILL SIZE: 150 mm

DATUM: Assumed

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY mm	SAMPLES: N-VALUE OR RQD %	MONITOR WELL/ PIEZOMETER
10		lower 3.0 m hand cloned and packed in sand, upper portion bentonite sealed and backfilled with cuttings. Note: Approximate elevation based on ground surface contours.						
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

UNDRAINED SHEAR STRENGTH kPa

50 100 150 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

Pocket Penetrometer kPa ▲

STANDARD PENETRATION TEST, BLOWS/0.3 m ●

10 20 30 40 50 60 70 80 90

Groundwater table ▼

Appvd: Feb 2 20 C 12 3 do

Stantec BOREHOLE RECORD BH2

CLIENT: Parkland County — PROJECT No.: 110126007

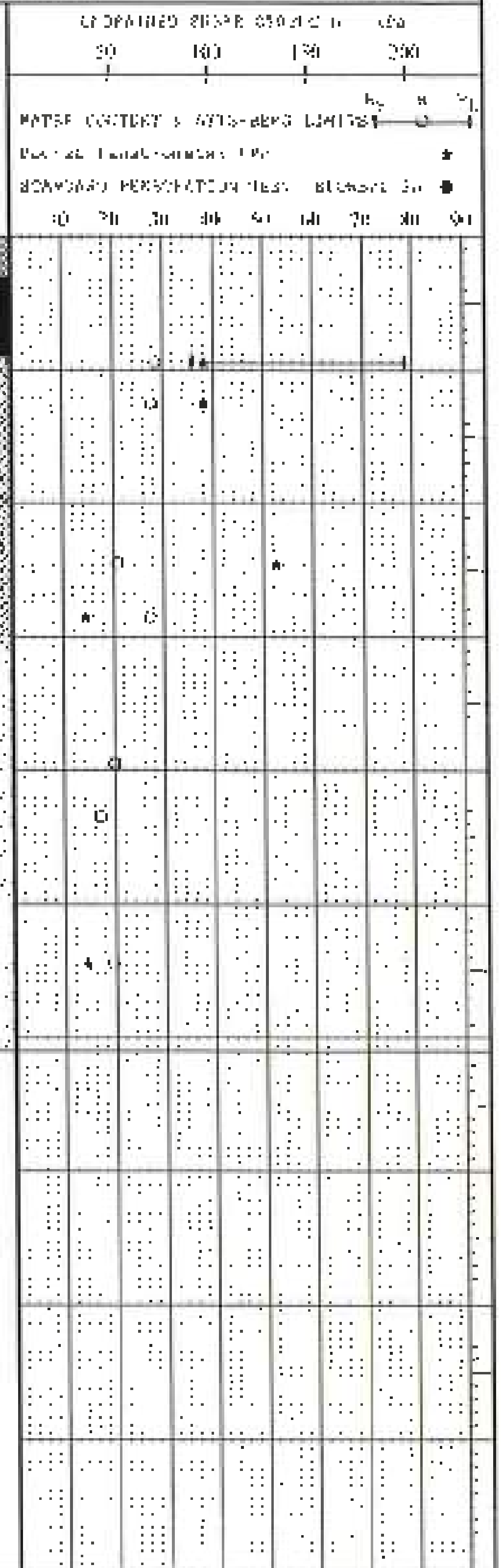
LOCATION: Proposed Sewage Lagoon & Buildings, Parkland County, AB — BIT SIZE: 150 mm

DATES (mm/dd/yy): BORING 12/4/09 — WATER LEVEL: Dry (Jan 20, 2010) — DATUM: Assumed

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION
0	777	Stiff brown CLAY (CH) - high plastic - frozen to 0.6 m
3	774.00	Firm to stiff to very stiff brown clay TILL (CL) - sandy, trace gravel - occasional coal fragments - frequent rust staining
6	770.90	End of borehole at 6.1 m. Upon completion borehole open and dry. - 25 mm standpipe installed to 6.1 m; lower 3.0 m hand slotted and packed in sand, upper portion bentonite sealed and backfilled with cuttings. Note: Approximate elevation based on ground surface contours.

SAMPLES

TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD %
BS	1		
BS	2		
ST	3	460	
BS	4		
BS	5		
ST	6	460	
BS	7		
BS	8		
ST	9	460	
BS	10		



Groundwater table ▽

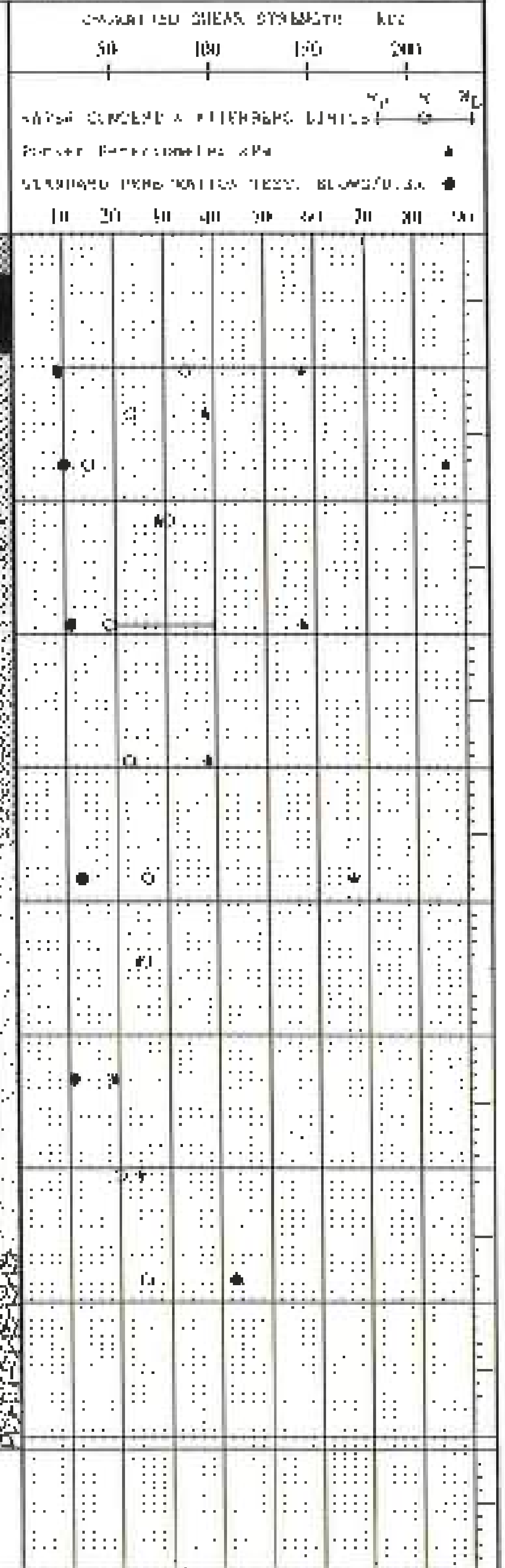
Appd. ________ Feb 2 2010 12:?

Stantec BOREHOLE RECORD BH3

CLIENT: Parkland County | PROJECT No.: 110126007
LOCATION: Proposed Sewage Lagoon & Buildings, Parkland County, AB | BH SIZE: 150 mm
DATES (mm/dd/yy): BORING 12/4/09 | WATER LEVEL: 4.6 mbg (Jan 20, 2010) | DATUM: Assumed

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	SAMPLE TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR RQD %
0	772	Stiff brown CLAY (CH) - high plastic - frozen to 1.0 m				
1			SS	1	400	9
	770.50		BS	2		
		Stiff brown clay TILL (CL) - sandy, occasional gravel, coal fragments and rust nodules - frequent sand pockets	SS	3	460	10
2			BS	4		
			ST	5	460	
3			SS	6	460	11
4			BS	7		
5		- becomes dark grey massive low to medium plastic clay TILL (CL) at 4.7 m	SS	8	460	13
			BS	9		
6			SS	10	460	12
7	765.00	Dense brown SAND (SM) - coarse grained, silty with occasional gravel - saturated with groundwater seepage at 7.0 m	BS	11		
8			SS	12	460	40
	763.90	Very weak, yellowish grey, weathered bedrock MUDSTONE (?) - sandy				
9	762.90	End of Borehole at 9.1 m Upon completion borehole was [illegible] with slough to ? m and groundwater table at 6.4 m				
10						

STRATA PLOT; MONITOR WELL / PIEZOMETER



Groundwater table

Appd. ______ Feb 2 2010 [illegible]

Stantec

BOREHOLE RECORD

BH3

CLIENT: Parkland County

PROJECT No: 110126007

LOCATION: Proposed Sewage Lagoon & Buildings, Parkland County, AB

BH SIZE: 150 mm

DATES (mm/dd/yy) BORING: 12/4/09

WATER LEVEL: 4.6 mbg (Jan 20, 2010)

DATUM: Assumed

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY mm	SAMPLES: N-VALUE OR RQD %	MONITOR WELL / PIEZOMETER	UNDRAINED SHEAR STRENGTH kPa: 50 / 100 / 150 / 200; WATER CONTENT & ATTERBERG LIMITS; POCKET PENETROMETER kPa; STANDARD PENETRATION TEST, blows/0.3 m: 10 / 20 / 30 / 40 / 50 / 60 / 70 / 80 / 90
10		- Note: Groundwater table measured at 4.6 mgb on Jan 20, 2010 - 25 mm standpipe installed to 7.6 m. Near 3.0 m hand slotted and packed in sand, upper portion bentonite sealed and backfilled with cuttings. Note: Approximate elevation based on ground surface contours.							
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									

Groundwater table ▽

Agrid _____ Feb 2 2010 10:34:41

LEGEND:

- MONITORING WELL LOCATION (INSTALLED 2011)

0 100

Scale: 1: 2 000 (metres)

CLIENT

Parkland County

A TETRA TECH COMPANY

MONITORING WELL INSTALLATION & GROUNDWATER MONITORING REPORT
PROPOSED PARKLAND COUNTY SEWAGE LAGOON EXPANSION,
7320 TOWNSHIP 534, NEAR ENTWHISTLE, AB

SITE PLAN AND GROUNDWATER MONITORING WELL LOCATIONS

PROJECT NO.	DWN	CKD	REV
E12101472	TK	SO	0

OFFICE	DATE
EDM	November 2011

Figure 1

Q:\Edmonton\Drafting\DIVISIONS\2007\E121\E12101472\ACAD\E12101472_FIG 1.dwg [FIGURE 1] November 02, 2011 - 2:51:42 pm (BY: KIROS, TKISTI)

PARKLAND MONITORING WELL INSTALLATION	PARKLAND COUNTY	PROJECT NO. - BOREHOLE NO.
7320 TWP RD 534	DRILL: SOLID STEM AUGER	E12101472-01
ENTWHISTLE, ALBERTA		

SAMPLE TYPE: DISTURBED | NO RECOVERY | SPT | A-CASING | SHELBY TUBE | CORE

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	MOISTURE CONTENT: PLASTIC — M.C. — LIQUID (20 40 60 80)	STANDARD PENETRATION (N) 20 40 60 80; UNCONFINED (kPa) 50 100 150 200; POCKET PEN. (kPa) 100 200 300 400
0	TOPSOIL - damp, black, rootlets			
	CLAY - silty, damp to moist, very stiff, high plastic, dark greyish brown			
1	- greyish brown			
	- moist, stiff to very stiff, mottled dark grey			
2	- sandy pockets			
	CLAY (TILL) - silty, sandy, moist, very stiff, medium plastic, dark brown, coal inclusions			
3				
	- stiff to very stiff			
4				
	- very stiff, gravel sizes			
5				
	SAND AND GRAVEL - clean, medium grained, uniform, damp, brown			
6				
	- moist, dark brown			
7				
	- wet			
8	- saturated			
9	▼ 0 hrs ▼ 7 days			
10	END OF BOREHOLE (9.91 metres) slough - 8.53 metres at 0 hrs. water - trace at 0 hrs. - 8.28 metres at 7 days Monitoring well installed to 8.94 metres			
11				
12				

Depth (ft): 0, 5, 10, 15, 20, 25, 30, 35, 39

▼ 0 hrs ▼ 7 days

eba A TETRA TECH COMPANY	LOGGED BY: DJK	COMPLETION DEPTH: 9.91 m
	REVIEWED BY: SD	COMPLETE: 11/09/22
	DRAWING NO: 12101472-01	Page 1 of 1

PARKLAND MONITORING WELL INSTALLATION	PARKLAND COUNTY	PROJECT NO. - BOREHOLE NO.
7320 TWP RD 534	DRILL: SOLID STEM AUGER	E12101472-02
ENTWHISTLE, ALBERTA		

SAMPLE TYPE: DISTURBED | NO RECOVERY | SPT | A-CASING | SHELBY TUBE | CORE

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	MOISTURE CONTENT: PLASTIC — M.C. — LIQUID (20 40 60 80)	STANDARD PENETRATION (N) 20 40 60 80; UNCONFINED (kPa) 50 100 150 200; POCKET PEN. (kPa) 100 200 300 400	Depth (ft)
0	CLAY (FILL) - silty, trace of sand, damp to moist, hard, medium plastic, greyish brown				0
	- moist, dark brown				
1	CLAY (TILL) - silty, sandy, moist, hard, medium platic, dark brown, coal inclusions				
	- gravel sizes				5
	- very stiff to hard				
2	- very stiff				
3	- stiff to very stiff				10
4	- mottled dark grey				
					15
5					
	- dark grey				
6	- stiff				20
7	- moist to wet				
	SAND AND GRAVEL - clean, medium grained, moist, brown				25
8					
	END OF BOREHOLE (8.38 metres)				
	slough - 7.32 metres at 0 hrs.				
9	water - dry at 0 hrs.				30
	- dry at 7 days				
	Monitoring well installed to 6.60 metres				
10					
					35
11					
12					39

LOGGED BY: DJK	COMPLETION DEPTH: 8.38 m
REVIEWED BY: SD	COMPLETE: 11/09/22
DRAWING NO: 12101472-02	Page 1 of 1

PARKLAND MONITORING WELL INSTALLATION	PARKLAND COUNTY	PROJECT NO. - BOREHOLE NO.
7320 TWP RD 534	DRILL: SOLID STEM AUGER	E12101472-03
ENTWHISTLE, ALBERTA		

SAMPLE TYPE: DISTURBED | NO RECOVERY | SPT | A-CASING | SHELBY TUBE | CORE

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	MOISTURE CONTENT: PLASTIC — M.C. — LIQUID (20 40 60 80)	STANDARD PENETRATION (N) 20 40 60 80; UNCONFINED (kPa) 50 100 150 200; POCKET PEN. (kPa) 100 200 300 400
0	CLAY (FILL) - silty, some sand, wet, firm, medium plastic, brown to dark grey			
	- moist, stiff			
1				
	- very stiff			
2				
	- hard, high plastic, mottled brown to dark grey			
	- sandy, medium plastic pockets			
3				
	CLAY - silty, moist, very stiff,f high plastic, brown mottled dark grey			
4				
	CLAY (TILL) - silty, sandy, moist, very stiff, medium plastic, dark brown, coal inclusions, white deposits			
	- gravel sizes			
5	- hard, mottled dark grey			
	- wet, 10 mm thick sand lens or pocket			
6				
7				
	- very stiff, dark grey			
8				
	- moist to wet, stiff			
7 days				
9	SAND - silty, medium grained, uniform, wet, brown			
	- saturated			
10	END OF BOREHOLE (9.91 metres)			
	slough - 9.60 metres at 0 hrs.			
	water - dry at 0 hrs.			
	- 8.32 metres at 7 days			
	Monitoring well installed to 9.75 metres			
11				
12				

Depth (ft): 0, 5, 10, 15, 20, 25, 30, 35, 39

7 days

LOGGED BY: DJK	COMPLETION DEPTH: 9.91 m
REVIEWED BY: SD	COMPLETE: 11/09/22
DRAWING NO: 12101472-03	Page 1 of 1

PARKLAND MONITORING WELL INSTALLATION	PARKLAND COUNTY	PROJECT NO. - BOREHOLE NO.
7320 TWP RD 534	DRILL: SOLID STEM AUGER	E12101472-04
ENTWHISTLE, ALBERTA		

SAMPLE TYPE: DISTURBED | NO RECOVERY | SPT | A-CASING | SHELBY TUBE | CORE

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	MOISTURE CONTENT: PLASTIC — M.C. — LIQUID (20 40 60 80)	STANDARD PENETRATION (N) 20 40 60 80; UNCONFINED (kPa) 50 100 150 200; POCKET PEN. (kPa) 100 200 300 400	Depth (ft)
0	CLAY (FILL) - silty, trace of organics for 50 mm, moist, stiff, medium to high plastic, dark greyish brown				0
	- wet, soft to firm, greyish brown				
	- moist, stiff				
1	CLAY - silty, trace of organics for 75 mm, moist, stiff, high plastic, dark greyish brown				
	- very stiff, white deposits				
	- mottled dark grey				
2	- stiff				5
	7 days				7 days
3	CLAY (TILL) - silty, sandy, moist, stiff, medium plastic, dark brown, coal inclusions				10
	- mottled dark grey, oxide staining				
4	- dark grey				15
5	SAND - trace of silt, medium grained, uniform, saturated, light brown				
	0 hrs.				0 hrs.
6	SANDSTONE - silty, clayey, medium grained, moist, light brown to light grey				20
7	END OF BOREHOLE (7.01 metres) slough - 6.10 metres at 0 hrs. water - 5.49 metres at 0 hrs. - 1.47 metres at 7 days Monitoring well installed to 6.55 metres				25
8					
9					30
10					
11					35
12					39

LOGGED BY: DJK	COMPLETION DEPTH: 7.01 m
REVIEWED BY: SD	COMPLETE: 11/09/22
DRAWING NO: 12101472-04	Page 1 of 1

PARKLAND MONITORING WELL INSTALLATION	PARKLAND COUNTY	PROJECT NO. - BOREHOLE NO.
7320 TWP RD 534	DRILL: SOLID STEM AUGER	E12101472-05
ENTWHISTLE, ALBERTA		

SAMPLE TYPE: DISTURBED | NO RECOVERY | SPT | A-CASING | SHELBY TUBE | CORE

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	MOISTURE CONTENT: PLASTIC — M.C. — LIQUID (20 40 60 80)	STANDARD PENETRATION (N) 20 40 60 80; UNCONFINED (kPa) 50 100 150 200; POCKET PEN. (kPa) 100 200 300 400
0	CLAY - silty, moist to wet, stiff,f high plastic, light greyish brown			
	- moist, very stiff			
1				
	- stiff, mottled dark grey			
2				
	- clay (till) pockets			
	7 days			
	CLAY (TILL) - silty, sandy, moist, stiff, medium plastic, dark brown, coal inclusions			
3	- oxide staining			
	- mottled dark grey			
4				
	- dark grey			
5				
	- siltier, wet, soft to firm			
	0 hrs.			
	SANDSTONE - silty, clayey, saturated, free water, soft, grey			
6	- dense			
7				
	END OF BOREHOLE (7.01 metres)			
	slough - 5.49 metres at 0 hrs.			
	water - trace at 0 hrs.			
	- 2.46 metres at 7 days			
8	Monitoring well installed to 6.71 metres			
9				
10				
11				
12				

Depth (ft): 0, 5, 10, 15, 20, 25, 30, 35, 39

7 days

0 hrs.

LOGGED BY: DJK	COMPLETION DEPTH: 7.01 m
REVIEWED BY: SD	COMPLETE: 11/09/22
DRAWING NO: 12101472-05	Page 1 of 1

PARKLAND MONITORING WELL INSTALLATION	PARKLAND COUNTY	PROJECT NO. - BOREHOLE NO.
7320 TWP RD 534	DRILL: SOLID STEM AUGER	E12101472-06
ENTWHISTLE, ALBERTA		

SAMPLE TYPE: DISTURBED | NO RECOVERY | SPT | A-CASING | SHELBY TUBE | CORE

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

Depth (m)	SOIL DESCRIPTION	SAMPLE TYPE	MOISTURE CONTENT: PLASTIC / M.C. / LIQUID (20 40 60 80)	STANDARD PENETRATION (N) 20 40 60 80; UNCONFINED (kPa) 50 100 150 200; POCKET PEN. (kPa) 100 200 300 400
0	CLAY (FILL) - silty, some sand, stiff, medium plastic			
1	CLAY - silty, moist, very stiff, high platic, brown to dark grey			
2	CLAY (TILL) - silty, sandy, moist, very stiff, medium plastic, dark brown, coal inclusions - oxide staining - stiff to very stiff			
3	- mottled dark grey			
4				
5	- dark grey			
6	- very stiff			
7	7 days END OF BOREHOLE (7.01 metres) slough - 6.96 metres at 0 hrs. water - dry at 0 hrs. - 6.39 metres at 7 days Monitoring well installed to 6.83 metres			
8				
9				
10				
11				
12				

Depth (ft): 0, 5, 10, 15, 20, 25, 30, 35, 39

7 days

LOGGED BY: DJK	COMPLETION DEPTH: 7.01 m
REVIEWED BY: SD	COMPLETE: 11/09/22
DRAWING NO: 12101472-06	Page 1 of 1

CONSULTANT

Stantec

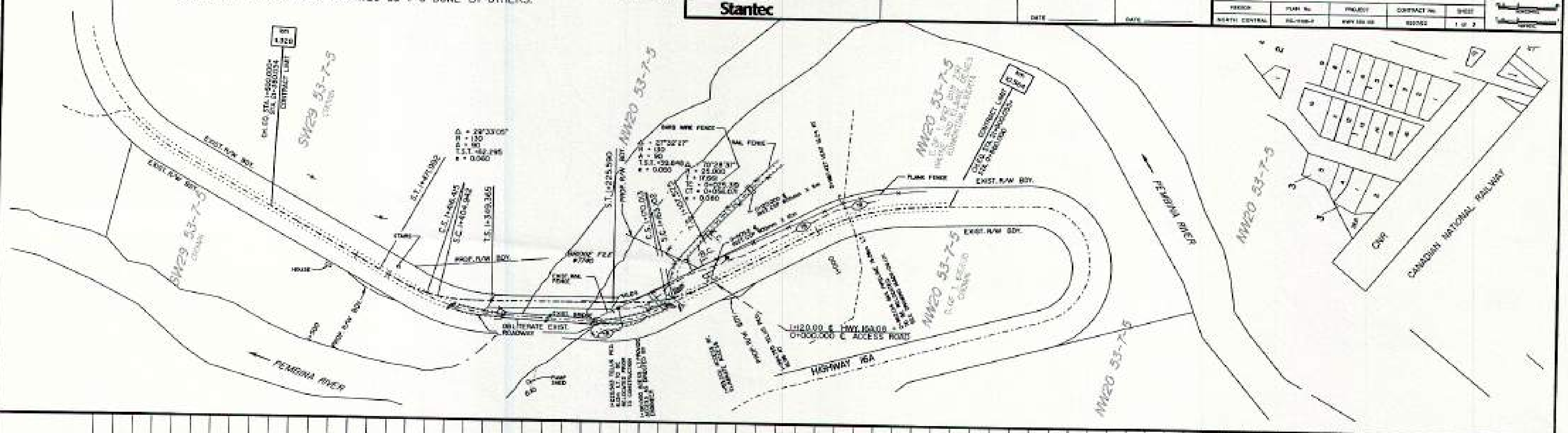
ORIGINAL DRAWINGS SIGNED AND STAMPED BY K.P. SMITH REGISTRATION No. M32174 ON 08/30/02 WITH STANTEC CONSULTING LTD., APEGGA PERMIT No. P 258 AND SIGNED BY C. CLAYTON ON 08/30/02.

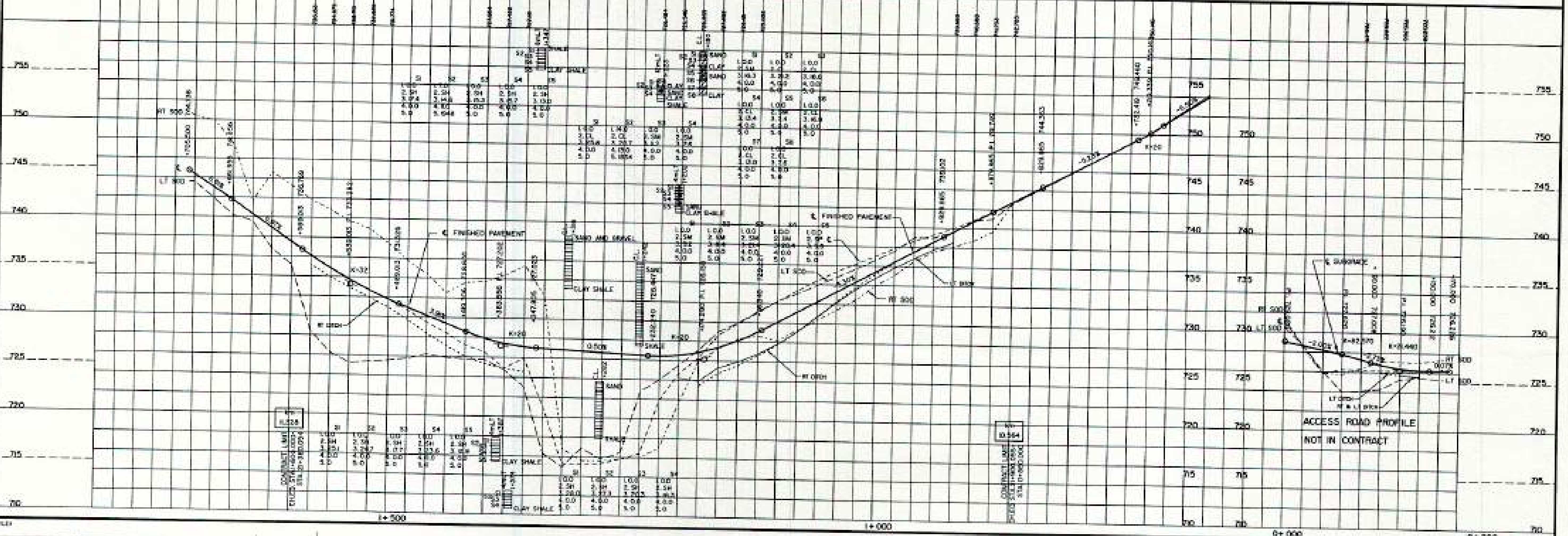
HIGHWAY 16A:08
PEMBINA RIVER BRIDGE ON HIGHWAY 16A:08 AT ENTWISTLE

Alberta INFRASTRUCTURE

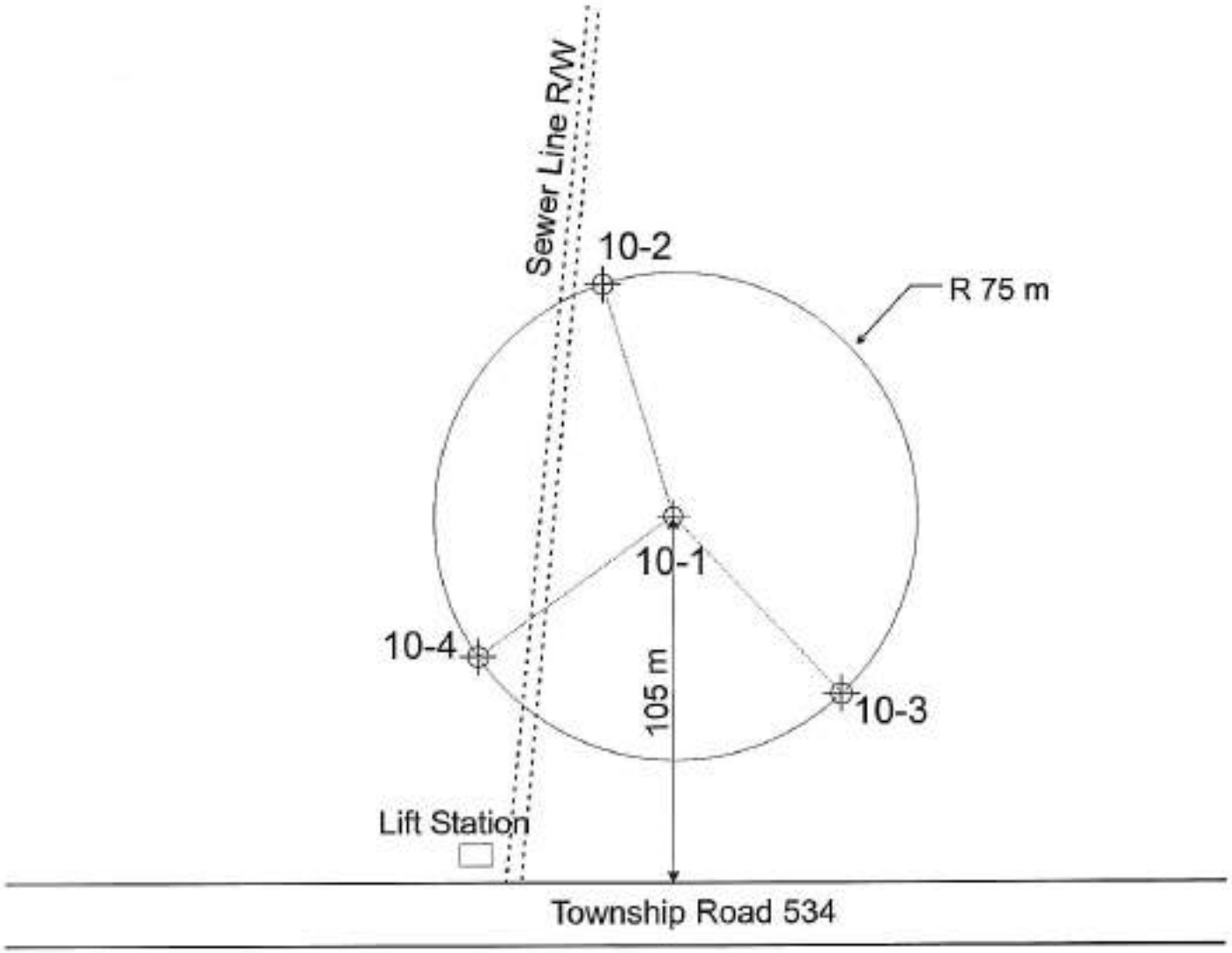
REGION: NORTH CENTRAL

GRADING, BASE, & FIRST LIFT OF ACP DONE BY OTHERS FROM 0+860 TO APPROX. 1+160. GRADING OF ACCESS ROAD TO NW20-53-7-5 DONE BY OTHERS.





HIGHWAY 16A:08
PEMBINA RIVER BRIDGE ON
HIGHWAY 16A:08 AT ENTWISTLE



Scale: Not to Scale

SABATINI EARTH TECHNOLOGIES INC.
12323-67 Street NW, Edmonton, Alberta
Phone: (780) 438-0844
Fax: (780) 435-1812

LEDCOR INFRASTRUCTURE SERVICES

Proposed Guyed Communication Tower-Entwistle
Portion of SW 28-53-7-W5M, Parkland County, Alberta
Site Plan Showing Approximate Borehole Locations

Job No: E1008-2316	Date: July 27, 2010	Plate: 7

SABATINI EARTH TECHNOLOGIES INC.

CLIENT: Ledcor Infrastructure Services
PROJECT: Proposed Guyed Communication Tower
LOCATION: Entwistle, SW-28-53-7-W5M, Parkland County, AB
JOB No.: E1006-2316
DATE: July 19, 2010
TECH: NI
TEST BORING 10-1

DRILL TYPE: Solid Stem Auger

MOISTURE CONDITIONS
ATTERBERG LIMITS

MOISTURE CONTENT %
10 20 30 40 50 60

SOIL PROFILE & DESCRIPTION

TEST RESULTS

DEPTH IN FEET	DEPTH (m)	DATUM: / SURFACE ELEVATION:	SOIL SYMBOL	SAMPLE TYPE	BLOW COUNT -N	MISCELLANEOUS TESTS
		TOP SOIL, silty, compressible, brown				PP = 250 kPa
3	1	**CLAY TILL**, sandy, silty, moist, very stiff, medium plastic, greyish brown, coal bits, pebbles				
						PP = 200 kPa
6	2					
		- sandy				PP = 200 kPa
10	3					PP = 100 kPa SO_4 = 0.00%
		- at 3.5 m silty, trace of sand, salt				
		Gravel, silty, clayey, contained cobbles, hard to drill				PP = 100 kPa
	4	- some silty clay				
15						PP = 100 kPa SO_4 = 0.00%
	5	- at 5.0 m auger refusal				
		End of Borehole = 5.0 m Slough Depth = 4.0 m Water level = 3.5 m, 0 hours Standpipe Piezometer Installed = 5.0 m				
20	6					
	7					
25						
	8					
30	9					
	10					
35						

⊙ MOISTURE CONTENT
⊡ LIQUID LIMIT
△ PLASTIC LIMIT

Q_u UNCONFINED COMPRESSION
γ_d DRY UNIT WEIGHT

SO_4 SULPHATE CONTENT
▽ WATER TABLE
N PENETRATION RESISTANCE

☒ STANDARD PENETRATION SAMPLE
☑ UNDISTURBED SAMPLE (SHELBY)
☒ BAG SAMPLE

PLATE No. 3

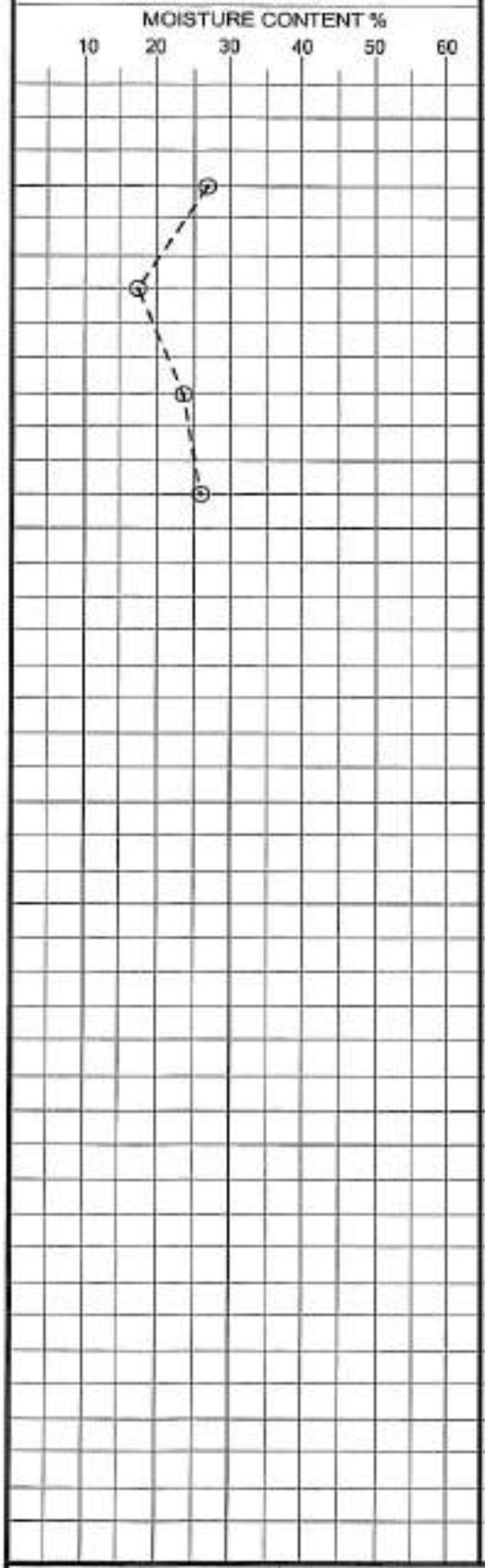
SABATINI EARTH TECHNOLOGIES INC.

CLIENT: Ledcor Infrastructure Services
PROJECT: Proposed Guyed Communication Tower
LOCATION: Entwistle, SW 26-53-7-M5W, Parkland County, AB
JOB No.: E1008-2316
DATE: July 19, 2010
TECH: NI

TEST BORING 10-2

DRILL TYPE: Solid Stem Auger

MOISTURE CONDITIONS
ATTERBERG LIMITS



SOIL PROFILE & DESCRIPTION

TEST RESULTS

DEPTH IN FEET	DEPTH (m)	DATUM: / SURFACE ELEVATION:	SOIL SYMBOL	SAMPLE TYPE	BLOW COUNT -N	MISCELLANEOUS TESTS
		TOPSOIL, silty, compressible, brown				
		CLAY TILL, damp, firm, medium plastic, brown				
3	1					PP = 75 kPa
		– sandy, silty, water seepage				PP = 75 kPa
6	2					PP = 50 kPa
						PP = 250 kPa
10	3	End of Borehole = 3.0 m				SO_4 = 0.01%
		Water level = 1.5 m, 0 hours				
		Standpipe Piezometer Installed = 3.0 m				
15	4					
	5					
20	6					
	7					
25	8					
30	9					
	10					
35						

⊙ MOISTURE CONTENT
⊡ LIQUID LIMIT
△ PLASTIC LIMIT

Q_u UNCONFINED COMPRESSION
γ_d DRY UNIT WEIGHT

SO_4 SULPHATE CONTENT
▽ WATER TABLE
N PENETRATION RESISTANCE

☒ STANDARD PENETRATION SAMPLE
☒ UNDISTURBED SAMPLE (SHELBY)
☒ BAG SAMPLE

PLATE No. 4

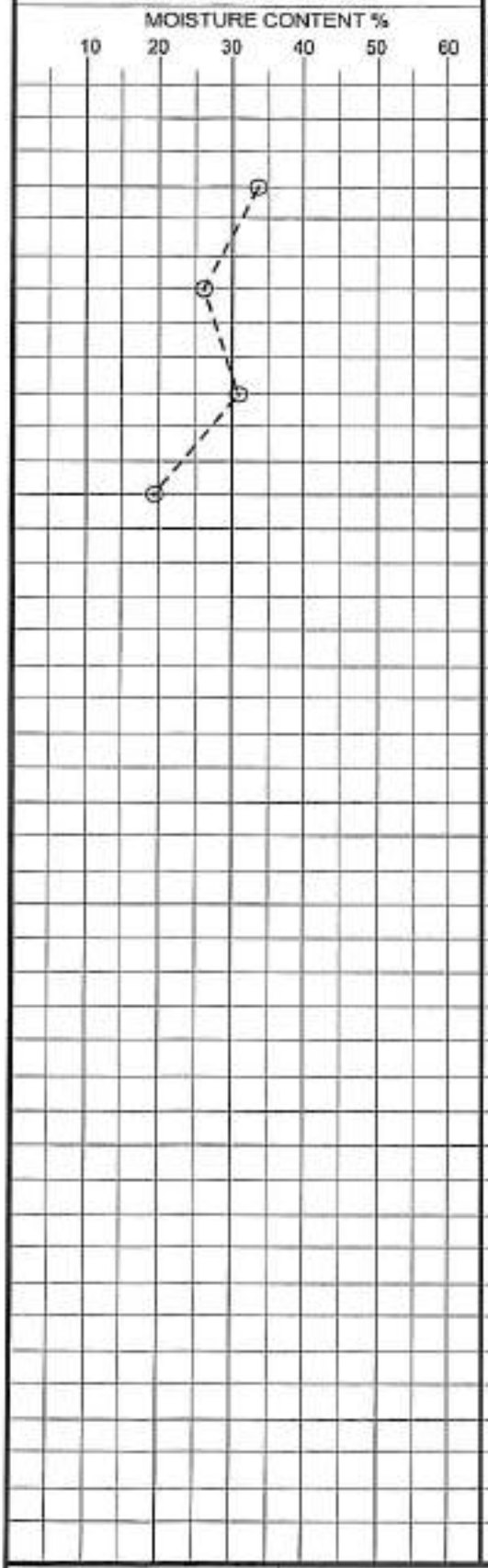
SABATINI EARTH TECHNOLOGIES INC.

CLIENT: Ledcor Infrastructure Services
PROJECT: Proposed Guyed Communication Tower
LOCATION: Entwistle, SW 26-53-7-W5M, Parkland County, AB
JOB No.: E1008-2316
DATE: July 19, 2010 TECH: TM

TEST BORING 10-3

DRILL TYPE Solid Stem Auger

MOISTURE CONDITIONS ATTERBERG LIMITS



SOIL PROFILE & DESCRIPTION

TEST RESULTS

DEPTH IN FEET	DEPTH (m)	DATUM: SURFACE ELEVATION:	SOIL SYMBOL	SAMPLE TYPE	BLOW COUNT -N	MISCELLANEOUS TESTS
		TOP SOIL, silty, compressible, brown				
		CLAY TILL, moist, stiff, medium plastic, grey				
3	1					PP = 200 kPa
		- dark brown				PP = 100 kPa
6	2					
		- organic clay (black), some shale content				PP = 150 kPa
		- grey				
						PP = 150 kPa
10	3	End of Borehole = 3.0 m Water level = 3.0 m(dry), 0 hours Standpipe Piezometer Installed = 3.0 m				
	4					
15	5					
	6					
20						
	7					
25						
	8					
	9					
30						
	10					
35						

⊙ MOISTURE CONTENT
⊡ LIQUID LIMIT
△ PLASTIC LIMIT

Q_u UNCONFINED COMPRESSION
γ_d DRY UNIT WEIGHT

SO_4 SULPHATE CONTENT
▼ WATER TABLE
N PENETRATION RESISTANCE

☒ STANDARD PENETRATION SAMPLE
☒ UNDISTURBED SAMPLE (SHELBY)
☒ BAG SAMPLE

PLATE No. 5

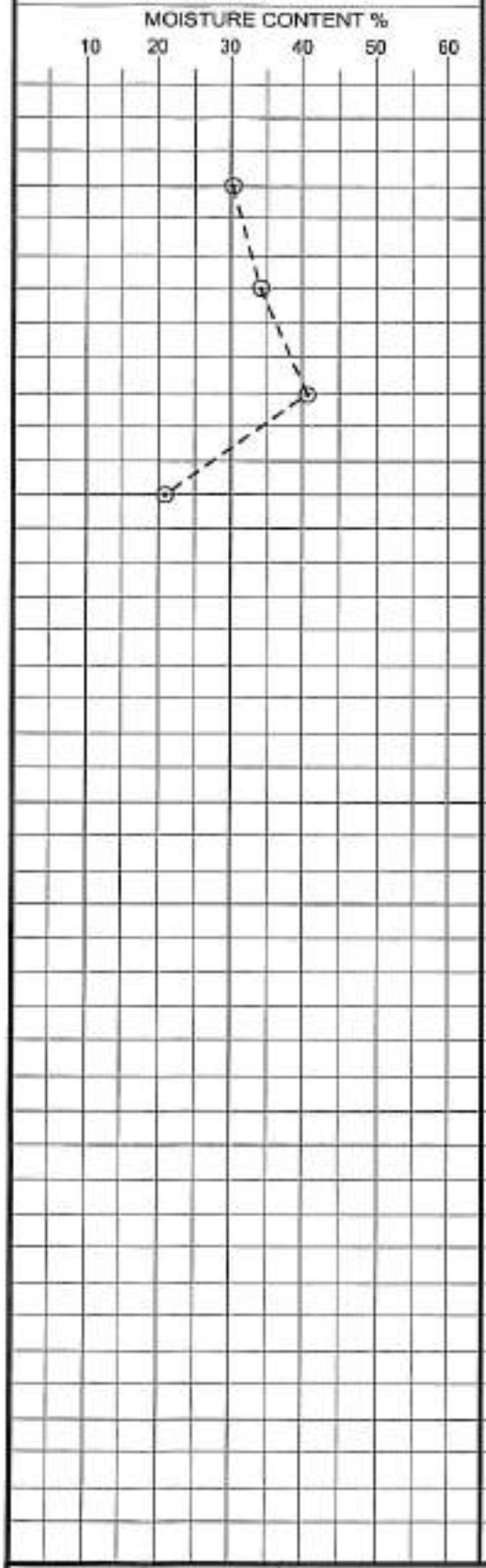
SABATINI EARTH TECHNOLOGIES INC.

CLIENT: Ledcor Infrastructure Services
PROJECT: Proposed Guyed Communication Tower
LOCATION: Entwistle, SW 28-53-7-W5M, Parkland County, AB
JOB No.: E1006-2316
DATE: July 19, 2010
TECH: TM

TEST BORING **10-4**

DRILL TYPE: Solid Stem Auger

MOISTURE CONDITIONS
ATTERBERG LIMITS



DEPTH IN FEET	DEPTH (m)	SOIL PROFILE & DESCRIPTION DATUM: SURFACE ELEVATION:	SOIL SYMBOL	SAMPLE TYPE	BLOW COUNT - N	TEST RESULTS MISCELLANEOUS TESTS
		TOP SOIL, silty, compressible, brown				
		CLAY TILL, moist, stiff, medium plastic, blackish brown				
3	1					PP = 150 kPa
						PP = 150 kPa
6	2	- silty, rust inclusion, greyish brown				
						PP = 75 kPa
		- blackish grey				
10	3					PP = 100 kPa
		End of Borehole = 3.0 m Water level = 3.0 m (dry), 0 hours Standpipe Piezometer Installed = 3 m				
15	4					
	5					
20	6					
	7					
25	8					
30	9					
	10					
35						

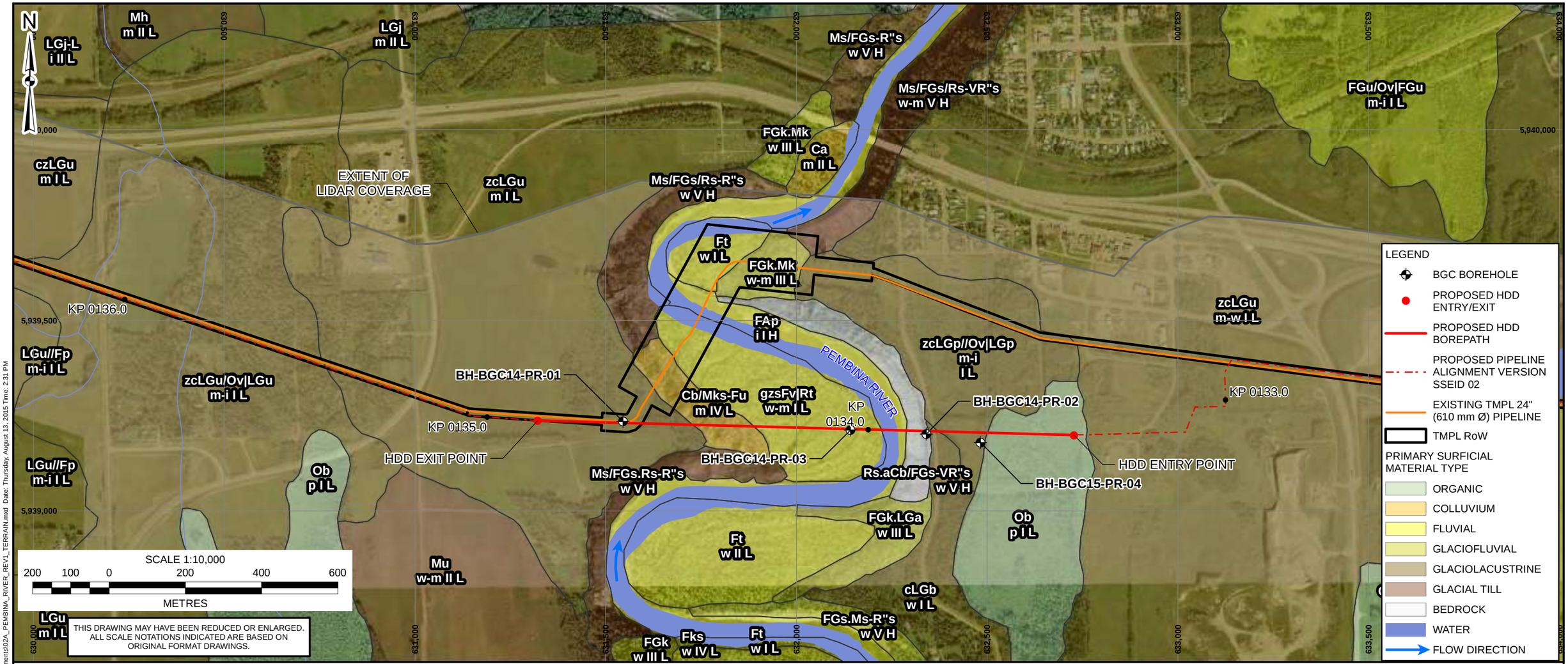
⊙ MOISTURE CONTENT
⊡ LIQUID LIMIT
△ PLASTIC LIMIT

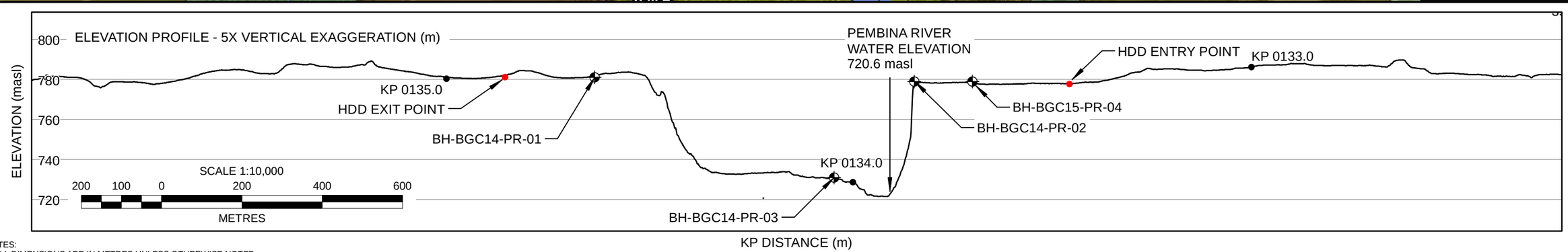
Q_u UNCONFINED COMPRESSION
γ_d DRY UNIT WEIGHT

SO_4 SULPHATE CONTENT
▼ WATER TABLE
N PENETRATION RESISTANCE

☒ STANDARD PENETRATION SAMPLE
▨ UNDISTURBED SAMPLE (SHELBY)
▣ BAG SAMPLE

PLATE No. **6**





NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - PEMBINA RIVER AT SSEID 02 KP 134 REVISION 1", AND DATED AUGUST 2015.
3. PROPOSED PIPELINE CENTRELINE VERSION SSEID 02 PROVIDED BY UPI LTD., DATED MAY 05, 2015.
4. WATERBODY AND STREAM DATA FROM NRCAN CANVEC.
5. ORTHOIMAGE PROVIDED BY KINDER MORGAN CANADA, FROM ORTHOSHOP GEOMATICS LTD., DATED BETWEEN 2005 AND 2006.
6. HILLSHADE SURFACE PROFILE BASED ON LiDAR, PROVIDED BY UPI, AND DATED APRIL 18, 2014.
7. PROPOSED HDD PROFILE PROVIDED BY UPI LTD. ON JUNE 12, 2013.
8. FOR A FULL EXPLANATION OF THE TERRAIN MAPPING TERMS AND SYMBOLS SEE THE COMPLETE LEGEND IN DRAWING 02B. TERRAIN POLYGONS BASED ON TERRAIN MAPPING COMPLETED UP TO JULY 2015 BY BGC.
9. THIS MAP IS A SNAPSHOT IN TIME. CHANGES IN LAND USE (E.G. DEVELOPMENT, RIVER MIGRATION) MAY WARRANT RE-DRAWING OF CERTAIN AREAS.
10. PROJECTION IS NAD 83 ZONE 11.
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SCALE:	1:10,000
DATE:	AUG 2015
DRAWN:	MIB
CHECKED:	SSM, LCH
APPROVED:	KSJ

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: TRANSMOUNTAIN

PROJECT: GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - PEMBINA RIVER AT SSEID 02 KP 134 REVISION 1

TITLE: TERRAIN MAP

PROJECT No.: 0095-150

DWG No.: 02A

X:\Projects\0095150\GIS\Production\Reports\20140915_TMEP_Preliminary_Geotechnical_HDD_Feasibility_Assessments\02A_PEMBINA_RIVER_REV1_TERRAIN.mxd Date: Thursday, August 13, 2015 Time: 2:31 PM

Survey Method: Handheld GPSMAP 62s
Co-ordinates (m): 632,341E, 5,939,202N
Ground Elevation (m): 779.0
Datum: NAD83
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT-750
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary/Wirelong Coring
Fluid: Bentonite Mud/Water
Casing: HWT/HQ **Cased To (m)**: 54.17
Depth To Rock (m): 3.96

Start Date: 02 Jul 14
Finish Date: 09 Jul 14
Final Depth of Hole (m): 59.13
Logged by: BNM
Reviewed by: SSM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
0					CLAY(CH) Some silt, high plasticity, firm to stiff, low sensitivity, light brown, no odour, moist, blocky, moderate cementation, low dry strength, no dilatancy, no foreigns. [GLACIOLACUSTRINE]	
1		SPT-01			SPT-01 - Recovered 0.45 m.	2 3 5
2					Water table measured at a depth of 2.3 m below ground surface on July 3, 2014 with the drill hole at a depth of 4.4 m.	
3		SPT-02			SPT-02 - Recovered 0.52 m. Changes to silty, some sand, some gravel, stiff, small coal fragments 1 mm in diameter.	3 7 8
4		SPT-03	W 2		Good Quality Interbedded SANDSTONE, SILTSTONE, and MUDSTONE SANDSTONE Slightly weathered, weak, light brownish red with thinly bedded layers of SILT(ML) rough, closely spaced discontinuities. SILTSTONE Highly weathered, stiff, reddish brown, fine to medium grained, thinly bedded with layers of SILT(ML), closely spaced discontinuities. MUDSTONE Slightly weathered, very stiff, light brown, fine, slightly bedded, closely spaced discontinuities. [PASKAPOO FORMATION] SPT-03 - Recovered 0.31 m. 4.4 m - Begin wireline coring.	32 R
5						
6						
7			W 2			
8						

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery
▲ UC/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80 | 20 40 60 80

(Continued on next page)

Survey Method: Handheld GPSMAP 62s
Co-ordinates (m): 632,341E, 5,939,202N
Ground Elevation (m): 779.0
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Start Date: 02 Jul 14
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Reviewed by: SSM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
8			W 2		Good Quality Interbedded SANDSTONE, SILTSTONE, and MUDSTONE SANDSTONE Slightly weathered, weak, light brownish red with thinly bedded layers of SILT(ML) rough, closely spaced discontinuities. SILTSTONE Highly weathered, stiff, reddish brown, fine to medium grained, thinly bedded with layers of SILT(ML), closely spaced discontinuities. MUDSTONE Slightly weathered, very stiff, light brown, fine, slightly bedded, closely spaced discontinuities. [PASKAPOO FORMATION]	
9						
10			W 2			
11			W 2		Good Quality Interbedded SANDSTONE and SILTSTONE SANDSTONE Slightly weathered to fresh, very weak, dark reddish brown to grey, medium grained, closely spaced discontinuities. SILTSTONE Fresh, weak light grey, medium grained, bedded fractures <1mm, very closely spaced discontinuities. [PASKAPOO FORMATION] 11.0 - 16.6 m - 100% of fluid circulations lost.	
12						
13			W 2		13.6 m - Drilling fluid additive added to mitigate fluid loss.	
14						
15			W 2		Water table measured at a depth of 15.0 m below ground surface on July 9, 2014 with the drill hole at a depth of 59.1 m.	
16						

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UC/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld GPSMAP 62s
Co-ordinates (m): 632,341E, 5,939,202N
Ground Elevation (m): 779.0
Datum: NAD83
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT-750
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary/Wirelong Coring
Fluid: Bentonite Mud/Water
Casing: HWT/HQ **Cased To (m)**: 54.17
Depth To Rock (m): 3.96

Start Date: 02 Jul 14
Finish Date: 09 Jul 14
Final Depth of Hole (m): 59.13
Logged by: BNM
Reviewed by: SSM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description
16			W 2		Good Quality Interbedded SANDSTONE and SILTSTONE SANDSTONE Slightly weathered to fresh, very weak, dark reddish brown to grey, medium grained, closely spaced discontinuities. SILTSTONE Fresh, weak, light grey, medium grained, bedded fractures <1mm, very closely spaced discontinuities. [PASKAPOO FORMATION] 16.6 - 25.0 m - 50% of fluid circulation lost.
17			W 1.5		
18					
19			W 1.5		
20					
21			W 1.5		
22					
23			W 1.5		
24					

SPT Blows per 150mm

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
20 40 60 80
▲ UC/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80

(Continued on next page)

Survey Method: Handheld GPSMAP 62s
Co-ordinates (m): 632,341E, 5,939,202N
Ground Elevation (m): 779.0
Datum: NAD83
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT-750
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary/Wirelong Coring
Fluid: Bentonite Mud/Water
Casing: HWT/HQ **Cased To (m)**: 54.17
Depth To Rock (m): 3.96

Start Date: 02 Jul 14
Finish Date: 09 Jul 14
Final Depth of Hole (m): 59.13
Logged by: BNM
Reviewed by: SSM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description
24					Good Quality Interbedded SANDSTONE and SILTSTONE SANDSTONE Slightly weathered to fresh, very weak, dark reddish brown to grey, medium grained, closely spaced discontinuities. SILTSTONE Fresh, weak, light grey, medium grained, bedded fractures <1mm, very closely spaced discontinuities. [PASKAPOO FORMATION] 25.0 - 28.8 m - 100% of fluid circulation lost.
25			W 1		
26					
27			W 1		
28					
28			W 1		28.5 m - Interpreted transition to SCOLLARD FORMATION. 28.8 - 33.0 m - 50% of fluid circulation lost.
29					
30			W 1		
31					
32			W 1		

SPT Blows per 150mm

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
20 40 60 80
▲ UC/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80

(Continued on next page)

Survey Method: Handheld GPSMAP 62s
Co-ordinates (m): 632,341E, 5,939,202N
Ground Elevation (m): 779.0
Datum: NAD83
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT-750
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary/Wirelong Coring
Fluid: Bentonite Mud/Water
Casing: HWT/HQ **Cased To (m)**: 54.17
Depth To Rock (m): 3.96

Start Date: 02 Jul 14
Finish Date: 09 Jul 14
Final Depth of Hole (m): 59.13
Logged by: BNM
Reviewed by: SSM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description
32			W 1		Good Quality Interbedded SANDSTONE and SILTSTONE SANDSTONE Slightly weathered to fresh, very weak, dark reddish brown to grey, medium grained, closely spaced discontinuities. SILTSTONE Fresh, weak, light grey, medium grained, bedded fractures <1mm, closely spaced discontinuities. [SCOLLARD FORMATION]
33		UCS1			33.0 - 37.2 m - 25% of fluid circulation lost.
34			W 1		
35					
36			W 1		
37			W 1		37.2 - 45.6 m - 100% of fluid circulation lost.
38		UCS2			
39			W 1		
40					

SPT Blows per 150mm

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
20 40 60 80
▲ UC/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80

(Continued on next page)

Survey Method: Handheld GPSMAP 62s
Co-ordinates (m): 632,341E, 5,939,202N
Ground Elevation (m): 779.0
Datum: NAD83
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT-750
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary/Wirelong Coring
Fluid: Bentonite Mud/Water
Casing: HWT/HQ **Cased To (m)**: 54.17
Depth To Rock (m): 3.96

Start Date: 02 Jul 14
Finish Date: 09 Jul 14
Final Depth of Hole (m): 59.13
Logged by: BNM
Reviewed by: SSM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
40			W 1		Good Quality Interbedded SANDSTONE and SILTSTONE SANDSTONE Slightly weathered to fresh, very weak, dark reddish brown to grey, medium grained, closely spaced discontinuities. SILTSTONE Fresh, weak, light grey, medium grained, bedded fractures <1mm, closely spaced discontinuities. [SCOLLARD FORMATION]	
41						
42			W 1			
43						
44			W 1			
45					45.6 - 49.6 m - 20% of fluid circulation lost.	
46			W 1			
47						
48						

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UC/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld GPSMAP 62s
Co-ordinates (m): 632,341E, 5,939,202N
Ground Elevation (m): 779.0
Datum: NAD83
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT-750
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary/Wirelong Coring
Fluid: Bentonite Mud/Water
Casing: HWT/HQ **Cased To (m)**: 54.17
Depth To Rock (m): 3.96

Start Date: 02 Jul 14
Finish Date: 09 Jul 14
Final Depth of Hole (m): 59.13
Logged by: BNM
Reviewed by: SSM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
48			Q 1		Good Quality Interbedded SANDSTONE and SILTSTONE SANDSTONE Slightly weathered to fresh, very weak, dark reddish brown to grey, medium grained, closely spaced discontinuities. SILTSTONE Fresh, weak, light grey, medium grained, bedded fractures <1mm, closely spaced discontinuities. [SCOLLARD FORMATION]	
49			W 1		49.6 - 50.5 m - 30% of fluid circulation lost.	
50			W 1		50.5 - 59.1 m - 100% of fluid circulation lost.	
51						
52			W 1			
53						
54			W 1			
55			W 1			
56						

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
▲ UC/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80
20 40 60 80

>>
>>

(Continued on next page)

Survey Method: Handheld GPSMAP 62s
Co-ordinates (m): 632,341E, 5,939,202N
Ground Elevation (m): 779.0
Datum: NAD83
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: HT-750
Drilling Contractor: Foundex Exploration Ltd.
Drill Method: Mud Rotary/Wirelong Coring
Fluid: Bentonite Mud/Water
Casing: HWT/HQ **Cased To (m)**: 54.17
Depth To Rock (m): 3.96

Start Date: 02 Jul 14
Finish Date: 09 Jul 14
Final Depth of Hole (m): 59.13
Logged by: BNM
Reviewed by: SSM
Approved by: KWB

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description
56					Good Quality Interbedded SANDSTONE and SILTSTONE SANDSTONE Slightly weathered to fresh, very weak, dark reddish brown to grey, medium grained, closely spaced discontinuities. SILTSTONE Fresh, weak, light grey, medium grained, bedded fractures <1mm, closely spaced discontinuities. [SCOLLARD FORMATION]
57			W 1		
58					
59			W 1		Borehole abandoned at a depth of 59.1 m below ground surface due to loss of containment. Borehole backfilled with bentonite chips from 59.1 m to 31.1 m and then grouted to surface with bentonite from 31.1 m. No instrumentation installed. SPT Sampler Details: 24" length, 2" diameter, driven by automatic trip hammer. All SPT sampling was carried out in accordance with ASTM D1586. Pocket penetrometer tests conducted on base of SPT sample when possible and on opened face of SPT sample as appropriate. Garmin GPSMAP 62s handheld GPS accuracy +/- 3 m. Elevation reported taken from LiDAR provided by Integrated Pipeline Projects Canada Ltd. (IPP) and received on August 20, 2013.
60					
61					
62					
63					
64					

SPT Blows per 150mm

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
20 40 60 80
▲ UC/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80

Survey Method: Handheld Garmin 62s
Co-ordinates (m): 632,483E, 5,939,180N
Ground Elevation (m): 777.8
Datum: NAD83 UTM Zone 11U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: FRASTE
Drilling Contractor: Geotech Drilling
Drill Method: Mud Rotary, Coring
Fluid: Water, Polymer
Casing: HWT **Cased To (m)**: 5.68
Depth To Rock (m): 6.9

Start Date: 03 Jun 15
Finish Date: 07 Jun 15
Final Depth of Hole (m): 70.7
Logged by: LCH
Reviewed by: LDM
Approved by: KSJ

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
0					TOPSOIL	
		1			SAND (SM) Fine, some silt, trace to some rootlets, uniformly graded, light brown with orange mottling, dry, homogeneous to laminated, no cementation, no odour, slight visible weathering, low plasticity silt. [GLACIOFLUVIAL] SPT 01 - Recovered 0.13 m.	3 2 3
1						
		2			CLAY (CH) Some silt to silty, trace sand, high plasticity, stiff, dark brown with light brown beds, near plastic limit (NPL), laminated, no cementation, no visible weathering, high dry strength, no dilatancy. [LACUSTRINE/GLACIOLACUSTRINE] SPT 02 - Recovered 0.42 m. Grainsize distribution: 3% sand, 97% fines. MC: 34%. PL: 25%, LL: 73%, PI: 48%.	4 4 6
2					2.4 m - Encountered cobble/boulder.	
3		3			SPT 03 - and SILT, sandy, trace gravel, wetter than plastic limit (WTPL), medium dry strength. Recovered 0.18 m.	2 5 36
					SILT (ML) and SAND (SW) Gravelly, trace clay, cobbles, hard, low plasticity, brown and orange, drier than plastic limit (DTPL), heterogeneous, no cementation, no odour, fine to coarse sand, multilithic gravel, maximum recovered particle size = 38 mm. Matrix supported. [GLACIOFLUVIAL]	
4						
		4a 4b			SPT 04 - Recovered 0.46 m. Two grab samples collected: 4a, 4b. 4a (4.32-4.49 m): Grainsize distribution: 41% sand, 59% fines. MC: 19%. 4b (4.49-4.79 m): Grainsize distribution: 11% sand, 89% fines. MC: 18%. LL: 46%, PL: 31%, PI: 15%. 4.5 - 6.4 m - Some sand, trace gravel, yellowish brown with orange mottling, laminated, medium dry strength, no dilatancy.	
5						
6						
		5	W 3		SPT 05 - Refusal due to SPT sampler bouncing on cobble. Recovered 0.21 m of 0.15 m.	R
		GS1	W 2		6.4 m - Sandstone cobble, slightly weathered with iron oxide staining on joint surfaces, very weak to weak, light grey.	
7			W 5		Interbedded Very Poor to Poor Quality SILTSTONE, SANDSTONE and MUDSTONE	
			W 2			
			W 4			
8						

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery
▲ UC/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80 20 40 60 80

(Continued on next page)

Survey Method: Handheld Garmin 62s
Co-ordinates (m): 632,483E, 5,939,180N
Ground Elevation (m): 777.8
Datum: NAD83 UTM Zone 11U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: FRASTE
Drilling Contractor: Geotech Drilling
Drill Method: Mud Rotary, Coring
Fluid: Water, Polymer
Casing: HWT **Cased To (m)**: 5.68
Depth To Rock (m): 6.9

Start Date: 03 Jun 15
Finish Date: 07 Jun 15
Final Depth of Hole (m): 70.7
Logged by: LCH
Reviewed by: LDM
Approved by: KSJ

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description
8			W 2		Interbedded Very Poor to Poor Quality SILTSTONE, SANDSTONE and MUDSTONE Completely weathered to slightly weathered, extremely weak to very weak, light brown, fine to medium grained, bedded sub-units approximately 40 cm thick. Sub-units are internally laminated. Laminations are light brown, red, orange and black due to iron oxide weathering. Very poor to fair RQD, very close to close fracture spacing. One dominant joint set along bedding planes at 80-90° to core axis. Joints are smooth to rough with iron oxide staining. [PASKAPOO FORMATION]
9			W 2		
10		UCS1	W 2		
11			W 4		Very Poor Quality SANDSTONE Completely weathered to residual soil, very stiff soil to extremely weak rock, light brown, medium grained, bedded to homogeneous. Very poor RQD, very close fracture spacing. Joints show minimal iron oxide straining. One major joint set along bedding planes at 80-90° to core axis. Many fractures opened due to drill action. [PASKAPOO FORMATION]
12		UCS2	W 4		Water table measured at a depth of 12.1 m below ground surface on June 7, 2015 with the drill hole at a depth of 59.1 m.
13			W 5		
14			W 2		Very Poor to Fair Quality SANDSTONE Slightly weathered to fresh, extremely weak to weak, light grey, medium grained, bedded to homogeneous. Some beds dark grey to black, sporadic coal seams approximately 1 mm thick. Very poor to excellent RQD, very close to wide fracture spacing with bedding planes opened during drilling. Two major joint sets along bedding planes at 70-80°, 80-90° to core axis. [PASKAPOO FORMATION]
15			W 1		
16					

SPT Blows per 150mm

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
▲ UC/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80
20 40 60 80

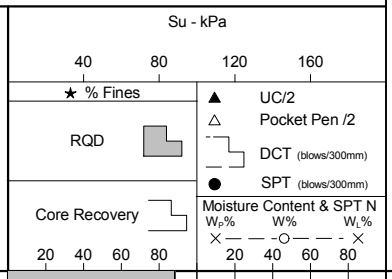
(Continued on next page)

Survey Method: Handheld Garmin 62s
Co-ordinates (m): 632,483E, 5,939,180N
Ground Elevation (m): 777.8
Datum: NAD83 UTM Zone 11U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: FRASTE
Drilling Contractor: Geotech Drilling
Drill Method: Mud Rotary, Coring
Fluid: Water, Polymer
Casing: HWT **Cased To (m)**: 5.68
Depth To Rock (m): 6.9

Start Date: 03 Jun 15
Finish Date: 07 Jun 15
Final Depth of Hole (m): 70.7
Logged by: LCH
Reviewed by: LDM
Approved by: KSJ

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
16			W 1		Very Poor to Fair Quality SANDSTONE Fresh and unweathered, extremely weak to weak, light grey, medium grained, bedded to homogeneous. Some beds dark grey to black, sporadic coal seams approximately 1 mm thick. Excellent to very poor RQD, wide to very close fracture spacing with bedding planes opened during drilling. Two major joint sets along bedding planes at 70-80°, 80-90° to core axis. [PASKAPOO FORMATION]	
17						
18			W 1			
19						
		UCS3			UCS3 - 3.7 MPa. MC: 16%.	
20			W 1			
					20.2 m - Brecciated pieces of coal in sandstone with coal seams approximately 1 mm wide. 20.5 m - Lost recovery due to lost drill fluid circulation. 20.7 m - Lost 100% of drill fluid circulation. Regained 90% drill fluid circulation after addition of G-Stop polymer.	
21			W 1			
22						
			W 1			
23			W 4 W 1.5		22.8 - 23.1 m - No recovery. Driller noted that the drill pressured up then depressurized indicating material washed away. Interpreted to be extremely weak rock.	
24						



(Continued on next page)

Survey Method: Handheld Garmin 62s
Co-ordinates (m): 632,483E, 5,939,180N
Ground Elevation (m): 777.8
Datum: NAD83 UTM Zone 11U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: FRASTE
Drilling Contractor: Geotech Drilling
Drill Method: Mud Rotary, Coring
Fluid: Water, Polymer
Casing: HWT **Cased To (m)**: 5.68
Depth To Rock (m): 6.9

Start Date: 03 Jun 15
Finish Date: 07 Jun 15
Final Depth of Hole (m): 70.7
Logged by: LCH
Reviewed by: LDM
Approved by: KSJ

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
24			W 1		Very Poor to Fair Quality SANDSTONE Fresh and unweathered, extremely weak to weak, light grey, medium grained, bedded to homogeneous. Some beds dark grey to black, sporadic coal seams approximately 1 mm thick. Excellent to very poor RQD, wide to very close fracture spacing with bedding planes opened during drilling. Two major joint sets along bedding planes at 70-80°, 80-90° to core axis. Coal seams approximately 1 mm thick spaced 1-10 mm apart between 23.9 - 24.1 m. [PASKAPOO FORMATION]	
25					25.0 - 26.5 m - Sandstone eroded by drill fluid circulation.	
26			W 1		26.5 - 28.0 m - Wide fracture spacing.	
27						
28			W 1			
29			W 1 W 2		Very Poor Quality SILTSTONE Slightly weathered to moderately weathered, very weak, dark greenish grey, fine grained, uniform. Coal beds up to 300 mm thick. Highly broken from both natural fractures and drill action. Very poor RQD, very close fracture spacing. Three joint sets at 30-40°, 50-60°, 70-80° to core axis. Smooth to rough joints. [SCOLLARD FORMATION]	
30					29.5 - 32.6 m - Extremely weak fault gouge 7 - 40 mm thick set at 75-85° to the core axis surrounded by extremely weak rock.	
31			W 2			
32			W		31.7 m - Highly weathered rock 30 mm thick.	

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UC/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld Garmin 62s
Co-ordinates (m): 632,483E, 5,939,180N
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Datum: NAD83 UTM Zone 11U
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Drilling Contractor: Geotech Drilling
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Fluid: Water, Polymer
Casing: HWT **Cased To (m)**: 5.68
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Start Date: 03 Jun 15
Finish Date: 07 Jun 15
Final Depth of Hole (m): 70.7
Logged by: LCH
Reviewed by: LDM
Approved by: KSJ

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description
32			2		Fair to Good Quality SILTSTONE Slightly weathered to fresh, very weak to medium strong, dark greenish grey, fine grained, bedded to uniform. Coal beds up to 300 mm thick. Highly broken from both natural fractures and drill action. Good to excellent RQD, moderate fracture spacing. Three joint sets at 30-40°, 50-60°, 70-80° to core axis. Smooth to rough joints. [SCOLLARD FORMATION]
		UCS4			UCS4 - 5.4 MPa. MC: 13%.
33			W 1.5		
					33.7 - 33.9 m - Intersecting healed joints.
34					34.0 m - Minor green alteration.
					34.4 m - 35.6 m - Interbedded layers of light and dark grey with black coal seams approximately 1-3 mm thick.
35			W 1		34.9 m - Healed joint with extremely weak infill approximately 1-5 mm thick.
					35.4 m - Healed joint with extremely weak infill approximately 1-3 mm thick. 35.6 - 36.1 m - Slightly altered, light green.
36			W 1		
			W 1		Fair Quality SANDSTONE Fresh and unweathered, very weak to weak, light grey with dark grey beds 1-2 mm thick, medium grained, bedded. Excellent RQD, wide fracture spacing. [SCOLLARD FORMATION]
37			W 1		Good Quality SILTSTONE Fresh to slightly weathered, weak to medium strong, dark grey with light grey and black beds 1-2 mm thick, fine grained, bedded to uniform. Good to excellent RQD, wide fracture spacing, slightly rough to rough joints with fault gouge up to 40 mm thick. Three joint sets at 27°, 70-80°, and 80-90° to core axis. [SCOLLARD FORMATION]
38			W 1.5		37.4 - 37.5 m - Brown, laminated, convoluted beds. 37.5 m - Coal seam 5 mm thick. 37.9 - 38.2 m - Light brown lenses interbedded in rock mass.
39					39.1 - 39.6 m - Interbedded siltstone and sandstone, predominantly sandstone.
			W 1		39.6 - 40.0 m - Convoluted beds 1-4 mm thick.
40					

SPT Blows per 150mm

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
▲ UC/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80 20 40 60 80

(Continued on next page)

Survey Method: Handheld Garmin 62s
Co-ordinates (m): 632,483E, 5,939,180N
Ground Elevation (m): 777.8
Datum: NAD83 UTM Zone 11U
Dip (degrees from horizontal): -90
Direction: N/A

Drill Designation: FRASTE
Drilling Contractor: Geotech Drilling
Drill Method: Mud Rotary, Coring
Fluid: Water, Polymer
Casing: HWT **Cased To (m)**: 5.68
Depth To Rock (m): 6.9

Start Date: 03 Jun 15
Finish Date: 07 Jun 15
Final Depth of Hole (m): 70.7
Logged by: LCH
Reviewed by: LDM
Approved by: KSJ

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description
40					Very Poor to Good Quality SILTSTONE Fresh to faintly weathered, weak to medium strong, light grey to light green, fine grained, uniform to microfractured. Good to excellent RQD, very close to moderate fracture spacing, slightly rough to rough joints with crushed rock and silt infill up to 20 mm thick. Three joint sets at 45-55°, 70-80°, and 80-90° to core axis. [SCOLLARD FORMATION]
41			W 1.5		40.8 - 41.0 m - Coal seam with extremely weak rock walls, matrix supported with gouge. 41.0 - 41.2 m - Healed fractures with crushed rock and fault gouge.
42			W 1		41.7 - 44.3 m - Light greenish grey, includes zones of bedded to microfractured rock, matrix and clast supported in fault gouge and healed joints with silt/fault gouge infill.
43			W 2 W 1		42.7 m - Shear with evidence of slickenslide. 42.7 - 43.5 m - Extremely weak, bedded to microfractured with hard soil.
44			W 1.5		44.0 m - Fault gouge 20 mm thick.
			W 1		44.3 m - Medium strong, dark grey fades to light greenish grey.
45			W 1		45.0 m - Green with reddish brown mottling, small black veins (<1 mm diameter up to 150 mm long).
46			W 1.5		46.0 m - Green with black veins 1-4 mm diameter. 46.3 - 46.5 m - Bedded to microfractured. 46.4 - 46.6 m - Healed fracture and faulted area with 40 mm of extremely weak rock and 10 mm of stiff soil fault gouge.
47			W 1		Fair Quality SANDSTONE Fresh and unweathered, very weak to weak, light grey, medium grained, bedded. Excellent RQD, wide fracture spacing. [SCOLLARD FORMATION]
48			W 1		

SPT Blows per 150mm

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UC/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

Survey Method: Handheld Garmin 62s
Co-ordinates (m): 632,483E, 5,939,180N
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Direction: N/A

Drill Designation: FRASTE
Drilling Contractor: Geotech Drilling
Drill Method: Mud Rotary, Coring
Fluid: Water, Polymer
Casing: HWT **Cased To (m)**: 5.68
Depth To Rock (m): 6.9

Start Date: 03 Jun 15
Finish Date: 07 Jun 15
Final Depth of Hole (m): 70.7
Logged by: LCH
Reviewed by: LDM
Approved by: KSJ

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description
48			W 2		Very Poor to Fair Quality SILTSTONE Fresh and unweathered, medium strong to extremely weak, light and dark grey, fine grained, bedded. Bedding planes spaced 1-3 mm apart at 80-90° to the core axis. Very poor to excellent RQD, very close to moderate fracture spacing, rough joints. [SCOLLARD FORMATION]
49			W 2		48.4 - 48.9 m - Microfractured. 48.9 - 49.2 m - Stiff to very stiff soil.
			W 1		49.2 - 49.6 m - Dark coal beds. 49.6 m - Sandstone interbed 60 mm thick.
50			W 1.5		49.9 m - Healed joint with 2 mm of silty sand infill.
51			W 1		50.6 - 50.7 m - Dark grey/black. 50.7 - 51.3 m - Greenish grey.
52			W 1		Fair Quality SANDSTONE Fresh and unweathered, very weak to weak, light greyish green, medium grained, uniform with occasional white veins. Good to excellent RQD, moderate to close fracture spacing, rough joints. Two joint sets at 65-70°, 45° to core axis. [SCOLLARD FORMATION]
53			W 1		Poor to Good Quality SANDSTONE Fresh and unweathered, weak to medium strong, light grey, medium grained, bedded, no natural joint sets. Black coal seams prevalent throughout (<1 to 3 mm in diameter). Very poor to excellent RQD, very close to wide fracture spacing. Bedding at 80-90° to core axis. [SCOLLARD FORMATION]
54			W 1		53.8 m - Fault gouge, stiff to very stiff soil approximately 30 mm thick. 53.9 - 55.5 m - Highly fractured.
55			W 2		54.6 m - Extremely weak rock with very stiff to hard silty sand and crushed rock infill approximately 30 mm thick. 54.8 m - Broken, crushed rock and hard soil 100 mm thick. 55.2 m - Healed fracture with crushed rock, broken rock and hard soil infill 8 mm thick.
56					55.6 - 56.0 m - Healed microfractured, extremely weak.

SPT Blows per 150mm

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
▲ UC/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80
20 40 60 80

(Continued on next page)

Survey Method: Handheld Garmin 62s
Co-ordinates (m): 632,483E, 5,939,180N
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Direction: N/A

Drill Designation: FRASTE
Drilling Contractor: Geotech Drilling
Drill Method: Mud Rotary, Coring
Fluid: Water, Polymer
Casing: HWT **Cased To (m)**: 5.68
Depth To Rock (m): 6.9

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Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description
56			W 1.5		Poor to Good Quality SANDSTONE Fresh, very weak to weak, dark grey, fine to medium grained, bedded. Very poor to excellent RQD, very close to wide fracture spacing. [SCOLLARD FORMATION] 56.2 - 56.5 m - Healed fractures with hard soil infill up to 6 mm thick spaced approximately 10 mm apart.
57					57.0 - 59.1 m - Interbedded siltstone and sandstone. 57.2 - 57.3 m - No recovery.
58			W 1		
59			W 1		
			W 1		Good Quality SANDSTONE Fresh, very weak to medium strong, light grey, medium grained, bedded. Good to excellent RQD, wide fracture spacing. [SCOLLARD FORMATION]
60					60.0 m - Very weak to extremely weak (R1.5 – R2). Easily peeled with knife but does not crumble when hit with hammer.
61			W 1		
		UCS5			61.3 m - Stiff to very stiff, grey sand bed 35 mm thick. UCS5: 1.5 MPa. MC: 15%.
62					
			W 1		
63					62.9 - 63.0 m - Coal beds <1 mm thick spaced 1-4 mm apart.
64			W		

SPT Blows per 150mm

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
▲ UC/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80
20 40 60 80

(Continued on next page)

Survey Method: Handheld Garmin 62s
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Drill Designation: FRASTE
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Fluid: Water, Polymer
Casing: HWT **Cased To (m)**: 5.68
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Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
64			1		Good Quality SANDSTONE Fresh, very weak to medium strong, light to dark green and grey, medium grained, bedded with irregular bedding. Good to excellent RQD, wide fracture spacing, slightly rough joints with sand infill <1 mm thick. [SCOLLARD FORMATION]	
65			W 1		65.3 - 66.1 m - Brecciated green particles 2-40 mm in diameter.	
			W 1			
66			W 1		Poor to Good Quality Interbedded SILTSTONE and SANDSTONE Fresh and unweathered, weak to medium strong, light green, fine to medium grained, uniform. Fair to excellent RQD, wide to very close fracture spacing, rough joints with fault gouge and crushed rock infill up to 60 mm thick. Joints sets at 70-80°, 80-90° to core axis. [SCOLLARD FORMATION]	
67			W 2		66.8 m - Very weak to weak, black alteration, joints spaced at 100 - 120 mm with 5 – 60 mm of infill oriented at 80-90° to the core axis. 67.3 - 67.5 m - Microfractured, light green.	
68			W 2		Very Poor to Good Quality SILTSTONE Slightly altered, extremely weak to medium strong, dark green, fine grained, bedded. Very poor to excellent RQD, very close to wide fracture spacing, rough joints, two joint sets at 70-80°, 80-90° to core axis. [SCOLLARD FORMATION]	
			W 3		68.0 - 68.8 m - Moderately altered, extremely weak, dark grey, microfractured, fault zone with fault gouge infill up to 6 cm thick in joints. Fault gouge swelled up as soon as drilled.	
69			W 1.5		69.2 - 70.7 m - Weak to medium strong, dark green, uniform with minor bedding, black veins 1-3 mm thick.	
70			W 1		End of hole notes on next page.	
71						
72						

Su - kPa: 40, 80, 120, 160
★ % Fines
RQD
Core Recovery: 20, 40, 60, 80
▲ UC/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%: 20, 40, 60, 80

(Continued on next page)

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Drilling Contractor: Geotech Drilling
Drill Method: Mud Rotary, Coring
Fluid: Water, Polymer
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Start Date: 03 Jun 15
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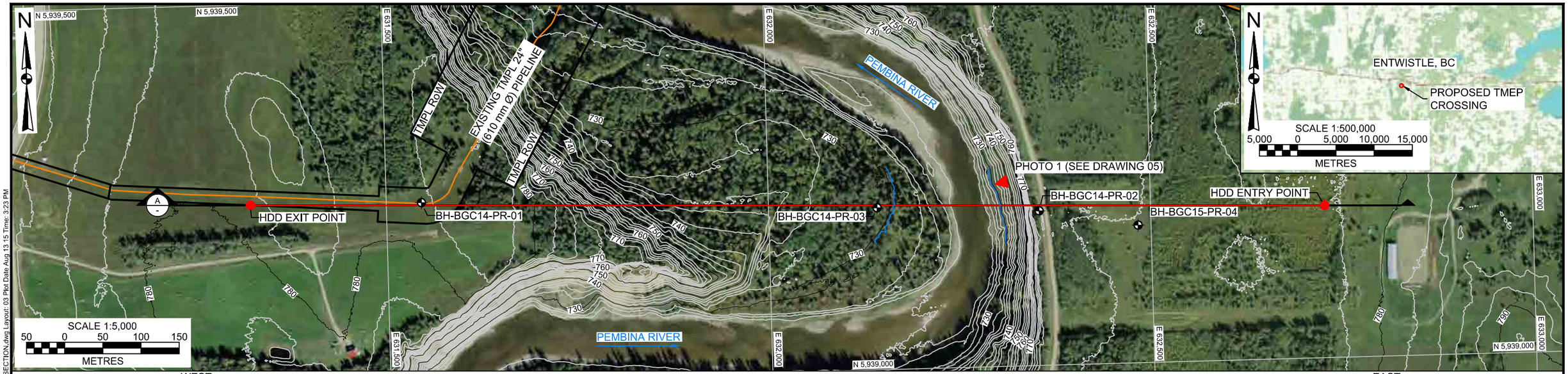
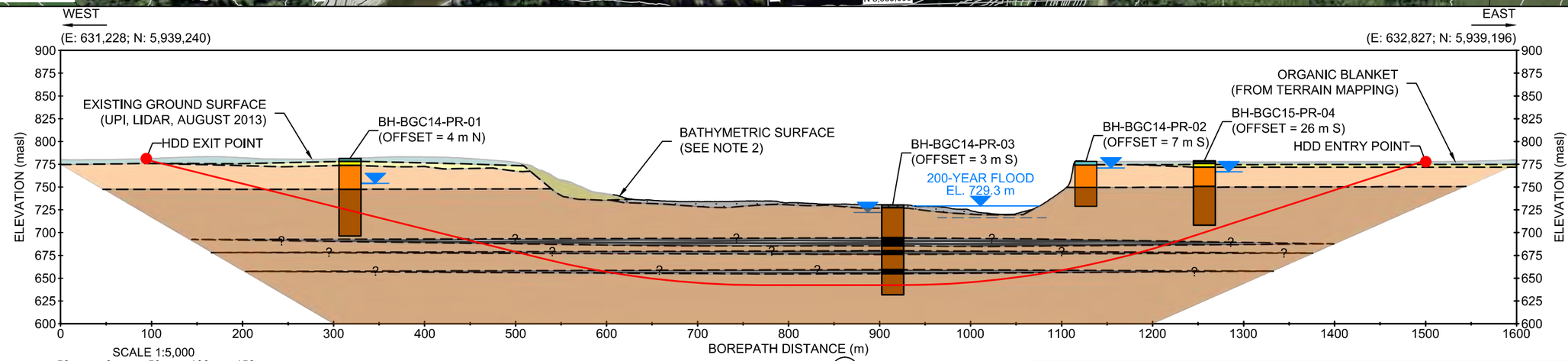
Approved by: KSJ

Depth (m)	Sample Type	Sample No.	Weathering Grade	Symbol	Lithologic Description	SPT Blows per 150mm
72					Borehole completed at target depth of 70.69 m below ground surface. Borehole grouted to surface with bentonite grout. Water table measured at 12.13 m bgs on June 7, 2015 with the drill hole at the final depth of 70.69 m. SPT Sampler Details: 24" length, 2" diameter, driven by automatic trip hammer. All SPT Sampling was carried out in accordance with ASTM D1586. Garmin GPSMAP 62s handheld GPS accuracy +/- 3 m. Ground elevation based on LiDAR survey provided by UPI Inc. and dated April 18, 2014.	
73						
74						
75						
76						
77						
78						
79						
80						

Su - kPa
40 80 120 160
★ % Fines
RQD
Core Recovery
20 40 60 80
▲ UC/2
△ Pocket Pen /2
DCT (blows/300mm)
● SPT (blows/300mm)
Moisture Content & SPT N
W_P% W% W_L%
20 40 60 80





THIS DRAWING MAY HAVE BEEN REDUCED OR ENLARGED. ALL SCALE NOTATIONS INDICATED ARE BASED ON ORIGINAL FORMAT DRAWINGS.

NOT FOR CONSTRUCTION

GROUNDWATER OBSERVATIONS			
BOREHOLE	INFERRED WATER LEVEL (mbgs)	ELEVATION (masl)	COMMENTS
BH-BGC14-PR-01	25.7	751.4	MEASURED JUNE 10, 2014 AND STABILIZED FOLLOWING BH COMPLETION
BH-BGC14-PR-02	15.0	763.6	MEASURED JULY 8, 2014 AND STABILIZED FOLLOWING BH COMPLETION
BH-BGC14-PR-03	8.3	722.2	MEASURED AUGUST 24, 2014 AND STABILIZED FOLLOWING BH COMPLETION
BH-BGC15-PR-04	12.1	765.7	MEASURED JUNE 7, 2015 DURING DRILLING WITH BH AT DEPTH OF 59.1 mbgs

LEGEND

PLAN
- PROPOSED HDD ENTRY / EXIT POINTS
- BGC BOREHOLE
- PHOTO LOCATION
- PROPOSED HDD BOREPATH
- 200-YEAR FLOW EXTENT

SECTION
- PROPOSED HDD BOREPATH
- BATHYMETRIC SURVEY
- INFERRED GEOLOGIC CONTACT
- UNCERTAIN GEOLOGIC CONTACT
- 200-YEAR FLOOD ELEVATION
- ESTIMATED 200-YEAR SCOUR DEPTH

BOREHOLE INTERPRETED GEOLOGY
- COLLUVIUM (FROM GEOPHYSICS AND TERRAIN MAPPING ONLY)
- GLACIOFLUVIAL SAND (SC)
- GLACIOLACUSTRINE CLAY (CL)
- FLUVIAL SILT AND GRAVEL (ML/GW)
- COAL
- PASKAPOO FORMATION - INTERBEDDED SANDSTONE, SILTSTONE, MUDSTONE
- SCOLLARD FORMATION - INTERBEDDED SANDSTONE, SILTSTONE, MUDSTONE WITH COAL

NOTES:
1. BASE TOPOGRAPHIC DATA BASED LIDAR PROVIDED BY UPI LTD., RECEIVED ON AUGUST 20, 2013. CONTOUR INTERVAL IS 2.0 m.
2. BATHYMETRIC PROFILE PROVIDED BY OPUS STEWART WEIR AND DATED JULY 17, 2014.
3. GROUND SURFACE PROFILE BASED ON LIDAR PROVIDED BY UPI LTD., RECEIVED ON AUGUST 20, 2013.
4. PROPOSED HDD ALIGNMENT AND PROFILE PROVIDED BY UPI LTD. DATED JUNE 13, 2014.
5. ORTHOIMAGE PROVIDED BY KINDER MORGAN, FROM ORTHOSHOP GEOMATICS LTD., AND DATED 2005 TO 2006.
6. THE LATERAL EXTENT OF THE OBSERVED COAL SEAMS AND THE POSITIONS OF OTHERS POTENTIALLY ALONG THE HDD BOREPATH IS UNCERTAIN.
7. PROPOSED SSEID 02 PIPELINE ALIGNMENT PROVIDED BY UPI INC., AND DATED MAY 5, 2015.
8. PROJECTION IS UTM NAD83 ZONE 11U.
9. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
10. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - PEMBINA RIVER AT SSEID 02 KP 134 - REVISION 1", AND DATED AUGUST 2015.
11. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING SHALL NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES OR LOSS ARISING IN ANY WAY FROM ANY USE OR MODIFICATION OF THIS DOCUMENT NOT AUTHORIZED BY BGC. ANY USE OF OR RELIANCE UPON THIS DOCUMENT OR ITS CONTENT BY THIRD PARTIES SHALL BE AT SUCH THIRD PARTIES' SOLE RISK.

SCALE:	AS SHOWN
DATE:	AUG 2015
DRAWN:	AH
CHECKED:	SSM/LCH
APPROVED:	KSJ

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: TRANSMOUNTAIN

PROJECT: GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - PEMBINA RIVER AT SSEID 02 KP 134 - REVISION 1

TITLE: INTERPRETED GEOLOGICAL SECTION

PROJECT No.: 0095-150

DWG No.: 03

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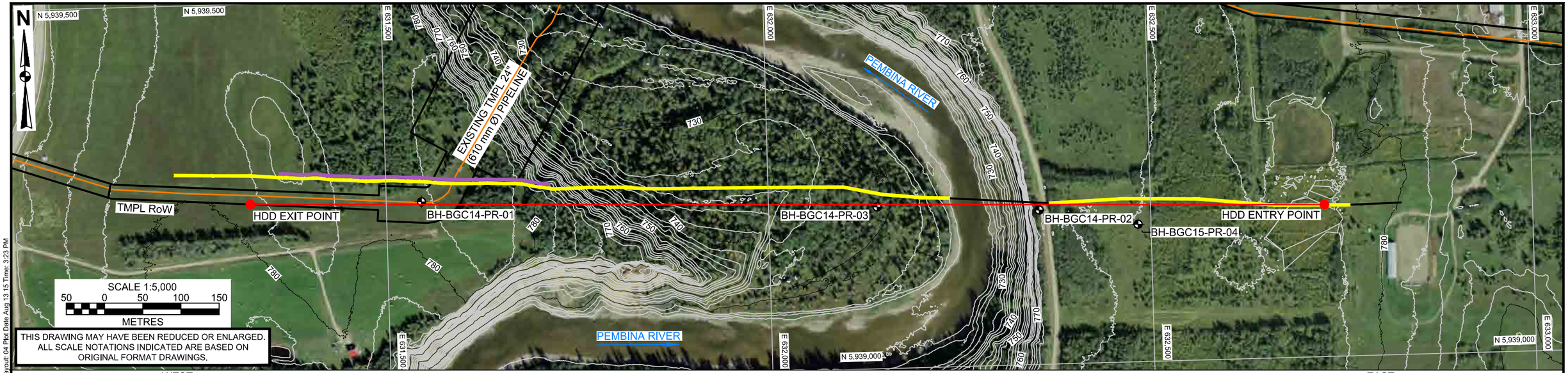
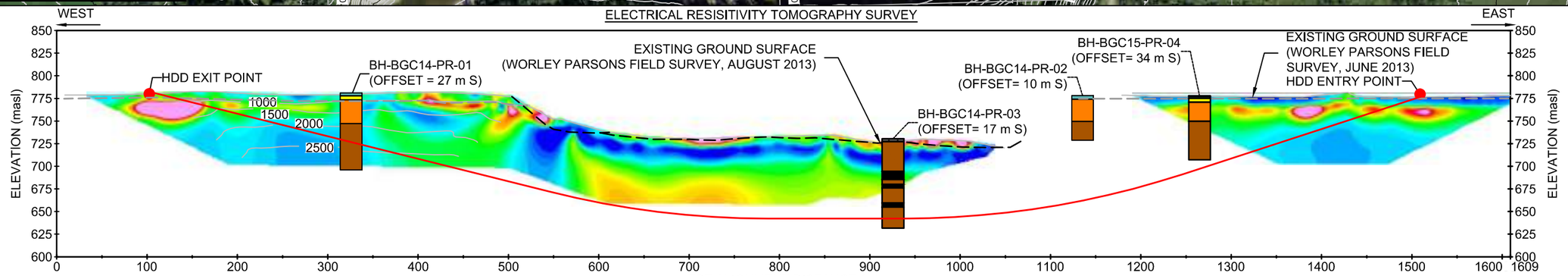
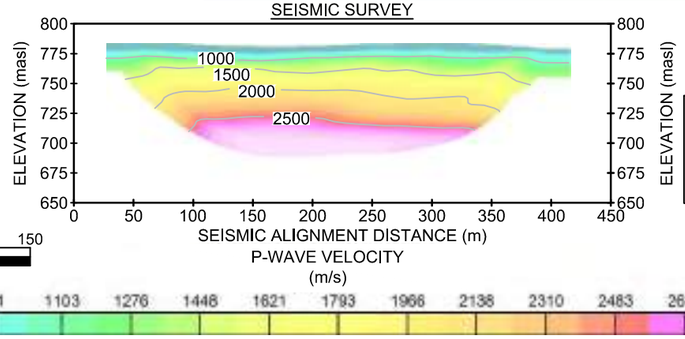




SCALE 1:5,000
50 0 50 100 150
METRES

FIELD PARAMETERS:
DATA COLLECTED:
19-JUNE-2013 AND 30-AUGUST-2013
ELECTRODE CONFIGURATION: GRADIENT PLUS
MINIMUM ELECTRODE SPACING: 5 m



SCALE 1:5,000
50 0 50 100 150
METRES

FIELD PARAMETERS:
DATA COLLECTED: 2-SEPTEMBER-2013
GEOPHONE SPACING: 5 m
SHOT SPACING: 20 m
SOURCE: SLEDGEHAMMER

NOT FOR CONSTRUCTION

LEGEND

PLAN
- PROPOSED HDD ENTRY / EXIT POINTS
- BGC BOREHOLE
- PROPOSED HDD BOREPATH
- SEISMIC SURVEY ALIGNMENT
- ERT SURVEY ALIGNMENT

SECTION
- P-WAVE VELOCITY CONTOURS
- INTERPRETED TOP OF BEDROCK
- INTERPRETED COLLUVIUM AND FLUVIAL CONTACTS

BOREHOLE GEOLOGY
- GLACIOFLUVIAL SAND (SC)
- GLACIOLACUSTRINE CLAY (CI)
- FLUVIAL SILT AND GRAVEL (ML/GW)
- COAL
- PASKAPOO FORMATION - INTERBEDDED SANDSTONE, SILTSTONE, MUDSTONE
- SCOLLARD FORMATION - INTERBEDDED SANDSTONE, SILTSTONE, MUDSTONE WITH COAL

NOTES:
1. GEOPHYSICS SURVEY INTERPRETATION AND GROUND SURFACE PROFILE PROVIDED BY WORLEY PARSONS, DATED FEBRUARY 10, 2014.
2. PROPOSED HDD ALIGNMENT AND PROFILE PROVIDED BY UPI LTD. DATED JUNE 13, 2014 AND PROJECTED ONTO WORLEY PARSONS FIELD SURVEY ALIGNMENT.
3. BASE TOPOGRAPHIC DATA BASED ON LIDAR PROVIDED BY UPI, RECEIVED ON AUGUST 20, 2013. CONTOUR INTERVAL IS 2.0 m.
4. ORTHOIMAGE PROVIDED BY KINDER MORGAN, FROM ORTHOSHOP GEOMATICS LTD., AND DATED 2005 TO 2006.
5. 1000 m/s SEISMIC VELOCITY CONTOUR CORRELATED WITH THE TOP OF BEDROCK AND 2000 m/s VELOCITY CONTOUR CORRELATED WITH THE WEATHERED BEDROCK/COMPETENT BEDROCK INTERFACE ACCORDING TO BOREHOLE DATA ASSOCIATED WITH BH-BGC14-PR-01.
5. PROPOSED SSEID 02 PIPELINE ALIGNMENT PROVIDED BY UPI INC., AND DATED MAY 5, 2015.
6. PROJECTION IS UTM NAD83 ZONE 11U.
7. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
8. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - PEMBINA RIVER AT SSEID 02 KP 134 - REVISION 1", AND DATED AUGUST 2015.
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SCALE:	AS SHOWN
DATE:	AUG 2015
DRAWN:	AH
CHECKED:	SSM/LCH
APPROVED:	KSJ

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: TRANSMOUNTAIN

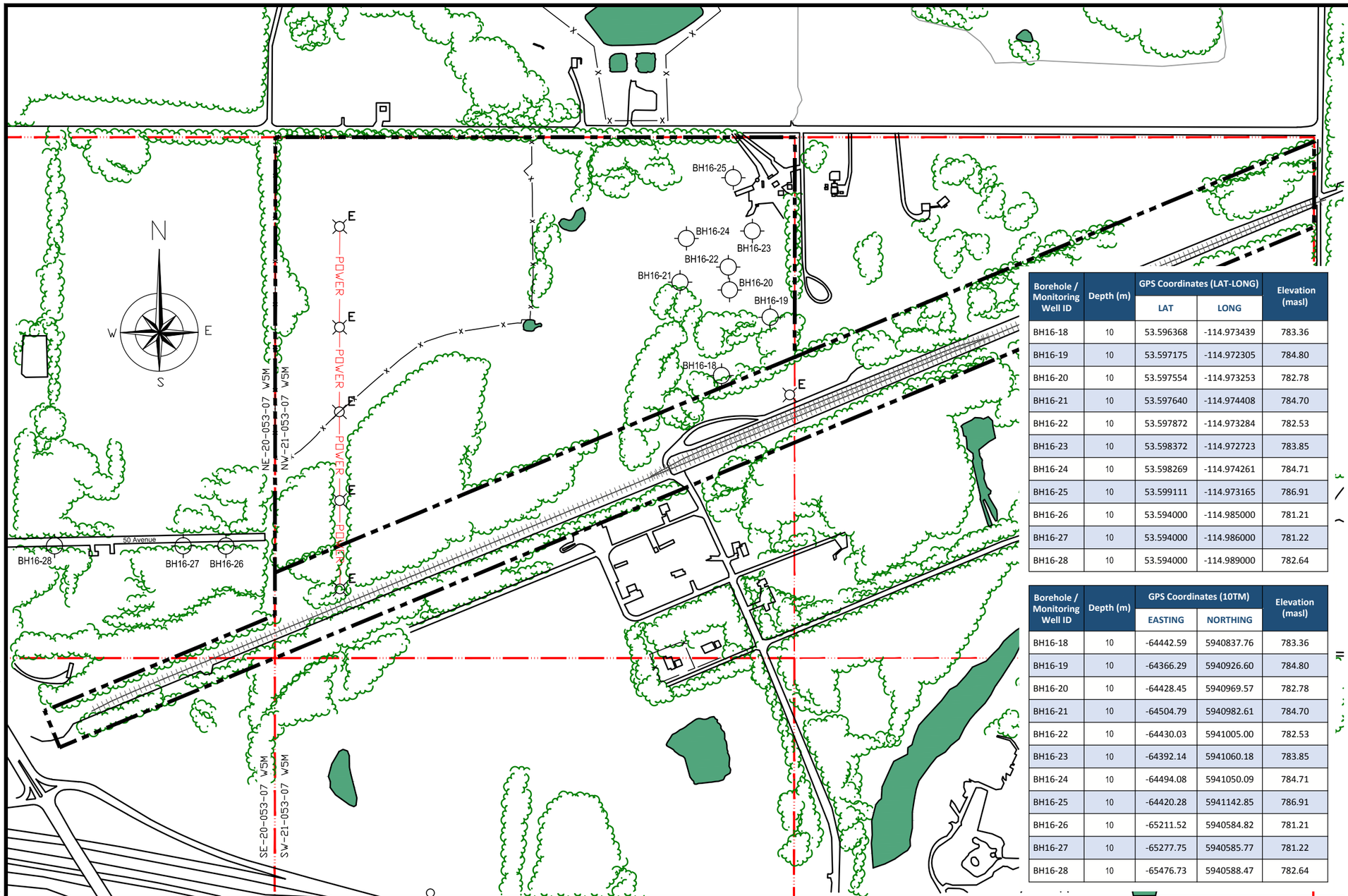
PROJECT: GEOTECHNICAL HDD FEASIBILITY ASSESSMENT - PEMBINA RIVER AT SSEID 02 KP 134 - REVISION 1

TITLE: GEOPHYSICS RESULTS

PROJECT No.: 0095-150

04

X:\Projects\0095150\CAD\2015 HDD CROSSINGS\PRODUCTION\REPORT\20150805_GEOTECHNICAL_HDD_FEASIBILITY_ASSESSMENT_-_PEMBINA_RIVER_REV_1\04_GEOPHYSICS_RESULTS.dwg Layout: 04 Plot Date: Aug 13, 15 Time: 3:23 PM



Borehole / Monitoring Well ID	Depth (m)	GPS Coordinates (LAT-LONG)		Elevation (masl)
		LAT	LONG	
BH16-18	10	53.596368	-114.973439	783.36
BH16-19	10	53.597175	-114.972305	784.80
BH16-20	10	53.597554	-114.973253	782.78
BH16-21	10	53.597640	-114.974408	784.70
BH16-22	10	53.597872	-114.973284	782.53
BH16-23	10	53.598372	-114.972723	783.85
BH16-24	10	53.598269	-114.974261	784.71
BH16-25	10	53.599111	-114.973165	786.91
BH16-26	10	53.594000	-114.985000	781.21
BH16-27	10	53.594000	-114.986000	781.22
BH16-28	10	53.594000	-114.989000	782.64

Borehole / Monitoring Well ID	Depth (m)	GPS Coordinates (10TM)		Elevation (masl)
		EASTING	NORTHING	
BH16-18	10	-64442.59	5940837.76	783.36
BH16-19	10	-64366.29	5940926.60	784.80
BH16-20	10	-64428.45	5940969.57	782.78
BH16-21	10	-64504.79	5940982.61	784.70
BH16-22	10	-64430.03	5941005.00	782.53
BH16-23	10	-64392.14	5941060.18	783.85
BH16-24	10	-64494.08	5941050.09	784.71
BH16-25	10	-64420.28	5941142.85	786.91
BH16-26	10	-65211.52	5940584.82	781.21
BH16-27	10	-65277.75	5940585.77	781.22
BH16-28	10	-65476.73	5940588.47	782.64

LEGEND

- LSD Boundary
- Proposed Development Area
- Treeline
- Extents of Partially Intact Existing Fence
- Water
- Borehole

G:\1141_OldServer_edm1-srv-0001\CADProjects\P-0012176-0-00\P-0012176-0-00-PL.dwg

Pinnacle. Renewable Energy Inc.

Englobe

Englobe Corp.
16114, 114 Avenue NW
Edmonton, Alberta
T5M 2Z5
780-481-1416

0 130 260m
65 195

1:6,500

Stamp

SITE DEVELOPMENT

NW1/4-21-053-07 W5M NEAR ENTWISTLE, ALBERTA

Site Plan Showing Borehole Locations

No.	Version	Date	By	Check	Appr.
A	PRELIMINARY	2017-01-17	D.W.	B.M.	P.G.

Discipline :	Geo-environment	Prepared by : D. WILSON	Checked by : B. MAZUR
Scale :	1:6,500	Drawn by : D. WILSON	Approved by : P. GINGRAS
Date :	2017-01-04	Figure no. :	FIGURE 1
Layout : BH	Paper size : ANSI full bleed B (11.00 x 17.00 Inches)	Registration no. :	—

Resp.	Project	Otp	Project/ Disc	Phase/ Type	Electronic ref./ Drawing no.	Rev.
---	P-0012176-0-00		---	---	P-0012176-0-00-PL	--

LOG OF BOREHOLE No. 18

Englobe

Project No. P-0003358-0-127 DRAWING No. 1

Project: Pinnacle Pellet Plant Sheet No. 1 of 1

Location: Entwistle, Alberta

N 5,940,837.76 W 64,442.59

Date Drilled: 19/12/2016

Drill Type: Solid Stem Augers

Datum: Geodetic

Split Spoon Sample
Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Shear Strength by Vane Test
Natural Moisture Content
Atterberg Limits
Undrained Triaxial at % Strain at Failure
Shear Strength by Penetrometer Test

GWL	SYMBOL	SOIL DESCRIPTION	ELEV. m	DEPTH
		TOPSOIL: (250 mm)	783.4	0
		CLAYEY SILT: trace organics, stiff, brown, very moist	783.1	
		SANDY SILTY CLAY: trace gravel, stiff to very stiff, brown, moist SS3: Gr: 1%, Sa: 32%, Si: 30%, Cl: 37%	781.3	2
		SAND: fine, some silt, trace gravel, compact to dense, brown, moist	777.9	6
		Terminated at 9.5 m Borehole advanced using continuous flight solid stem augering equipment on December 19, 2016 by Landmark Drilling Services Limited.	773.9	9

Standard Penetration Test N Value: 20, 40, 60, 80
Shear Strength kPa: 50, 100, 150, 200
Natural Moisture Content % Atterberg Limits (% Dry Weight): 20, 40, 60

SAMPLES	Natural Unit Weight, kN/m³	Percent of Fines, %
	20.4	
	21.5	

Time	Water Level (m)	Depth to Cave (m)

Approved By: H.Akbari
Checked By: M.Mohsen
Logged By: M. Kamala

LOG A GWWL02_ENGLOBE_AB P-0003358-0-127.GPJ LOG A GWGL02.GDT 25/1/17

LOG OF BOREHOLE No. 19

Englobe

Project No. P-0003358-0-127 DRAWING No. 1

Project: Pinnacle Pellet Plant Sheet No. 1 of 1

Location: Entwistle, Alberta

N 5,940,926.60 W 64,366.29

Date Drilled: 19/12/2016

Drill Type: Solid Stem Augers

Datum: Geodetic

Split Spoon Sample
Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Shear Strength by Vane Test
Natural Moisture Content
Atterberg Limits
Undrained Triaxial at % Strain at Failure
Shear Strength by Penetrometer Test

GWL	SYMBOL	SOIL DESCRIPTION	ELEV. m	DEPTH
		TOPSOIL: (250 mm)	784.8 784.6	0
		CLAYEY SILT: trace organics, stiff, brown, very moist	783.5	1
		SANDY SILTY CLAY: trace gravel, stiff to very stiff, brown, moist		2
		SS3: Gr: 1%, Sa: 37%, Si: 38%, Cl: 24%		3
				4
				5
				6
			777.8	7
		SAND: fine, some silt, trace gravel, dense to very dense, brown, moist		8
			775.4	9
		Terminated at 9.5 m Borehole advanced using continuous flight solid stem augering equipment on December 19, 2016 by Landmark Drilling Services Limited.		

Standard Penetration Test N Value: 20 40 60 80
Shear Strength: 50 100 150 200 kPa
Natural Moisture Content % Atterberg Limits (% Dry Weight): 20 40 60

SAMPLES | Natural Unit Weight, kN/m³ | Percent of Fines, %

19.3

Time	Water Level (m)	Depth to Cave (m)

Approved By: H.Akbari
Checked By: M.Mohsen
Logged By: M. Kamala

LOG A GWWL02_ENGLOBE_AB P-0003358-0-127.GPJ LOG A GWGL02.GDT 25/1/17

LOG OF BOREHOLE No. 20

Englobe

Project No. P-0003358-0-127 DRAWING No. 1

Project: Pinnacle Pellet Plant Sheet No. 1 of 1

Location: Entwistle, Alberta

N 5,940,969.57 W 64,428.45

Date Drilled: 20/12/2016

Drill Type: Solid Stem Augers

Datum: Geodetic

Split Spoon Sample
Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Shear Strength by Vane Test
Natural Moisture Content
Atterberg Limits
Undrained Triaxial at % Strain at Failure
Shear Strength by Penetrometer Test

GWL	SYMBOL	SOIL DESCRIPTION	ELEV. m	DEPTH
		TOPSOIL: (250 mm)	782.8 782.5	0
		CLAYEY SILT: trace organics, brown, very moist	781.3	1
		SILTY CLAY: some sand, trace gravel, stiff, brown, very moist	778.8	2
		SANDY SILTY CLAY: trace gravel, very stiff, brown, moist SS4: Gr: 1%, Sa: 34%, Si: 11%, Cl: 54%	777.3	3
		SAND: fine, some silt, trace gravel, compact to dense, brown, moist	773.3	4
		Terminated at 9.5 m Borehole advanced using continuous flight solid stem augering equipment on December 20, 2016 by Landmark Drilling Services Limited.		5

Standard Penetration Test N Value: 20 40 60 80
Shear Strength: 50 100 150 200 kPa
Natural Moisture Content % Atterberg Limits (% Dry Weight): 20 40 60

SAMPLES

Natural Unit Weight, kN/m³: 20.8

Percent of Fines, %

Approved By: H.Akbari
Checked By: M.Mohsen
Logged By: M. Kamala

Time	Water Level (m)	Depth to Cave (m)

LOG A GWWL02_ENGLOBE_AB P-0003358-0-127.GPJ LOG A GWGL02.GDT 25/1/17

LOG OF BOREHOLE No. 21

Englobe

Project No. P-0003358-0-127 DRAWING No. 1

Project: Pinnacle Pellet Plant Sheet No. 1 of 1

Location: Entwistle, Alberta

N 5,940,982.61 W 64,504.79

Date Drilled: 20/12/2016

Drill Type: Solid Stem Augers

Datum: Geodetic

Split Spoon Sample
Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Shear Strength by Vane Test
Natural Moisture Content
Atterberg Limits
Undrained Triaxial at % Strain at Failure
Shear Strength by Penetrometer Test

GWL	SYMBOL	SOIL DESCRIPTION	ELEV. m	DEPTH
			784.7	0
		TOPSOIL: (200 mm)	784.5	
		CLAYEY SILT: trace organics, brown, very moist	783.7	1
		SANDY SILTY CLAY: trace gravel, stiff to very stiff, brown, moist		2
				3
				4
				5
			778.7	6
		SAND: fine, some silt, trace gravel, compact, brown, moist		7
				8
			775.3	9
		Terminated at 9.5 m		
		Borehole advanced using continuous flight solid stem augering equipment on December 20, 2016 by Landmark Drilling Services Limited.		

Standard Penetration Test N Value: 20 40 60 80
Shear Strength: 50 100 150 200 kPa
Natural Moisture Content % Atterberg Limits (% Dry Weight): 20 40 60

SAMPLES

Natural Unit Weight, kN/m³: 19.9

Percent of Fines, %

Approved By: H.Akbari
Checked By: M.Mohsen
Logged By: M. Kamala

LOG A GWWL02_ENGLOBE_AB P-0003358-0-127.GPJ LOG A GWGL02.GDT 25/1/17

Time	Water Level (m)	Depth to Cave (m)

LOG OF BOREHOLE No. 22

Englobe

Project No. P-0003358-0-127 DRAWING No. 1

Project: Pinnacle Pellet Plant Sheet No. 1 of 1

Location: Entwistle, Alberta

N 5,941,005.00 W 64,430.03

Date Drilled: 19/12/2016

Drill Type: Solid Stem Augers

Datum: Geodetic

Split Spoon Sample
Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Shear Strength by Vane Test
Natural Moisture Content
Atterberg Limits
Undrained Triaxial at % Strain at Failure
Shear Strength by Penetrometer Test

GWL	SYMBOL	SOIL DESCRIPTION	ELEV. m
			782.5
		TOPSOIL: (200 mm)	782.3
		CLAYEY SILT: trace organics, brown, very moist	781.8
		SILTY CLAY: trace sand, trace gravel, stiff, brown, very moist	
		SS4: Gr: 0%, Sa: 1%, Si: 32%, Cl: 67%	779.7
		SANDY SILTY CLAY: trace gravel, very stiff, brown, moist	778.5
		SAND: fine, some silt, trace gravel, compact to very dense, brown, moist	773.1
		Terminated at 9.5 m	

Borehole advanced using continuous flight solid stem augering equipment on December 19, 2016 by Landmark Drilling Services Limited.

DEPTH 0 1 2 3 4 5 6 7 8 9

Standard Penetration Test N Value: 20 40 60 80

Shear Strength kPa: 50 100 150 200

Natural Moisture Content % Atterberg Limits (% Dry Weight): 20 40 60

SAMPLES

Natural Unit Weight, kN/m³

Percent of Fines, %

Time	Water Level (m)	Depth to Cave (m)

Approved By: H.Akbari

Checked By: M.Mohsen

Logged By: M. Kamala

LOG A GWWL02_ENGLOBE_AB P-0003358-0-127.GPJ LOG A GWGL02.GDT 25/1/17

LOG OF BOREHOLE No. 23

Englobe

Project No. P-0003358-0-127 DRAWING No. 1

Project: Pinnacle Pellet Plant Sheet No. 1 of 1

Location: Entwistle, Alberta

N 5,941,060.18 W 64,392.14

Date Drilled: 19/12/2016

Drill Type: Solid Stem Augers

Datum: Geodetic

Split Spoon Sample
Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Shear Strength by Vane Test
Natural Moisture Content
Atterberg Limits
Undrained Triaxial at % Strain at Failure
Shear Strength by Penetrometer Test

GWL	SYMBOL	SOIL DESCRIPTION	ELEV. m	DEPTH
			783.9	0
		TOPSOIL: (200 mm)	783.7	
		CLAYEY SILT: trace organics, brown, very moist		
			782.5	1
		SANDY SILTY CLAY: trace gravel, very stiff, brown, moist		
		SS3: Gr: 2%, Sa: 33%, Si: 40%, Cl:25%		2
				3
				4
				5
			778.4	
		SAND: trace silt, medium course, compacted, moist		6
				7
		becomes dense		8
				9
			774.4	
		Terminated at 9.5 m		
		Borehole advanced using continuous flight solid stem augering equipment on December 19, 2016 by Landmark Drilling Services Limited.		

Standard Penetration Test N Value: 20, 40, 60, 80
Shear Strength: 50, 100, 150, 200 kPa
Natural Moisture Content % Atterberg Limits (% Dry Weight): 20, 40, 60

SAMPLES | Natural Unit Weight, kN/m³ | Percent of Fines, %

20.9

Time	Water Level (m)	Depth to Cave (m)

Approved By: H.Akbari
Checked By: M.Mohsen
Logged By: M. Kamala

LOG A GWWL02_ENGLOBE_AB P-0003358-0-127.GPJ LOG A GWGL02.GDT 25/1/17

LOG OF BOREHOLE No. 24

Englobe

Project No. P-0003358-0-127 DRAWING No. 1

Project: Pinnacle Pellet Plant Sheet No. 1 of 1

Location: Entwistle, Alberta

N 5,941,050.09 W 64,494.08

Date Drilled: 20/12/2016

Drill Type: Solid Stem Augers

Datum: Geodetic

Split Spoon Sample
Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Shear Strength by Vane Test
Natural Moisture Content
Atterberg Limits
Undrained Triaxial at % Strain at Failure
Shear Strength by Penetrometer Test

GWL	SYMBOL	SOIL DESCRIPTION	ELEV. m	DEPTH
		TOPSOIL: (250 mm)	784.7 784.5	0
		CLAYEY SILT: trace organics, brown, very moist	784.0	
		SANDY SILTY CLAY: trace gravel, stiff to very stiff, brown, moist		1
				2
				3
				4
				5
		SS7: Gr: 1%, Sa: 33%, Si: 13%, Cl:53%		6
			777.7	7
		SAND: trace silt, trace gravel, compact to dense, moist		8
				9
			775.3	
		Terminated at 9.5 m Borehole advanced using continuous flight solid stem augering equipment on December 20, 2016 by Landmark Drilling Services Limited.		

Standard Penetration Test N Value: 20 40 60 80
Shear Strength: 50 100 150 200 kPa
Natural Moisture Content % Atterberg Limits (% Dry Weight): 20 40 60

SAMPLES	Natural Unit Weight, kN/m³	Percent of Fines, %
	18.7	
	20.6	

Approved By: H.Akbari
Checked By: M.Mohsen
Logged By: M. Kamala

Time	Water Level (m)	Depth to Cave (m)

LOG A GWWL02_ENGLOBE_AB P-0003358-0-127.GPJ LOG A GWGL02.GDT 25/1/17

LOG OF BOREHOLE No. 25

Englobe

Project No. P-0003358-0-127 DRAWING No. 1

Project: Pinnacle Pellet Plant Sheet No. 1 of 1

Location: Entwistle, Alberta

N 5,941,142.85 W 64,420.28

Date Drilled: 20/12/2016

Drill Type: Solid Stem Augers

Datum: Geodetic

Split Spoon Sample
Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Shear Strength by Vane Test
Natural Moisture Content
Atterberg Limits
Undrained Triaxial at % Strain at Failure
Shear Strength by Penetrometer Test

GWL	SYMBOL	SOIL DESCRIPTION	ELEV. m	DEPTH
			786.9	0
		TOPSOIL: (200 mm)	786.7	
		CLAYEY SILT: trace organic, light brown, very moist to moist	786.2	
		SANDY SILTY CLAY: trace gravel, stiff to very stiff, brown, moist		1
				2
		SS4: Gr: 4%, Sa: 32%, Si: 37%, Cl:27%		3
				4
				5
			781.4	
		SAND: trace of silt and clay, fine course, dense, dark brown		6
				7
				8
			777.5	9
		Terminated at 9.5 m		
		Borehole advanced using continuous flight solid stem augering equipment on December 19, 2016 by Landmark Drilling Services Limited.		

Standard Penetration Test N Value: 20 40 60 80
Shear Strength kPa: 50 100 150 200
Natural Moisture Content % Atterberg Limits (% Dry Weight): 20 40 60

SAMPLES	Natural Unit Weight, kN/m³	Percent of Fines, %
	19.8	

Approved By: H.Akbari
Checked By: M.Mohsen
Logged By: M. Kamala

Time	Water Level (m)	Depth to Cave (m)

LOG A GWWL02_ENGLOBE_AB P-0003358-0-127.GPJ LOG A GWGL02.GDT 25/1/17

LOG OF BOREHOLE No. 26

Englobe

Project No. P-0003358-0-127 DRAWING No. 1

Project: Pinnacle Pellet Plant Sheet No. 1 of 1

Location: Entwistle, Alberta

N 5,940,584.82 W 65,211.52

Date Drilled: 20/12/2016

Drill Type: Solid Stem Augers

Datum: Geodetic

Split Spoon Sample
Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Shear Strength by Vane Test

Natural Moisture Content
Atterberg Limits
Undrained Triaxial at % Strain at Failure
Shear Strength by Penetrometer Test

GWL	SYMBOL	SOIL DESCRIPTION	ELEV. m	DEPTH
		TOPSOIL: (500 mm)	781.2	0
		CLAYEY SILT: some organic, light brown, very moist to moist	780.7	
				1
				2
				3
		Terminated at 3.5 m	777.8	
		Borehole advanced using continuous flight solid stem augering equipment on December 20, 2016 by Landmark Drilling Services Limited.		

Standard Penetration Test N Value: 20 40 60 80

Shear Strength kPa: 50 100 150 200

Natural Moisture Content % Atterberg Limits (% Dry Weight): 20 40 60

SAMPLES: 122.7 98.3 91.5

Natural Unit Weight, kN/m³

Percent of Fines, %

Approved By: H.Akbari

Checked By: M.Mohsen

Logged By: M. Kamala

Time	Water Level (m)	Depth to Cave (m)

LOG OF BOREHOLE No. 27

Englobe

Project No. P-0003358-0-127 DRAWING No. 1

Project: Pinnacle Pellet Plant Sheet No. 1 of 1

Location: Entwistle, Alberta

N 5,940,585.77 W 65,277.75

Date Drilled: 20/12/2016

Drill Type: Solid Stem Augers

Datum: Geodetic

Split Spoon Sample
Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Shear Strength by Vane Test
Natural Moisture Content
Atterberg Limits
Undrained Triaxial at % Strain at Failure
Shear Strength by Penetrometer Test

GWL	SYMBOL	SOIL DESCRIPTION	ELEV. m	DEPTH
		TOPSOIL: (900 mm)	781.2	0
		CLAYEY SILT AND PEAT: some organics, soft, very moist	780.3	1
		CLAYEY SILT AND PEAT: compacted, very moist	779.0	2
		SILT CLAY: some organic, light brown, very moist to moist	778.4	3
		Terminated at 3.5 m	777.8	

Borehole advanced using continuous flight solid stem augering equipment on December 20, 2016 by Landmark Drilling Services Limited.

Standard Penetration Test N Value: 20 40 60 80
Shear Strength kPa: 50 100 150 200
Natural Moisture Content % Atterberg Limits (% Dry Weight): 20 40 60

SAMPLES: 151

Natural Unit Weight, kN/m³

Percent of Fines, %

Time	Water Level (m)	Depth to Cave (m)

Approved By: H.Akbari

Checked By: M.Mohsen

Logged By: M. Kamala

LOG A GWWL02_ENGLOBE_AB P-0003358-0-127.GPJ LOG A GWGL02.GDT 25/1/17

LOG OF BOREHOLE No. 28

Englobe

Project No. P-0003358-0-127 DRAWING No. 1

Project: Pinnacle Pellet Plant Sheet No. 1 of 1

Location: Entwistle, Alberta

N 5,940,588.47 W 65,476.73

Date Drilled: 20/12/2016

Drill Type: Solid Stem Augers

Datum: Geodetic

Split Spoon Sample
Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Shear Strength by Vane Test
Natural Moisture Content
Atterberg Limits
Undrained Triaxial at % Strain at Failure
Shear Strength by Penetrometer Test

GWL	SYMBOL	SOIL DESCRIPTION	ELEV. m	DEPTH
		TOPSOIL: (500 mm)	782.6	0
		CLAYEY SILT AND PEAT: some organics, soft, very moist	782.1	
		SILT CLAY: some organic, brown, very moist to moist SS4: Gr: 0%, Sa: 2%, Si: 11%, Cl:87%	780.6	1 2
		Terminated at 3.5 m Borehole advanced using continuous flight solid stem augering equipment on December 20, 2016 by Landmark Drilling Services Limited.	779.2	3

Standard Penetration Test N Value
20 40 60 80
Shear Strength kPa
50 100 150 200

Natural Moisture Content % Atterberg Limits (% Dry Weight)
20 40 60

SAMPLES

Natural Unit Weight, kN/m³

Percent of Fines, %

102.7

Time	Water Level (m)	Depth to Cave (m)

Approved By: H.Akbari

Checked By: M.Mohsen

Logged By: M. Kamala

LOG A GWWL02_ENGLOBE_AB P-0003358-0-127.GPJ LOG A GWGL02.GDT 25/1/17

APPENDIX C

Selected Photographs from Site Reconnaissance

H:\18000\18683 Entwistle High Level Bank Stability Review\Drafting\18683-PHOTOPLATE C.dwg - 1 - Nov. 24, 2017

PHOTO 1 SITE 1 - RIVER ACCESS PATH WITH CURVED TREES

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C1

parkland county

DRAWN BY	ML
DESIGNED BY	SEC
APPROVED BY	RVC
SCALE	N.T.S.
DATE	NOVEMBER 2017
FILE No.	18683

THURBER ENGINEERING LTD.

PHOTO 2 SITE 1 - RIVER ACCESS PATH WITH CURVED TREES

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C2

parkland county

DRAWN BY	ML
DESIGNED BY	SEC
APPROVED BY	RVC
SCALE	N.T.S.
DATE	NOVEMBER 2017
FILE No.	18683

THURBER ENGINEERING LTD.

H:\18000\18683 Entwistle High Level Bank Stability Review\Drafting\18683-PHOTOPLATE C.dwg - 3 - Nov. 24, 2017

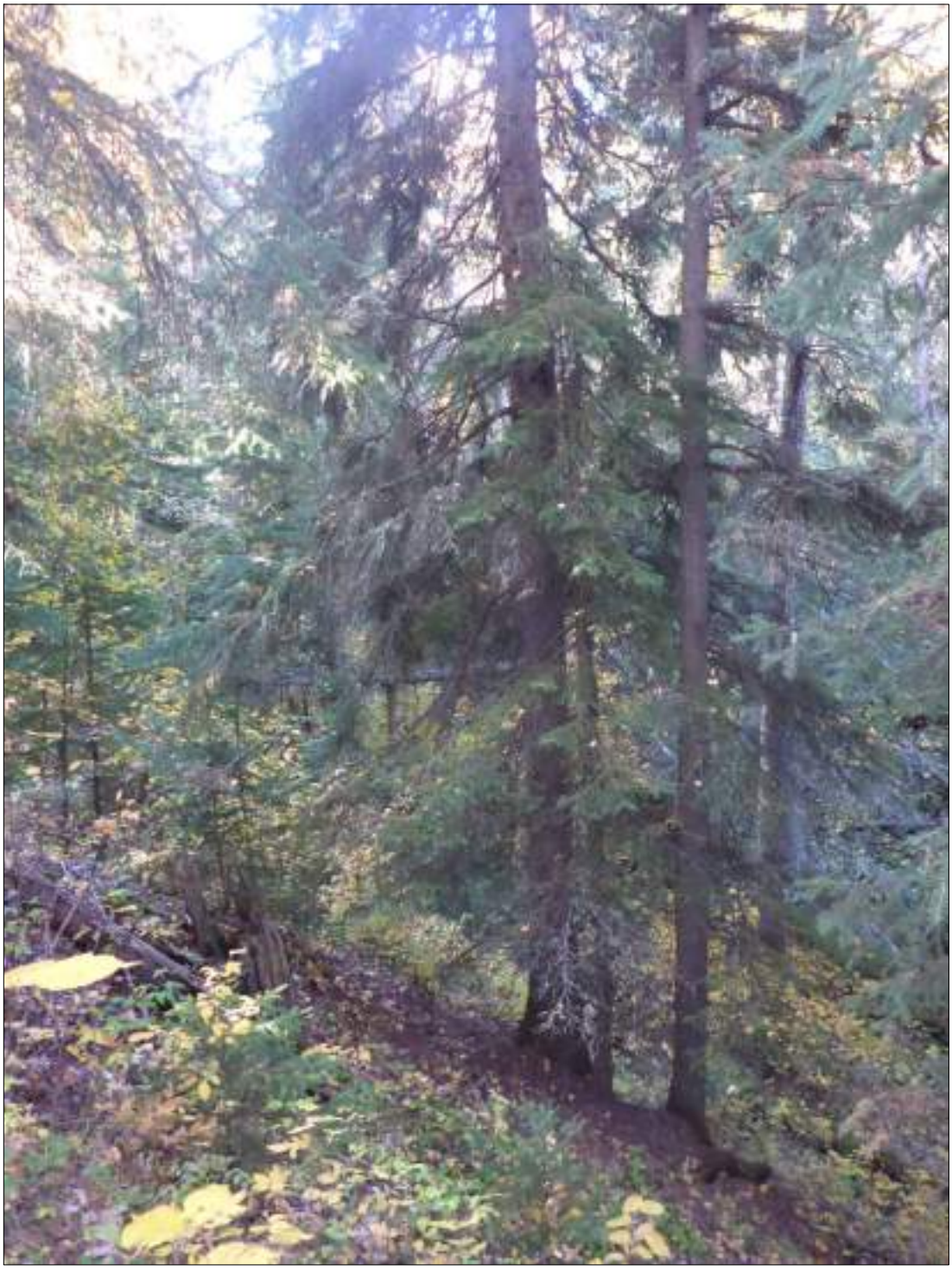


PHOTO 3 SITE 1 - TYPICAL SLOPE VEGETATION CONDITIONS

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C3

parkland county

DRAWN BY	ML
DESIGNED BY	SEC
APPROVED BY	RVC
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PHOTO 4 SITE 1 - TYPICAL SLOPE VEGETATION CONDITIONS

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C4

parkland county

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PHOTO 5 SITE 1 - TYPICAL SLOPE VEGETATION CONDITIONS

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C5

parkland county

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PHOTO 6 SITE 1 - EXPOSED SANDSTONE OUTCROP

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C6

parkland county

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PHOTO 7 SITE 2 - OVERALL VALLEY SLOPE - SOUTH

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C7

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PHOTO 8 SITE 2 - OVERALL VALLEY SLOPE - SOUTH

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C8

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PHOTO 9 SITE 2 - EXPOSED SANDSTONE VERTICAL SLOPE

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C9

parkland county

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PHOTO 10 SITE 2 - MIDSLOPE SEEPAGE AND COLLUVIUM SLOPE

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C10

parkland county

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PHOTO 11 SITE 2 - OVERALL VALLEY SLOPE - NORTH

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C11

parkland county

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PHOTO 12 SITE 2 - OVERALL VALLEY SLOPE - NORTH

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C12

parkland county

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PHOTO 13 SITE 2 - OVERALL VALLEY SLOPE - NORTH

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C13

parkland county

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PHOTO 14 SITE 3 - OVERALL VALLEY SLOPE - SOUTH

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C14

parkland county

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PHOTO 15 SITE 3 - OVERALL VALLEY SLOPE - MIDDLE

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C15

parkland county

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PHOTO 16 SITE 3 - OVERALL VALLEY SLOPE - NORTH

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C16

parkland county

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PHOTO 17 SITE 3 - TOE OF POSSIBLE LANDSLIDE ZONE

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C17

parkland county

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PHOTO 18 SITE 3 - COLLUVIUM SLOPES

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C18

parkland county

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PHOTO 19 SITE 3 - COLLUVIUM SLOPES

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C19

parkland county

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PHOTO 20 SITE 4 - TYPICAL SLOPE VEGETATION CONDITIONS

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C20

parkland county

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PHOTO 21 SITE 4 - TYPICAL SLOPE VEGETATION CONDITIONS

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C21

parkland county

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PHOTO 22 SITE 4 - OVERALL VALLEY SLOPE - SOUTH

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C22

parkland county

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PHOTO 23 SITE 4 - OVERALL VALLEY SLOPE - MIDDLE

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C23

parkland county

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PHOTO 24 SITE 4 - OVERALL VALLEY SLOPE - MIDDLE

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C24

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PHOTO 25 SITE 4 - OVERALL VALLEY SLOPE - NORTH

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C25

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PHOTO 26 SITE 4 - OVERALL VALLEY SLOPE - NORTH

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C26

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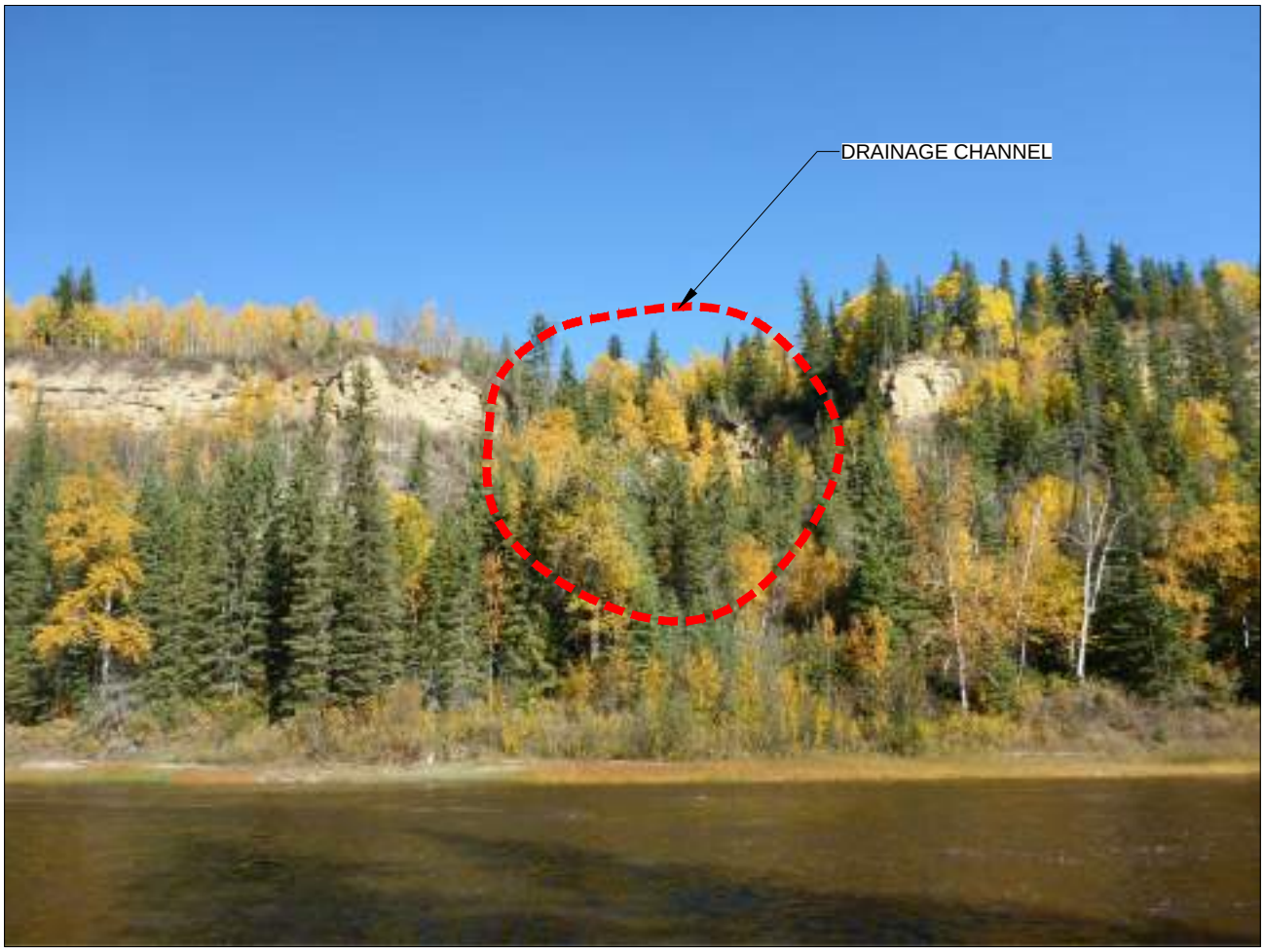

PHOTO 27 SITE 4 - DRAINAGE CHANNEL

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHS

PLATE C27

parkland county

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60 YEARS

APPENDIX D

Panoramic Photographic Mosaics from Drone Flights

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PHOTO D1 SITE 2 NORTH

parkland county

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPH

PLATE D1

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PHOTO D2 SITE 2 SOUTH

parkland county

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPHY

PLATE D2

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PHOTO D3 SITE 3

parkland county

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPH

PLATE D3

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PHOTO D4 SITE 4

parkland county

HIGH LEVEL BANK STABILITY REVIEW
ENTWISTLE, ALBERTA

SELECTED SITE PHOTOGRAPH

PLATE D4

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60 YEARS

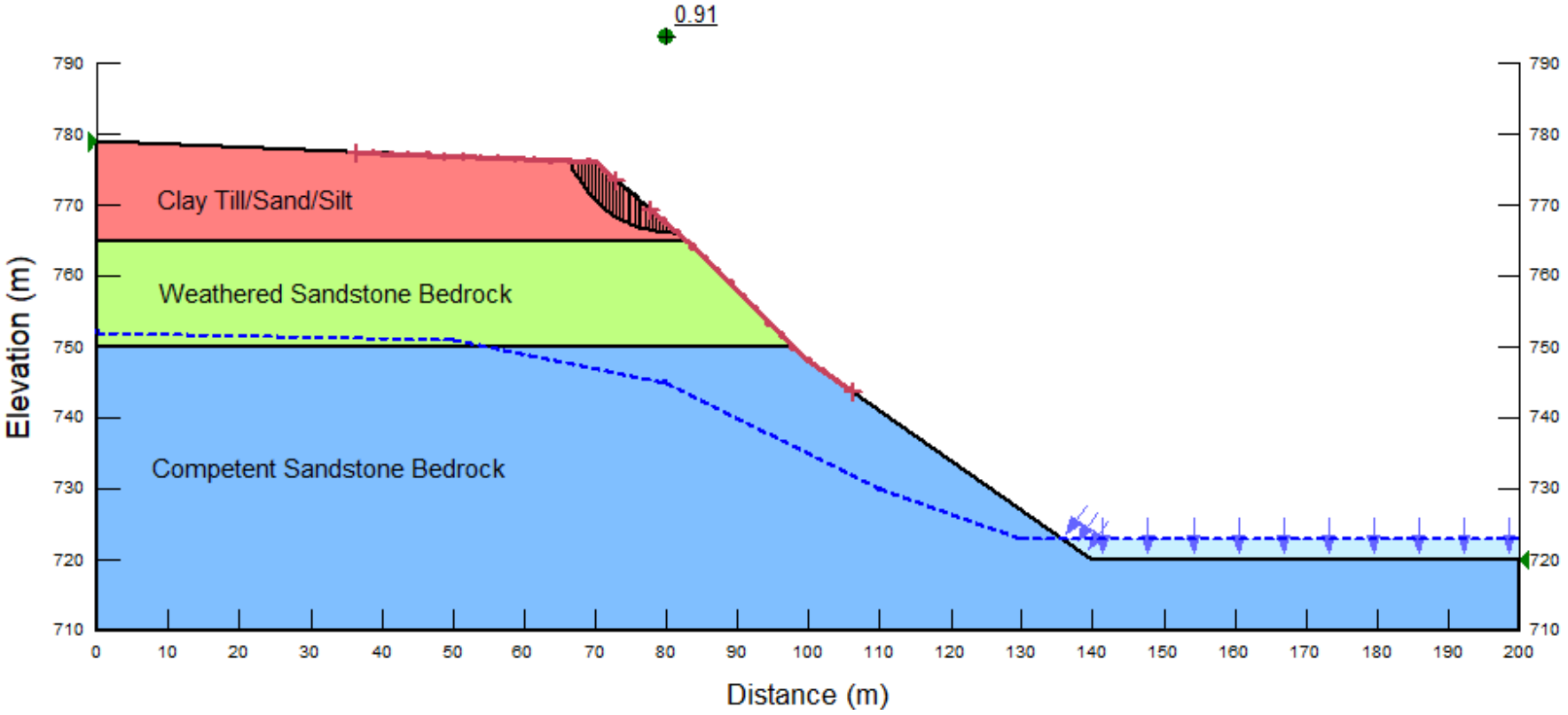
APPENDIX E

Slope Stability Analysis Figures

Entwistle High Level Bank Stability Assessment
Figure E1 - Site 3 (B-B') - Backanalysis

Date: 2017-11-13
Time: 8:12:55 PM
File Name: 16983_Site 3_Backanalysis.gsz

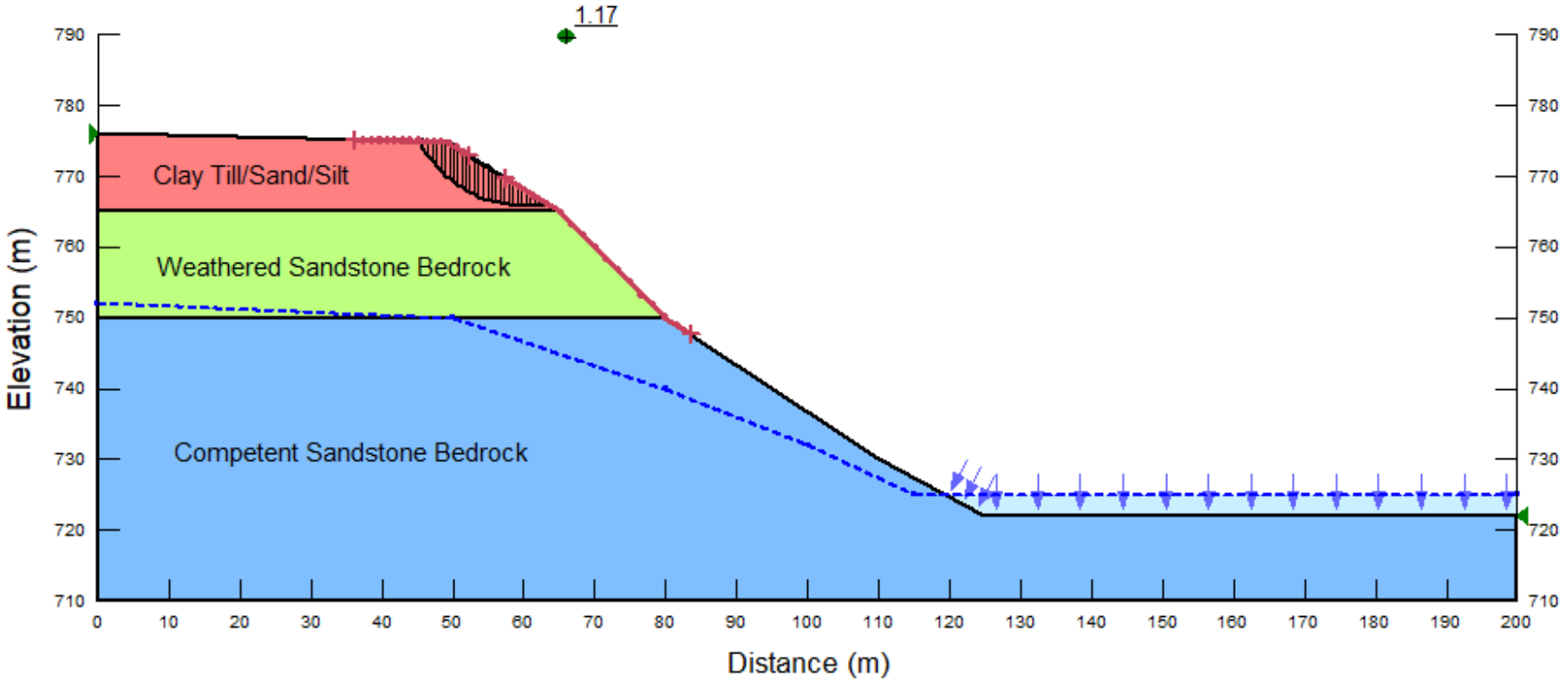
Name: Competent Sandstone Bedrock Model: Bedrock (Impenetrable) Piezometric Line: 1
Name: Clay Till/Sand/Silt Model: Mohr-Coulomb Piezometric Line: 1 Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 25 °
Name: Weathered Sandstone Bedrock Model: Mohr-Coulomb Piezometric Line: 1 Unit Weight: 24 kN/m³ Cohesion: 50 kPa Phi: 45 °



Entwistle High Level Bank Stability Assessment
Figure E2 - Site 2 (A-A') - Analysis

Date: 2017-11-13
Time: 8:13:30 PM
File Name: 16983_Site 2_Analysis.gsz

Name: Competent Sandstone Bedrock Model: Bedrock (Impenetrable) Piezometric Line: 1
Name: Clay Till/Sand/Silt Model: Mohr-Coulomb Piezometric Line: 1 Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 25 °
Name: Weathered Sandstone Bedrock Model: Mohr-Coulomb Piezometric Line: 1 Unit Weight: 24 kN/m³ Cohesion: 50 kPa Phi: 45 °



Entwistle High Level Bank Stability Assessment
Figure E3 - Site 4 (C-C') - Analysis

Date: 2017-11-13
Time: 8:26:45 PM
File Name: 16983_Site 4_Analysis.gsz

Name: Competent Sandstone Bedrock Model: Bedrock (Impenetrable) Piezometric Line: 1
Name: Clay Till/Sand/Silt Model: Mohr-Coulomb Piezometric Line: 1 Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 25 °
Name: Weathered Sandstone Bedrock Model: Mohr-Coulomb Piezometric Line: 1 Unit Weight: 24 kN/m³ Cohesion: 50 kPa Phi: 45 °