BEAR CREEK CORRIDOR GEOHAZARD SLOPE STABILITY AND EROSION ASSESSMENT

GRANDE PRAIRIE, ALBERTA

PREPARED FOR

THE CITY OF GRANDE PRAIRIE

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EXECUTIVE SUMMARY

Numerous active and historical landslides have occurred within the Bear Creek corridor within the City of Grande Prairie. As part of a comprehensive assessment program, The City of Grande Prairie commissioned ParklandGEO to undertake a detailed geohazard study of the Bear Creek.

This report outlines the findings of the overall stability assessment as it relates to geohazard risk, and highlights potential areas of concern. Erosion of the creek banks has long been known to be a trigger of many landslides in this area, and as such an erosion assessment was conducted as part of this investigation.

The geohazard evaluation consisted of the qualitative and quantitative assessment of the risk of a development within or near the river valley. The evaluation considered the stability analyses, site reconnaissance findings, historical reports and existing land uses. Based on this, a framework was developed based around an engineering evaluation of reasonable setback distances, coupled with the general nature of the current analyses and that future developments will have site specific investigations conducted which would be able to set site specific setbacks.

The proposed framework assesses that a staged investigation approach would best meet the needs of the community and provide a balance between the level of engineering evaluation required and the level of potential risk. A set of recommended minimum expectations for the performance of a geotechnical investigation were prepared. More stringent investigation requirements were recommended for areas closer to the top-of-bank.

Based on the level of risk associated with top-of-bank developments, and the historical problems associated with slopes along Bear Creek, guidelines for the evaluation of slope stability studies within the City of Grande Prairie were developed. The aim of these recommendations is not to remove engineering judgement but to provide a consistent framework for the City to evaluate geotechnical investigation reports, and to provide guidance to geotechnical practitioners when preparing and executing investigations.

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1.0 INTRODUCTION

Numerous active and historical landslides have occurred within the Bear Creek corridor within the City of Grande Prairie. As part of a comprehensive assessment program, The City of Grande Prairie has commissioned ParklandGEO to undertake a detailed geohazard study of the Bear Creek. The study area is shown on Figures 1 and 2.

This report outlines the findings of the overall stability assessment as it relates to geohazard risk, and highlights potential areas of concern, including areas adjacent to existing developments and for areas that will be developed in the future. Erosion of the creek banks has long been known to be a trigger of many landslides in this area, and as such an erosion assessment was conducted as part of this investigation.

This assessment was not intended to provide a comprehensive stability assessment of every portion of Bear Creek, nor remove the requirement of current and future developers from having to conduct detailed stability assessments on a site-by-site basis. Rather, our work provides a framework for the City to use in future land-use planning, and to be a benchmark when assessing development proposals that contain top-of-bank development plans.

Recommendations presented in this report should be used as a framework for the planning of future geotechnical and planning studies. Our recommendations for investigation requirements form a minimum suggested standard which top-of-bank geotechnical studies would be expected to meet. The intent is that developers wishing to develop along the top-of-bank will have ample opportunity to retain experienced geotechnical engineers to undertake detailed studies to set site-specific setback standards.

This study was not intended to be a catalogue or inventory of landslides. There were over one hundred identified in 2009/2010, many of which were very small slumps (less than 300 m^3 in soil volume), but several larger failures were found (in excess of 5000 m^3), along with numerous slides of between 1000 and 2000 m^3.

2.0 SCOPE OF WORK

The scope of work was outlined in ParklandGEO's proposal dated February 2, 2009, submitted to the City of Grande Prairie. The scope of work include the following:

- Undertake a detailed inspection of the Bear Creek from areas approximately 8 km north of the City to immediately south of the City limits. It is understood that future expansion of the City will not occur further to the south.
- Evaluate the potential risk of slope instability along the entire length of Bear Creek, with specific emphasis on identifying historical instability and the causes.
- Assess and document areas of significant erosion. Identify areas of erosion that may significantly impact infrastructure and would require remediation. Prioritize locations and develop preliminary remediation alternatives.
- Identify specific areas where public infrastructure may or is at significant risk due to slope instability and make recommendations for further study as part of subsequent stages of this contract.
- Review geotechnical and geological reports to assess the overall near-surface geology of the Grande Prairie area, and specifically along Bear Creek.
- Obtain a LiDAR survey of the Bear Creek corridor.
- Utilize the LiDAR survey, existing geomatic data with the City and other sources of information to develop typical slope sections and, from the inspection work, develop slope models to arrive at typical setback distances.
- From the generalized slope stability investigation, and survey identify potential areas where private development may be encroaching within the generic setback zone. Field verify potential encroachment locations and document the findings for the City. The intent is to establish generalized setback lines that can be used to evaluate the potential risk to a development or structure. The need for a detailed study can be evaluated based on the generalized study findings.

Information from this phase of the work program will involve multiple reports and deliverables, including:

- The LiDAR survey data would be provided in digital form for download and incorporation into the City GIS system.
- Aerial photographs, both current and historical, that are obtained by ParklandGEO will be provided in digital form for future use by the City. The aerial photographs were utilized to identify historical and active failure zones, and to assess typical slope regressions.

- Prepare a report on the risk to City infrastructure due to slope instability and/or erosion. Erosion and instability of stormwater outfalls was evaluated and presented in a separate report prepared by ParklandGEO under this same contract.

- Prepare a summary report outlining the locations of known current and historical instability and an evaluation of the likely causes of instability. Establish general top-of-bank lines and recommended setback distances for general evaluation purposes.

Authorization to proceed with the assessment was provided by Ms. Kristine Donnelly, P.Eng., Engineering Services Manager with the City of Grande Prairie.

3.0 ASSESSMENT METHODOLOGY

3.1 LiDAR SURVEY

Comprehensive LiDAR survey imagery was obtained from Airborne Imaging of Calgary, Alberta (File 1124, survey date October 2007). LiDAR (Light Distance And Ranging) utilizes an airborne laser to accurately generate a point cloud, or survey points on a very dense spacing. This allows the data to be processed as traditional survey coordinates (i.e. points with horizontal and vertical location), but due to the density of points, physical objects can be seen as shapes when the data files are rendered.

Because of the number of data points, and that lasers can bend around objects such as branches and leaves, LiDAR data can give the height and density of tree cover, as well as the ground elevation below a thick tree cover.

The typical absolute vertical accuracy for LiDAR imagery is around +/- 0.15 m on hard surfaces and open terrain, to +/- 0.30 to 0.50 m on vegetated surfaces or hilly terrain. The data for this site has an expected accuracy of 0.30 m.

Absolute horizontal accuracy is usually around +/- 0.50 to 0.75 m on all but extremely hilly terrain. The data for this site has an expected accuracy of 0.45 m.

The relative accuracy, that being the elevation and position difference between two nearby points, is considerably greater (i.e. less error), hence LiDAR provides a high degree of accuracy when surveying slopes with and without tree cover.

LiDAR data showing the variation in ground surface slope is presented in Appendix B. Using software provided by the vendor, slope profiles were created at 62 representative and known critical slope locations, and are presented in Appendix C. These were then used in the engineering evaluation of slope stability. The section locations are shown on Figure 3.

Due to the high degree of resolution, the LiDAR survey data can easily be compared to a later survey to accurately measure slope regressions, or lateral creek migration over time.

Red laser LiDAR is unable to measure below the surface of water, and as such, is not suitable for conducting a bathymetry survey.

3.2 FIELD RECONNAISSANCE

Two field reconnaissance surveys were conducted.

The first initial survey consisted of a visual ground inspection of all accessible areas of the creek corridor in June 2009. A low-level airborne inspection was also conducted at that time. The intent was to identify high risk areas, document large slope movements and identify potential areas for future investigation.

In October 2010, a second site inspection was conducted. This work included a ground level inspection of several key areas along Bear Creek that were found during the desktop study to be at potential risk, and to confirm details used in the engineering assessment.

3.3 HISTORICAL REPORTS AND AERIAL PHOTOGRAPHS

All geotechnical reports that were on-file with the City of Grande Prairie were reviewed to determine typical soil stratigraphy, depth to groundwater and assess soil strength. This included reports from areas further back from the Bear Creek valley, which provided information on soil stratigraphy and soil property variation.

Slope stability reports were also reviewed to determine and assess the typical soil strength parameters used in assessments.

Laboratory data of advanced soil strength data was reviewed. Only two instances of advanced laboratory testing were found, which provided direct shear tests of peak and residual soil strength.

Aerial photographs were reviewed that covered the entire City. Some were historical and covered only a portion of the creek corridor, while the more recent photograph coverage included the entire study area. A detailed historical review along the entire creek corridor was not conducted, but rather evidence of larger landslides was examined to determine previous regression distances.

3.4 STABILITY ANALYSES

A numerical modeling study was conducted on representative sections along the entire creek corridor. A total of about 50 sections were analyzed, with multiple analyses runs per section. Due to the extensive length of the creek corridor, the number of sections was considered adequate to assess the range of slopes found throughout the City, and were spread over a sufficient area that an adequate distribution of soil profiles and slope configurations was examined.

A detailed discussion on the modeling methods, and example analyses results is presented in Appendix D.

For each analyses, the LiDAR survey data was used to generate the typical or critical cross section. The soil profiles were estimated based on the geotechnical database of historical reports, and typical soil properties were utilized. In general the soil properties were not significantly changed between analyses sections, however in some areas where site specific information suggested weaker soil deposits were present, correspondingly lower soil strengths were used.

Given the general nature of this assessment, the use of typical soil strength parameters was reasonable and was found to correspond well to model calibration against known slides within various areas of Grande Prairie.

Model calibration was performed using a comparison of model predictions of slope regression to actual observed failures. Where a known failure occurred, the predicted slope regression was found to be within 1 to 3 m of the actual top-of-bank regression, after model calibration. This back analyses was conducted at five locations along the length of Bear Creek. Modifications to the soil strength parameters were made in some instances to obtain model results that were close to the observed behavior, and these strength parameters were applied over a wider area.

In order to predict the slope regression to a greater degree of accuracy, a series of characteristic failure curves was developed from the stability analyses. The curves (Figure 4) present the relationship between slope regression and inclination at three factors of safety (1.1, 1.3 and 1.5). A factor of safety of 1.1 was the lower bound that had a good correlation to observed behaviour, as relatively few sections had a factor of safety of 1.0. The curves present the potential slope regression, or more accurately setback distance, normalized to slope height. The design curves were most applicable to slopes over 5 m in height.

From the LiDAR data, the slope height and slope inclination was generated along the entire length of the creek. At over 250 locations, the estimated location of the 1.3 and 1.5 factor of safety lines was determined, with the 1.5 line being the most relevant for purposes of this study. The top-of-bank line was also determined from the LiDAR data and aerial photography.

3.5 GEOHAZARD RISK EVALUATION

The geohazard evaluation consisted of the qualitative and quantitative assessment of the risk of a development within or near the river valley. The evaluation considered the stability analyses, site reconnaissance findings, historical reports and existing land uses.

Based on this, a framework was developed based around an engineering evaluation of reasonable setback distances, coupled with the general nature of the current analyses and that future developments will have site specific investigations conducted which would be able to set site specific setbacks. We also considered that historical stability assessments utilized various estimates for soil strengths and that these estimates were in many cases un-conservative.

The proposed framework assesses that a staged investigation approach would best meet the needs of the community and provide a balance between the level of engineering evaluation required and the level of potential risk. From this, a set of recommended minimum expectations for the performance of a geotechnical investigation were prepared. More stringent investigation requirements were recommended for areas closer to the top-of-bank.

4.0 STUDY AREA

The study area was divided into 5 regions which were selected partly based on location within the City, but also because the slopes within each region tended to have similar characteristics, both in terms of geometery (valley depth, slope inclinations), geology and patterns of urban development.

Figure 5 presents the location and orientation of photographs included in Appendix A.

The five main areas are described below:

4.1 NORTH CITY LIMIT TO THE RESERVOIR

The northern portion of the study area encompasses several distinct areas, and are discussed separately.

4.1.1 Bear Lake to North City Limit

The area from the Bear Creek headwater leading from Bear Lake about 8 km northwest of the City (Photograph 1), to the north City limit was typified by a highly meandering stream, which was flanked by cultivated pasture land, residential farmsteads, and occasional stands of trees. The creek was generally narrow, with the outside bends having characteristically over-steepened slopes. Some evidence of slope instability was observed. The general valley depth was less than 5 m and the flow volume was generally low. There were no outfalls discharging into the creek until the north City limit.

4.1.2 North City Limit to 132 Avenue

Immediately north of the City limit, Bear Creek passes below 116 Street and turns southwards past two acreage residences and the Bear Creek Golf Club (Photograph 2). This portion of the creek has been significantly modified by development of 116 Street, with an old creek channel and oxbow lakes present on the west side of 116 Street. About 80% of the creek leading down to 132 Avenue was a man-made channel.

Numerous slope failures were noted along this portion of the creek, with some areas of bank slumping extending for over 100 m parallel to the creek. Although these slumps were found to only be resulting in modest 2 to 4 m lateral regressions, the number of slumps and volume of soil involved was substantial. It was evident that water flow would erode the failed soil mass within a year or two and a new series of retrogressive failures would take place. The typical embankment height was only 2 to 3 m throughout this area.

Two acreage residences were noted in the area just south of the northern City limit, but none were observed to be in immediate danger from slope regression. The observed residences appeared to be constructed away from the immediate area of the creek.

4.1.3 132 Avenue to Reservoir

South of 132 Avenue the creek enters a large wetland area located in the northwest corner of the NW1/4-34-71-6-W6M (Photograph 6). In this area the creek channel is difficult to identify.

A single channel leaves the wetland tending southeast. The channel begins to progressively become deeper, with a valley depth up to 5 m in areas. The outside bends along this portion of the creek are also typically over-steepened, although relatively few slope failures were observed.

Within the southeast portion of the section, the creek turns to the south and passes through the remainder of the quarter section. Here the creek begins to cut deeper into the subsoils and widen, with several outside bends beginning to show signs that the creek with cut through the outside slope and form an oxbow lake within the next 50 to 100 years. The slope heights increase to around 6 to 12 m (Photograph 8).

At the south end of the area, near the bypass road, the original creek channel has been pushed westwards by infilling a portion of the valley by a development on the eastern river bank (Photograph 10). It is also just downstream of this area, that the first of the City storm outfalls discharge into Bear Creek. The river then crosses the bypass road and discharges into the Reservoir. Beaver activity was observed in this area.

4.2 RESERVOIR TO 100 AVENUE

Bear Creek then enters a stormwater reservoir, which was formerly a natural wetland but has been modified and enlarged to accommodate the stormflows (Photograph 11). The area surrounding the reservoir includes gentle slopes along the entire perimeter, with urban parkland on the north shore, and the Grande Prairie Regional College campus along a large portion of the south shore.

The depth of water in the reservoir was controlled by a weir located at the east end (Photograph 12). Due to siltation the reservoir had a limited depth of water, ranging from less than 200 mm to about 1.5 m, with typical low-water depths of less than 400 mm.

Erosion was not found to be an issue along the reservoir banks but active and historical slope failures were observed that were due to upland developments.

Downstream of the weir to the 100 Street bridges, the creek channel was relatively straight, with gentle bends (Photographs 13 and 14). There was likely some historical straightening of the channel but the lack of meandering is also likely the result of the geology, which likely minimized lateral migration of the channel and promoted down-cutting. The creek width also tended to be wider throughout this stretch that would result in lower flow velocities. The creek was only about 1 to 2 m below the surrounding public parkland bordering the channel. Some minor evidence of toe erosion was noted but none was considered significant.

To the east and west of the creek, a wide flood plain was present along almost all of the creek length from the Reservoir to south of 100 Avenue. A secondary valley slope lead up to a higher top-of-bank which bordered the upland public and private developments. There was some public development within this flood plain area, which included the museum and park areas.

4.3 100 AVENUE TO 84 AVENUE

South of 100 Avenue to about 90 Avenue, the creek channel is relatively straight but with an increasing amount number of bends, indicative of the establishment of a sinusoidal pattern that is more characteristic of lateral channel migration. The area typically passed through older areas of Grande Prairie and the area above the top-of-bank was part of the public park system, with paved walking trails and numerous natural vegetation growth.

To the east of the creek, a large flood plain was present along large portions of the area south of 100 Avenue to about 84 Avenue. A secondary valley slope lead up to a higher top-of-bank. Private developments tended to border to top-of-bank in areas north of 89 Avenue, while a public roadway bordered portions of the top-of-bank south of 89 Avenue to 84 Avenue.

The valley depth became progressively deeper the further to the south, with the creek channel ranging from 4 to 15 m in depth.

Several slope failures were noted along the creek, which were typically on the outside meander bends and appear to be the result of toe erosion. At least two oxbow lakes were present, one around 91 Avenue (Photograph 21) and another at about 86 Avenue. The northern oxbow lake was about 5 m above the current creek elevation.

A large area of land on the west side of the valley, extending north from 84 Avenue, is undeveloped land that lies between the Canfor mill and the river (Photograph 28). It is expected that at this area will be developed for residential homes in the future.

4.4 84 AVENUE TO 68 AVENUE

From just north of 84 Avenue to about 200 m south, the creek alignment had been significantly altered during construction of the 84 Avenue bridge (Photograph 32). Several areas were straightened, and wetland areas created.

Further to the south, the creek becomes more meandering, with about five of the meanders nearly forming oxbow lakes. A new oxbow lake was observed to have formed at about 74 Avenue within the last 2 to 5 years. With the current rate of erosion, it is likely that at least three new oxbow lakes are likely to form in the next one to two decades (Photographs 39 and 40). This will likely result in changes to the downstream hydrology.

The valley slopes become steeper and the slope heights on outside bends become progressively higher, with slopes of 10 to 15 m high becoming common.

Several active and historical slope failures were observed or known to occur in this area. Several other slopes are significantly over steepened, and in some cases near vertical. It is expected that slope failures will continue in this portion of Grande Prairie for an extended period of time. With the formation of new oxbow lakes, it is possible that this will increase the rate of toe erosion in some areas, possibly leading to additional instances of slope instability.

Residential development has pushed closer to the valley than in areas north of 84 Avenue, with Mission Estates, Southview and Coachman Mobile Home Parks, and the Bear Creek Village Condominiums being areas that have been impacted, by slope regressions in the past 10 years.

4.5 68 AVENUE TO THE SOUTHEAST CITY LIMIT

The areas south of 68 Avenue are currently undeveloped within the immediate vicinity of the Bear Creek. Current development is primarily public parkland, with municipal infrastructure, which includes several pedestrian bridges that cross Bear Creek, two major utility bridges (immediately south of 68 Avenue and at South Bear Creek Road (Photograph 41)), and several ball diamonds (Photograph 42). A reclaimed landfill was located west of South Bear Creek Road and north of the river.

Urban development was occurring west of the creek, immediately south of 68 Avenue, although none of this development was near the top-of-bank.

The creek continued to be highly meandering, with one large oxbow lake located on the south side of the river, immediately northwest of the waste water treatment plant. This oxbow was at least 6 m above the current river elevation. Several other oxbow lakes were likely to form within the next 10 to 20 years.

The valley slopes become steeper and the slope heights along the length of the creek become progressively higher, with slopes of 10 to 25 m high becoming common, with the highest slopes near South Bear Creek Road. There was generally fewer landslides in this area, likely due to the river having cut down into more competent clay till and possibly shale bedrock in areas. The more competent soils have limited the lateral migration in areas and minimized the amount of toe erosion. The steeper slopes appear to experience some surface spalling due to weathering, but large top-of-bank regressions were not common.

The surface topography dropped towards the east, and as such the valley slopes near the east City boundary were less than 8 m high.

Beaver activity was observed in the areas east of South Bear Creek Road.

5.0 SUBSURFACE CONDITIONS

5.1 REGIONAL GEOLOGY

The historical and current issues with geohazards experienced in the City of Grande Prairie is directly related to the geological setting and development of the City in the area of Bear Creek.

The City is entirely located within a large upland plain, with the unconsolidated post-glacial sediments and the near surface bedrock being heavily influenced by the last glacial period. Three separate glacial storms advanced from the north and northeast during the Pleistocene period (the last of which was about 10,000 years ago) which deposited material during ice advance and retreat sequences. The glaciation deposited glacial sediments (till) directly over the weathered clayshale, siltstone and sandstone bedrock deposits. The till was later overlain by lacustrine and glacio-lacustrine deposits predominantly consisting of silty clays. The drift thickness above the bedrock in the Grande Prairie area is in the range of about 15 m to 50 m.

Present day water courses such as Bear Creek have actively downcut and sidecut valleys through the lacustrine clay and clay till. The creek has not yet eroded into the underlying bedrock for most of the channel length, with the exception of the portion of the creek that runs mostly east towards the City limits.

Towards the north portion of the City, Bear Creek is a very shallow channel with low flow velocity throughout most of the year, and slope heights of less than 4 metres in most areas, particularly north of the Reservoir. South of the weir, the channel becomes progressively deeper, with the upland areas rising about 30 m above the creek bed at the far southeast corner fo the City. From the weir to about 68 Avenue, the creek channel has been highly modified, including significant straightening through some sections.

Bear Creek is highly meandering within a wide valley. The creek has kept on changing alignments, forming terraces and oxbow lake features. Some oxbow lakes with water still exist between 84 Avenue and 98 Avenue. Old oxbow features with dense tree cover are present within the creek valley. For much of the lower valley, a small discontinuous flood plain areas exists, with some sewer outfalls being located in these zones. Some paved walking trails are also present within the floodplain but the trails are more commonly located along the top-of-bank, well above the high water level. The largest development within the floodplain occurs immediately south of the reservoir weir, where public parks and a museum are located on the east and west river banks.

The lowering and widening of the creek channel has resulted in landslides and erosion. The silty lacustrine clay is highly erodible, with the clay till being less erodible and more stable. The lacustrine clay is typically medium to highly plastic, while the clay till is a high plastic soil with peculiar engineering properties, possessing a relatively high cohesion and moderate friction angle which give the till a high intact strength that is quickly lost once the till begins to move. Hence, the northern reaches of the creek are eroding the lacustrine deposits, while areas south of the creek tend to be eroding the clay till. Due to the different soil types and valley depth, slope failures in the northern portion of the City tend to be smaller in both lateral and vertical extent, yet they are more frequent, while south of the reservoir the failures tend to be larger, extending further back but there are fewer failures.

5.2 TYPICAL SOIL PROFILES

Representative slope sections with soil stratigraphy are including as Figures 6 and 7. Additional idealized sections are presented in Appendix D, which were used in the modeling assessment. Soil strength properties are summarized in Appendix D.

The typical soil profile consisted of lacustrine clay, with occasional silt layers and strata, overlying a medium to high plastic clay till. Bedrock was not typically encountered within much of the study area. Some occurrences of rafted bedrock were noted, which were large masses of shale or sandstone that had been pushed up into the overlying clay sediments. These would not impact the stability analyses or risk assessment.

5.2.1 Clay

Variable thickness of lacustrine clay deposits were typically encountered below the surface covering throughout most areas of Grande Prairie, particularly along the creek corridor. The lacustrine clay was typically of high plasticity, silty and with trace amounts of sand. In some areas, the silt content was significant, with thicker silt lenses and silt stratum being present in some localized areas.

In some areas a reworked till was found that had distinct bedding or strata. This was a clay till that had been reworked and then deposited in water. Lacustro-till is weaker than an intact clay till, as found at deeper depths.

The north portions of the study area, primarily upstream of the reservoir, a large portion of the valley slopes were cut through the lacustrine clays.

5.2.2 Clay Till

Clay till was generally encountered below the lacustrine clay throughout the study area, and was the soil layer that was most dominant in slopes, particularly those south of the reservoir.

The clay till is typically a high plastic soil, with relatively equal portions of sand, silt and clay, with occasional to trace gravel size particles.

The local clay till that has been found to have a wide range of strength characteristics. One trait that has been measured in the laboratory is the unusual strength parameters found during direct shear testing for samples collected in the south portions of the City. The clay till has been found to have a moderately high intact strength, with effective cohesion and friction angle ranges of 6 to 33 kPa and 13 to 23 degrees respectively. However upon failure (shearing), a significant decrease in strength was observed, with no effective cohesion (0 kPa) and friction angles reducing by about 3 to 6 degrees from peak values, to between 8 and 19 degrees. To the north of the Reservoir more conventional behavior was measured, with effective cohesion and friction angle ranges of 3 to

7 kPa and 24 to 25 degrees respectively. Residual strengths of 0 kPa cohesion and 19 to 20 degrees friction angle were found.

These soil strength parameters have been confirmed by back analyses on several slope failures.

5.3 GROUNDWATER

Groundwater levels vary widely across the City of Grande Prairie, and experience over the last 20 years has found a significant decrease in the shallow groundwater table over much of the City. Some increases have been observed in some areas in the past 2 years due to higher precipitation levels.

Due to the lack of data in many areas, a typical or expected normal water table elevation was chosen for the stability analyses. In general, the shallow groundwater table has been found to be at or above the creek elevation in most areas, and as such this was used as the standard assumption in this assessment. However, site specific groundwater table measurements would be expected from any detailed investigation.

6.0 STABILITY AND SETBACK ASSESSMENT

6.1 PROPOSED ASSESSMENT ZONES

Assessment zones have been defined based on the top-of-bank line, which is generally considered the demarcation between the slope face and the upland area, and an Estimated Development Line, which was determined by ParklandGEO as part of this study.

The *Estimated Development Line* (EDL) was determined from stability analyses calculations using estimated soil properties and LiDAR survey data. The EDL is the off-set where the slope stability Factor of Safety was about 1.3 to 1.4, and would be close to the estimated location where urban development would be expected to approach the river valley. Allowances for slope inclination and slope height were included as part of the stability analyses used to establish this line. However, given the local variables this line has not been rigorously set for all slope areas along Bear Creek. In addition, the EDL does not reflect site specific factors, such as lateral river erosion, historical instability or unusual site specific geologic features. Therefore, the EDL is not a default setback line. The EDL is simply a reference line that the City intends to use to set the minimum requirements for geotechnical investigations for proposed development near City slopes.

From the engineering assessment ParklandGEO has identified four risk zones, and proposed a graduated plan for dealing with each zone. Figure 2 presents the location of detailed setback plans covering the entire City, which are presented on Figures 8 to 14.

The risk zones are:
1. Areas below the top-of-bank;
2. The area extending upslope of the top-of-bank to the EDL;
3. The area from the EDL to 40 m upslope of the EDL; and
4. Areas beyond 40 m upslope of the EDL to a maximum of ten times (10x) the slope height.

Areas which are more than 10 times the height of the slope back from the top-of-bank are considered to be low risk and should not require an assessment. Where a development straddles risk zones, the higher risk zone criteria would apply.

The stability assessment does not take into account the potential that engineered solutions to increase slope stability could be implemented, which would allow for development within very close proximity to the creek.

6.2 RECOMMENDED ASSESSMENT PRACTICES

The primary purpose of the geotechnical assessment is to present recommendations and supporting documentation for establishment of for the development setbacks. One or two setback recommendations may be required, depending on the situation.

1. *Long-Term Stability Line (LTSL).* For new developments, the geotechnical engineer is expected to establish, as part of their study, an *Estimated Long-Term Stability Line*,

otherwise commonly referred to as the *Building Set-Back Line*. This is generally considered the point at surface where the estimated factor of safety would be at or above 1.5 for the expected duration of the development or 100 years for permanent structures.

2. *Urban Development Line (UDL)*. For new developments, the geotechnical engineer is expected to establish, as part of their study, the *Urban Development Line*, or occasionally referred to as the Rear Lot Line or *Development Restriction Line*. This is generally considered the point at surface where the estimated factor of safety would be at or above 1.3 for the expected duration of the development or 100 years for permanent structures. This line will demarcate land between the Top-of-Bank and the UDL for environmental reserve. In cases with pre-existing property lines where site redevelopment will not include new subdivision, the need for a UDL is not required. The pre-existing property lines would be grand-fathered even if they do not meet the present UDL standards.

In addition to the above, the geotechnical engineer is expected to set a water features restriction line, and provide appropriate recommendations on fill placement and grading, construction recommendations, utility specifications, roof drainage discharge, vegetation, clearing, and any other recommendations necessary for the safe development of the site.

Specific developments will be required to incorporate either a top-of-bank walkway (with lots backing onto the creek) or roadway (with lots fronting onto the creek) into the development plan. For clarity purposes, the location of a top-of-bank walkway and roadway are depicted below. As it is expected that top-of-bank road right-of-ways will include buried infrastructure, and provide a critical transportation link, all roadways must be located upslope of the Long-Term Stability Line.

Based on the level of risk associated with top-of-bank developments, and the historical problems associated with slopes along Bear Creek, including the significant use of assumptions when conducting slope stability assessment, ParklandGEO has developed the following guidelines for the evaluation of slope stability studies within the City of Grande Prairie.

The aim of these recommendations is not to remove engineering judgement but to provide a consistent framework for the City to evaluate geotechnical investigation reports, and to provide guidance to geotechnical practitioners when preparing and executing investigations.

Where applicable, recommendations are provided for both existing single residential size lots, and for any developments larger than an existing single family residential lot. A distinction is being made in that placing significant restrictions or assessment expectations on an individual private resident, would in many cases, be an unreasonable burden and economically impractical.

In certain cases it may be valuable to carry out a probabilistic risk assessment. Such an assessment will evaluate the probability of occurrence of a certain factor of safety for slope stability, for comparison with the probability of occurrence of the long term factor of safety of 1.5. In the event that the probability of occurrence of a lower factor of safety (say FS of 1.3) is similar to that for a FS of 1.5, a strong case may be made for adopting the development line that corresponds to the lower factor of safety. However, it is important that probabilistic risk assessments be carried out by qualified geotechnical engineers with expertise and experience in probabilistic risk assessments using the quantitative approach. This type of expertise and experience is very rare amongst professional members of the geotechnical community. Nevertheless, the successful completion of this type of quantitative assessment may be beneficial to the City and the proponent.

The minimum requirements for the level of site assessment required to support a development proposal are summarized in Table 1.

TABLE 1: RECOMMENDED ASSESSMENT REQUIREMENTS vs. LOCATION RELATIVE TO TOP-OF-BANK

Risk Zone	**1**	**2**	**3**	**4**
Assessment Requirement / Location	**Below TOB**	**TOB to EDL**	**-EDL to EDL+40m**	**> EDL +40m to Maximum 10x Slope Height**
Determine Site Location Relative to Risk Zone	**Required**	**Required**	**Required**	**Required**
Site Visit by Geotechnical Engineer	Required	Required	Recommended	Not Required
Establish Top-of-Bank Line	Not Required	Required	Required	Not Required
Establish Long-Term Stability Line	Not Required	Required	Required	Not Required
Establish Urban Development Line	Not Required	Required	Required	Not Required
Establish Development Restrictions	Required Refer to **Section 6.2.1** for detailed assessment requirements.	Required Refer to **Section 6.2..2** for detailed assessment requirements.	Required Refer to **Section 6.2.3** for detailed assessment requirements.	Site Specific Refer to **Section 6.2.4** for detailed assessment requirements.
Slope Survey				
Aerial Photograph Review				
Field Investigation				
Detail Laboratory Testing				
Routine Laboratory Testing				
Numerical Modeling				

Estimated Development Line (EDL) — Estimated Development Line, as discussed in Section 4.0.

Top-of-Bank (TOB) Line — Top-of-Bank line established by a qualified geotechnical engineer.

6.2.1 Risk Zone 1: Below The Top-of-Bank Line

For development below the top-of-bank, which would typically exclude most private development, the City would need to consider the type of development and assess the scope of any engineering assessment. Typical developments may include, new bridges, utility crossings, pipelines, trails or other public work projects.

Guidance from experienced geotechnical consultants on the appropriate scope of any investigation would be necessary.

6.2.2 Risk Zone 2: Top-of-Bank Line to EDL

The following are the recommended minimum assessment components for developments located between the top-of-bank and the Estimated Development Line:

- Establishment of the top-of-bank line by an experienced geotechnical engineer, at sufficient points along the proposed development to avoid ambiguity. The top-of-bank line must be surveyed by a qualified legal surveyor, and the location marked with suitable monuments and the line registered on title.

- A topographic survey including the top-of-bank, upland area extending a suitable distance away from the slope, and downslope at sufficient locations that the engineer will be able to establish worst-case and typical slope inclinations. All surveys should extend down to the river. For large areas, slopes too steep to safely survey by a crew or where tree cover will render GPS or total station surveys impractical, LiDAR data coupled with ground-level verification would be recommended.

- A detailed aerial photograph review which should assess the proposed site at sufficient time intervals to understand historical landslide activity over the entire period of available aerial photograph coverage for the site.

- A comprehensive intrusive field investigation must be conducted that may take several forms, and may use various techniques, including boreholes, CPT, wet rotary coring or geophysics. The number of sampling locations will depend on the development size, but should be of sufficient scope to provide coverage along the entire length of the study area, and determine the soil stratigraphy both parallel and perpendicular to the slope, and to a sufficient depth below the base of any expected slide, or to a depth of 130% of the slope height. Samples for high quality laboratory testing must be collected from representative soil strata along the length of the development.

- Groundwater elevations must be obtained from multiple locations on more than one date to verify that stabilized levels have been determined.

- A comprehensive laboratory investigation would be required that must include advanced testing of high quality soil specimens, and should at a minimum define the soil strength properties, specifically internal angle of friction and cohesion, at both peak and residual strain conditions. At least two samples per stratigraphic unit that have a direct and significant impact on the stability of the slope should be subjected to advanced strength testing. Direct shear or triaxial testing is preferred. The number of advanced tests conducted should be appropriate to the size of the development, but a series of samples collected at between 150 to 250 m spacing along the creek length is suggested.

- All investigations should include routine field and laboratory tests for soil index properties and soil strength. Routine index testing for grain size, plasticity and soil sensitivity is the recommended means to identify and characterize soil facie, and correlate these to soils subjected to more advanced tests which would include site specific testing for the project and available published test data for the area. Routine field and laboratory strengths tests, including pocket penetrometer, Tor Vane and unconfined compressive strength tests are not a suitable substitute for high quality laboratory tests such as direct shear or triaxial testing.

- A suitable numerical modeling assessment, coupled with an engineering evaluation should be prepared by a qualified geotechnical engineer. It would be expected that examples of the supporting analyses be provided that demonstrates a reasonable factor of safety for the proposed development. The analyses and engineering evaluation should consider a range of soil strengths, groundwater conditions, and the potential impacts of residual strength on slope regression.

- Development setback lines referenced to the top-of-bank line should be presented for lot lines, building location setback, and water features restrictions. The City of Grande Prairie has previously recommended a minimum factor of safety of 1.5 to the building setback.

The minimum report submission requirement is for a full geotechnical report prepared by a qualified geotechnical engineer. The report must include:

- a description of the site, and the proposed development, including a clear classification of the risk zone outlined in Table 1 in Section 6.2;

- a comprehensive description of the local geology and subsurface profile supported by borehole logs or equivalent;

- a comprehensive description of the soil properties for the major soil units within the subsurface profile;

- site plan(s) and slope profiles drawn to scale illustrating the location of the development site relative to the top-of-bank line, slope and local creek channel. The site plan must be based on a surveyor prepared drawing of the site and relevant surrounding area including the slope;

- discussion of the slope stability modeling and subsequent geotechnical evaluation including representative example figures of the modeling results;

- development setback recommendations referenced to the top-of-bank line for new property lines and proposed building locations. As previously mentioned, building setbacks acceptable to the City of Grande Prairie are required to meet the minimum factor of safety of 1.5.

- development recommendations including any restrictions concerning slope reconfiguration, lot grading, vegetation removal, location of water features, etc.

6.2.3 Risk Zone 3: EDL To 40 m Upslope Of EDL

Where a development is not proposed to be any closer than the zone covered in Section 6.2.2, a less comprehensive assessment would be acceptable. It is not suggested that the recommendations in Sections 6.2.2 and 6.2.3 be cumulative, but only the more comprehensive program be implemented.

- Establishment of the top-of-bank line by an experienced geotechnical engineer, at sufficient points along the proposed development to avoid ambiguity. The top-of-bank line must be surveyed by a qualified legal surveyor, and the location marked with suitable monuments and the line registered on title.

- A topographic survey including the top-of-bank, upland area extending a suitable distance away from the slope, and downslope at sufficient locations that the engineer will be able to establish worst-case and typical slope inclinations. All surveys should extend down to the river. For large areas, slopes too steep to safely survey by a crew or where tree cover will render GPS or total station surveys impractical, LiDAR data coupled with ground-level verification would be recommended.

- An aerial photograph review over as long of a time frame as coverage allows should be included.

- An intrusive field investigation must be conducted with the number of sampling locations depending on the development size, but should be of sufficient scope to provide coverage along the entire length of the study area, and determine the soil stratigraphy both parallel and perpendicular to the slope, and to a sufficient depth below the base of any expected slide, or to depth of 120% of the slope height. Samples for high quality laboratory testing must be collected from representative soil strata along the length of the development.

- Groundwater elevations must be obtained from multiple locations on more than one date to verify that stabilized levels have been determined.

- Advanced testing of high quality soil specimens is required, and should at a minimum define the soil strength properties, specifically internal angle of friction and cohesion, at both peak and residual strain conditions. At least one sample per stratigraphic unit that has a direct and significant impact on the stability of the slope should be subjected to advanced strength testing. Direct shear or triaxial testing is preferred. The number of advanced tests conducted should be appropriate to the size of the development, but a series of samples collected at between 200 to 400 m spacing along the creek length is suggested.

- All investigations should include routine field and laboratory tests for soil index properties and soil strength. Routine index testing for grain size, plasticity and soil sensitivity is the recommended means to identify and characterize soil facie, and correlate these to soils subjected to more advanced tests which would include site specific testing for the project and available published test data for the area. Routine field and laboratory strengths tests, including pocket penetrometer, Tor Vane and unconfined compressive strength tests are not a suitable substitute for high quality laboratory tests such as direct shear or triaxial testing.

- A suitable numerical modeling assessment, coupled with an engineering evaluation should be prepared by a qualified geotechnical engineer. It would be expected that suitable examples of the supporting analyses be provided that demonstrate a reasonable factor of safety for the proposed development. The analyses should consider a range of soil strengths, and the engineering evaluation should consider the potential impacts of residual strength on slope regression.

- Development setback lines referenced to the top-of-bank line should be presented for lot lines, building location setback, and water features restrictions. The City of Grande Prairie has previously recommended a minimum factor of safety of 1.5 to the building setback.

The minimum report submission requirement is for a full geotechnical report prepared by a qualified geotechnical engineer. The report must include:

- a description of the site and the proposed development including a clear classification of the risk zone outlined in Table 1 in Section 6.2;

- a comprehensive description of the local geology and subsurface profile supported by borehole logs or equivalent;

- a comprehensive description of the soil properties for the major soil units within the subsurface profile;

- site plan(s) and slope profiles drawn to scale illustrating the location of the development site relative to the top-of-bank line, slope and local creek channel. The site plan must be based on a surveyor prepared drawing of the site and relevant surrounding area including the slope;

- discussion of the slope stability modeling and subsequent geotechnical evaluation including representative example figures of the modeling results;

- development setback recommendations referenced to the top-of-bank line for new property lines and proposed building locations. As previously mentioned, building setbacks acceptable to the City of Grande Prairie are required to meet the minimum factor of safety of 1.5.

- development recommendations including any restrictions concerning slope reconfiguration, lot grading, vegetation removal, location of water features, etc.

6.2.4 Risk Zone 4: Areas Beyond 40 m Up-Slope Of The EDL

Where a development is not proposed to be any closer than the zone covered in Section 6.2.3, a less comprehensive assessment would be acceptable. It is not suggested that the recommendations in the previous sections be cumulative, but only the most applicable program be implemented.

It is considered that the slope assessment policy not apply for developments located further than 10 times the maximum slope height in the area bordering the development.

- Establishment of the top-of-bank line by an experienced geotechnical engineer, at sufficient points along the proposed development to avoid ambiguity. It is expected that for developments at this distance from the top-of-bank, that the line location would have been previously established. This should be verified and it would be expected that the initially established line be utilized.

- All site assessments and site investigations require a detailed site visit by qualified geotechnical personnel.

- The extent of any topographic survey of the top-of-bank must be consistent with the need to establish slope inclinations and provide suitable estimates of the slope geometry and location.

- The minimum aerial photograph review requirement to assess a proposed site for historical landslide activity should include the recent available aerial photograph and at least one historical aerial photo taken at least 10 years prior to the assessment.

- A field investigation is recommended. The number of sampling locations will depend on the development size, but should be of sufficient scope to provide coverage along the entire length of the study area, and determine the soil stratigraphy both parallel and perpendicular to the slope.

- Advanced testing of high quality soil specimens would not typically be required, but should be considered where sufficient data from other nearby investigations closer to the slope are not available.

- A suitable numerical modeling assessment, coupled with an engineering evaluation should be prepared by a qualified geotechnical engineer. It would be expected that suitable examples of the supporting analyses be provided that demonstrates a reasonable factor of safety for the proposed development. The analyses should consider a range of soil strengths, and the engineering evaluation should consider the potential impacts of residual strength on slope regression.

- Development setback lines are expected to have been previously established, and should be referenced in the assessment. Where these have not been previously established, appropriate recommendations should be provided.

- The minimum requirement for a basic site assessment is a letter report prepared by a qualified geotechnical engineer. The report should include a site plan drawn to scale including verified measurements between the development site and the local top-of-bank line. The report should provide any development setback recommendations for lot lines and building locations which might impact the development; and any development any restrictions concerning slope reconfiguration, vegetation removal, location of water features, etc.

6.3 MINOR DEVELOPMENTS

It is expected that re-development of older properties or modifications to existing developments (i.e. a house addition), will occur on lots that are located within the area between the top-of-bank and the 40 m development line off-set, this being in Risk Zones 2 through 4.

For non-permanent structures, including unattached decks or sheds, the need for a comprehensive geotechnical study would not be appropriate in most cases.

For a changes to a structure, including minor house additions, or complete re-development of a lot, top-of-bank properties should have a geotechnical engineering assessment performed in compliance with this Guideline.

6.4 EXISTING POTENTIAL ENCROACHMENT

Figures 8 to 14 indicate that several existing structures encroach on or past the *expected development line*, with several residential properties also located in close proximity to this line. As the *expected development line* was based on having a Factor of Safety of about 1.3, indicating that these developments are not at a high or immediate risk of failure but that monitoring or assessment should be considered.

The following is a summary of structures that encroach on or across the EDL:

TABLE 2: SUMMARY OF ENCROACHMENT OVER EDL

Fig. Ref.	Building Name	Street Location	Notes/Comments
9	Private Residence/Barn	W 108 Street; @ 125 Avenue	High potential risk with existing failure near the barn and house in close proximity to the creek.
10	Centre 2000	106 Street; N 112 Avenue	Low potential risk due to wide floodplain and tree cover. Biennial visual inspection recommended.
11	Golden Age Seniors Centre	W 102 Street; @ 101 Avenue	Low potential risk due to location on upper slope area. Visual inspection recommended but no on-going work.
11	Private Residences	W 102 Street @ 95 Avenue	High potential risk. Annual inspection of private property recommended.
12	Private Residences	E 102 Street @ 80 Ave., 81 Ave. and 82 Ave. Cul-de-sacs	Moderate risk likely to be caused by homeowners rather than the river. Historical failures in area. Annual visual inspection recommended.
12	Private Residences (Mission Hts.)	E 102 Street; N 76 Avenue	Low potential risk from creek. Risk most likely due to actions by homeowners. Annual visual inspection recommended.
12	Coachman Mobile Home Park	S 84 Avenue; W 100 Street	Low potential risk but annual inspection recommended.
13	Private Residences (Mission Hts.)	E 102 Street @ 72A Avenue Cul-de-sac	Moderate risk due to homeowners and partially due to river erosion. Historical failures in area. Annual visual inspection recommended.

In the numerous instances where the *expected development line* does cross into private property along top-of-bank lots, future development applications will need to be reviewed and assessed with reference to the City Policy and likely in greater detail than the original development.

6.5 SIGNIFICANT SLOPE FAILURES

Figure 15 presents the location of several larger slope failures, or failures that have potential impacts on current or future developments, or municipal infrastructure. Known failures that have been remediated are also indicated.

Several of these failures are the subject of previous or current investigations, some by private land owners and others by the City of Grande Prairie.

In general, most existing failures are located north of 68 Avenue, which was expected as the Bear Creek channel is located in softer, weaker and more erodible soils further to the north.

6.6 CAUSES OF INSTABILITY

Several causes were identified that were leading to slope instability. In general, three main causes were identified, along with one significant factor that was contributing to the size of the observed failures. Based on experience in investigating failures throughout the City, as well as the visual inspections conducted in 2009 and 2010, the following conclusions were drawn.

Natural erosion of the slope toe by Bear Creek was the primary cause of the majority of slope failures. This includes the minor but linearly extensive small slumps, but several larger slope failures were triggered by loss of support at the toe caused by erosion. Attempting to control erosion in order to minimize risk would be difficult due to the length of the creek, but for some areas this could be considered as a risk mitigation measure. Vegetation and soft bank armour are means that could be considered for implementation on specific areas of concern.

Drainage issues with upland developments have been the cause of several failures, which have been typically related to increasing groundwater seepage (i.e. over-watering of lawns) or poor surface drainage causing infiltration or erosion. Typical examples include slope failures at the Coachman Mobile Home Park and the north reservoir slope at the Elks Lodge. At least two failures were documented by other consultants related to the inappropriate placement of fill on a slope and excessive watering of residential lawns.

Fill placed near or over the top-of-bank to re-grade or expand a lot has been identified as the cause of failure at several locations. The People Church site is one recent example and the Bear Creek Village Condominiums is an older case-study. Fill adds load at a critical location on a slope and as such, warrant attention at the site design and construction stage. The history of failures induced by the inappropriate placement of fill indicates that this is a critical issue in the City of Grande Prairie.

Over-steepened slopes, particularly cut slopes, have failed for unknown reasons, and can be explained by the weakening of the soil to the point of failure. This represents only a few locations within the City but it is expected that some minor slope failures in older areas will begin to experience slope instability at some locations.

Further issues have been identified with the presence of historical landslides that have pre-existing shear surfaces. These pre-existing shear surfaces are significantly weaker zones that can result in a re-mobilization of a failure mass with less disturbance than intact soils. Where historical failures are identified, suitable investigation and analyses would be necessary to identify if and how a pre-existing failure would impact future stability.

Due to the strain softening characteristics of the of the local clay till, several slope failures have extended upslope a further distance that what would be typically expected. Although not a direct cause of instability, the soil behaviour has contributed to slope failures and needs to be recognized as a critical factor when assessing slopes and soil behaviour.

Issues that have not historically been the cause of slope failures in Grande Prairie include: seepage from underground sprinklers or ponds - likely due to a lack of these types of water features in the City; and stormwater discharges from outfalls - which is likely due to the relatively small size of most outfall structures.

Factors that have minimized damages to structures and private property are: the majority of development close to the valley have had reasonable setback standards, and these are recent developments within the last 20 years; that there is a wide flood plain located between the river and the upland development in the older portions of the City between 100 Avenue and 84 Avenue which has minimize most properties from damage.

7.0 EROSION ASSESSMENT

Erosion has long been known to be a significant landslide trigger mechanism. Although an accurate inventory of erosion induced landslides has not been completed in the City of Grande Prairie, it was estimated during this assessment that over 75% of slides were directly caused by erosion, or erosion was a significant contributing factor or trigger.

Toe erosion along the Bear Creek corridor was observed along the entire length of the channel. Both straight sections of the creek and outside bends were affected. The areas of the creek less vulnerable to erosion were those with well established and thick vegetation, specifically those with grasses and shrub cover.

Erosion on the slope face was also identified as a contributing factor in at least two existing failures and in some historical slides. Typically the cause of surface erosion was due to concentrated surface run-off being directed over the top-of-bank. Inadequate maintenance of the slope face to repair erosion damage allowed the deepening and widening of erosion channels that could cause slope instability. This was observed at several stormwater outfalls that discharged onto the upper portions of the slope, as well as from private and municipal ditches that drained over the top-of-bank.

Erosion along the channel upstream of the reservoir is causing significant siltation within the reservoir, and a significant reduction in stormwater storage/retention capacity. Although not an immediate safety concern, because the reservoir is an important engineered component of the municipal drainage plan for the northern part of the City, an evaluation should be undertaken to determine the impact on the reduction in capacity on the stormwater management plan.

Erosion was found to be contributing to damage to the following municipal infrastructures:

- A large stormwater outfall at 72 Avenue (Outfall 46) was failing due to a erosion induced landslide;
- Several stormwater outfalls were identified in the 2009 stormwater outfall assessment report, where erosion was causing minor damage to the outfall, and repairs were recommended on each outfall.
- Surface water was found to causing erosion to slopes that would lead to a slope failure if not remediated. This includes the slope leading down from the Coachman Mobile Home Park and adjacent to the South Bear Creek Road.

For areas north of the Reservoir, continued erosion of the creek banks and base are expected to continue for the foreseeable future. Large amount of clay and silt sediment will be deposited into the reservoir, with a portion of this material transported farther downstream. Efforts to minimize this natural process could be considered, but with the exception of planting vegetation, most engineered solutions would be costly and would be impairing natural stream formation.

8.0 LIMITATIONS AND CLOSURE

This report has been prepared for the exclusive use of The City of Grande Prairie. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. It has been prepared in accordance with generally accepted geotechnical engineering practices. No other warranty, either express or implied, is made.

We trust that this report meets with your current requirements. If there are any questions, please contact the undersigned at 780 / 416 - 1755.

Respectfully Submitted

PARKLAND GEO-ENVIRONMENTAL LTD.
APEGGA Permit to Practice No. P - 8867

August 23, 2011

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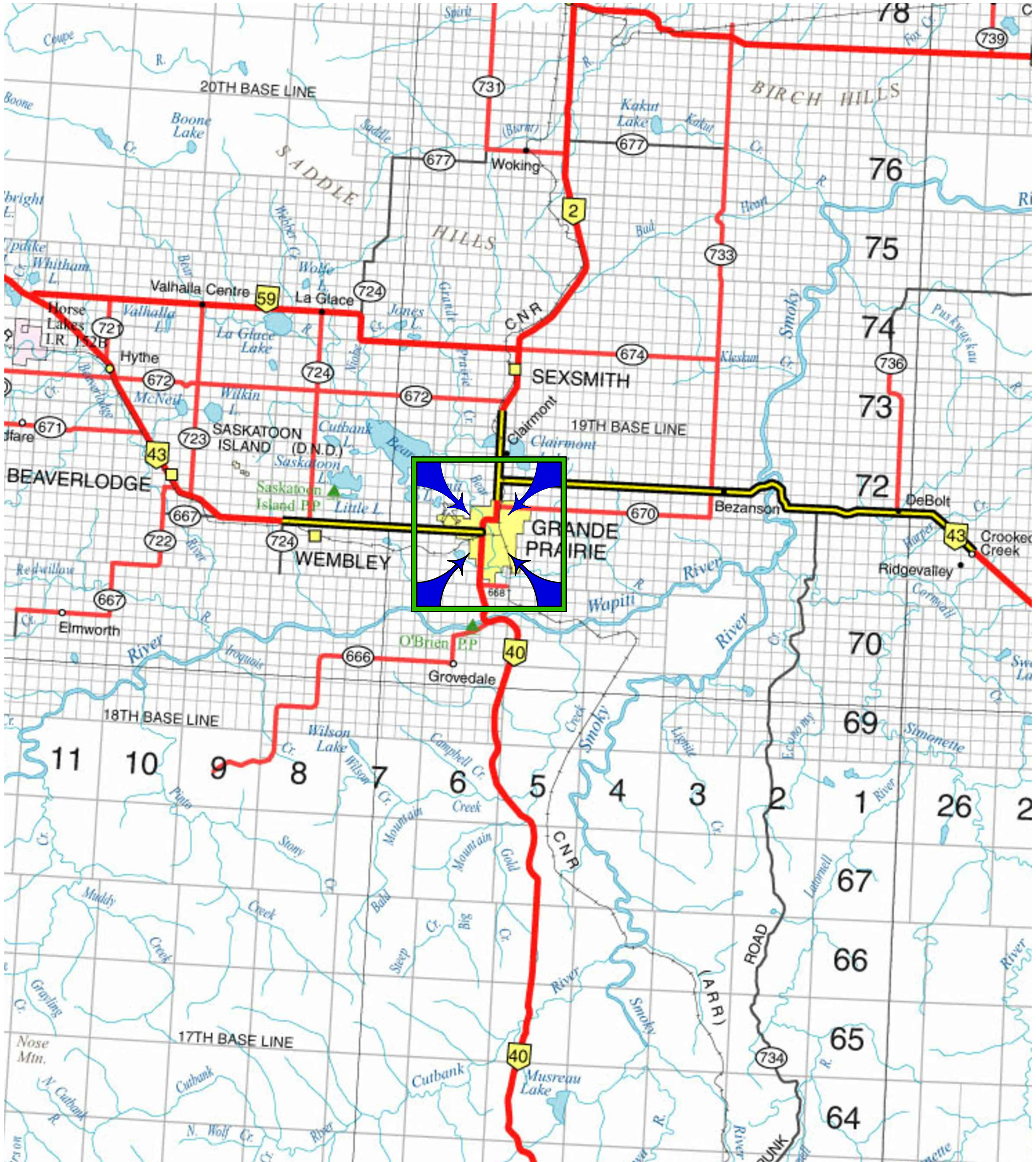
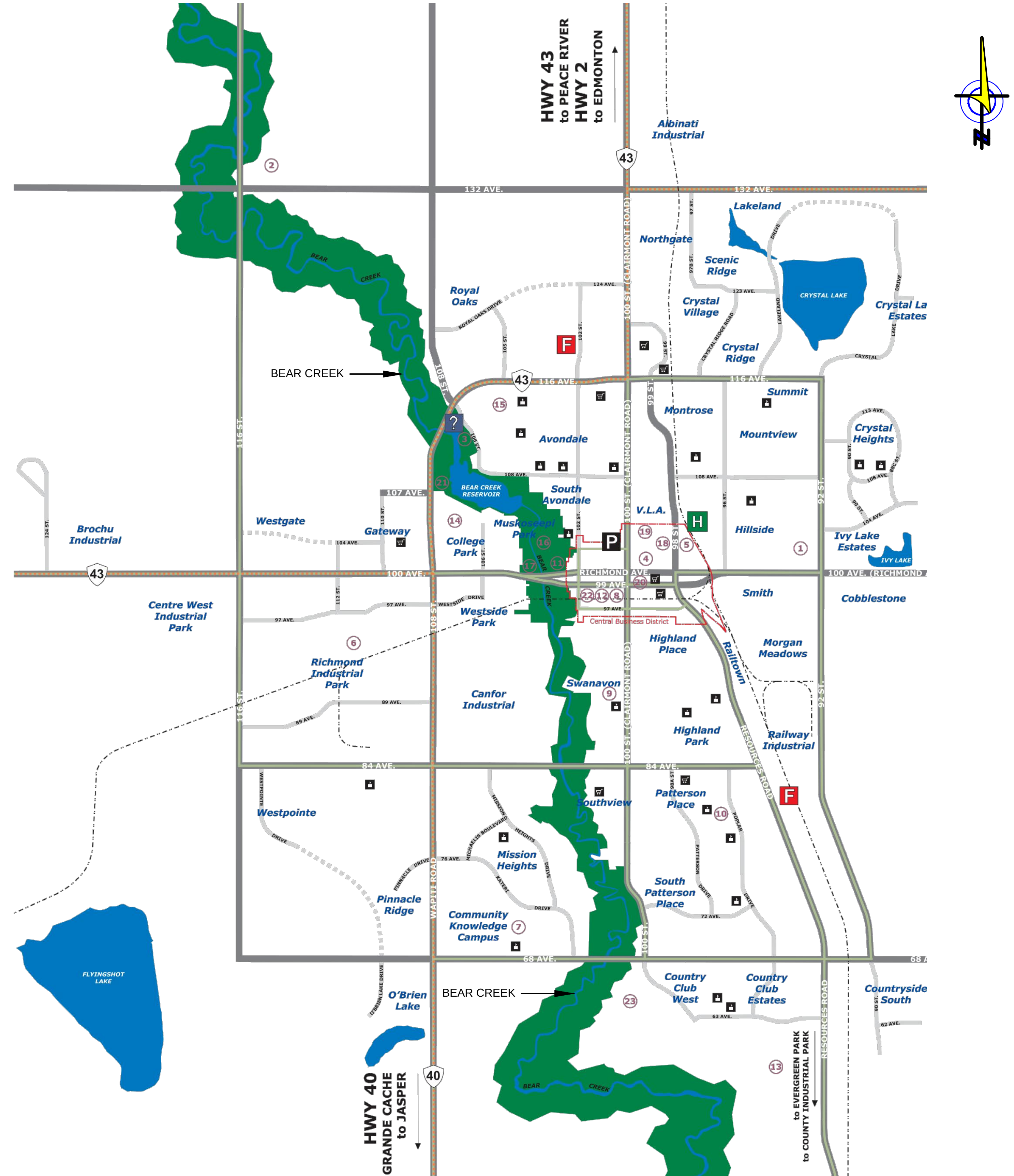
FIGURES





REV #	DATE	DETAILS

DRAWN: BK | CHK'D.: MMc | REV #: 0 | DATE: DECEMBER 2010

ParklandGEO

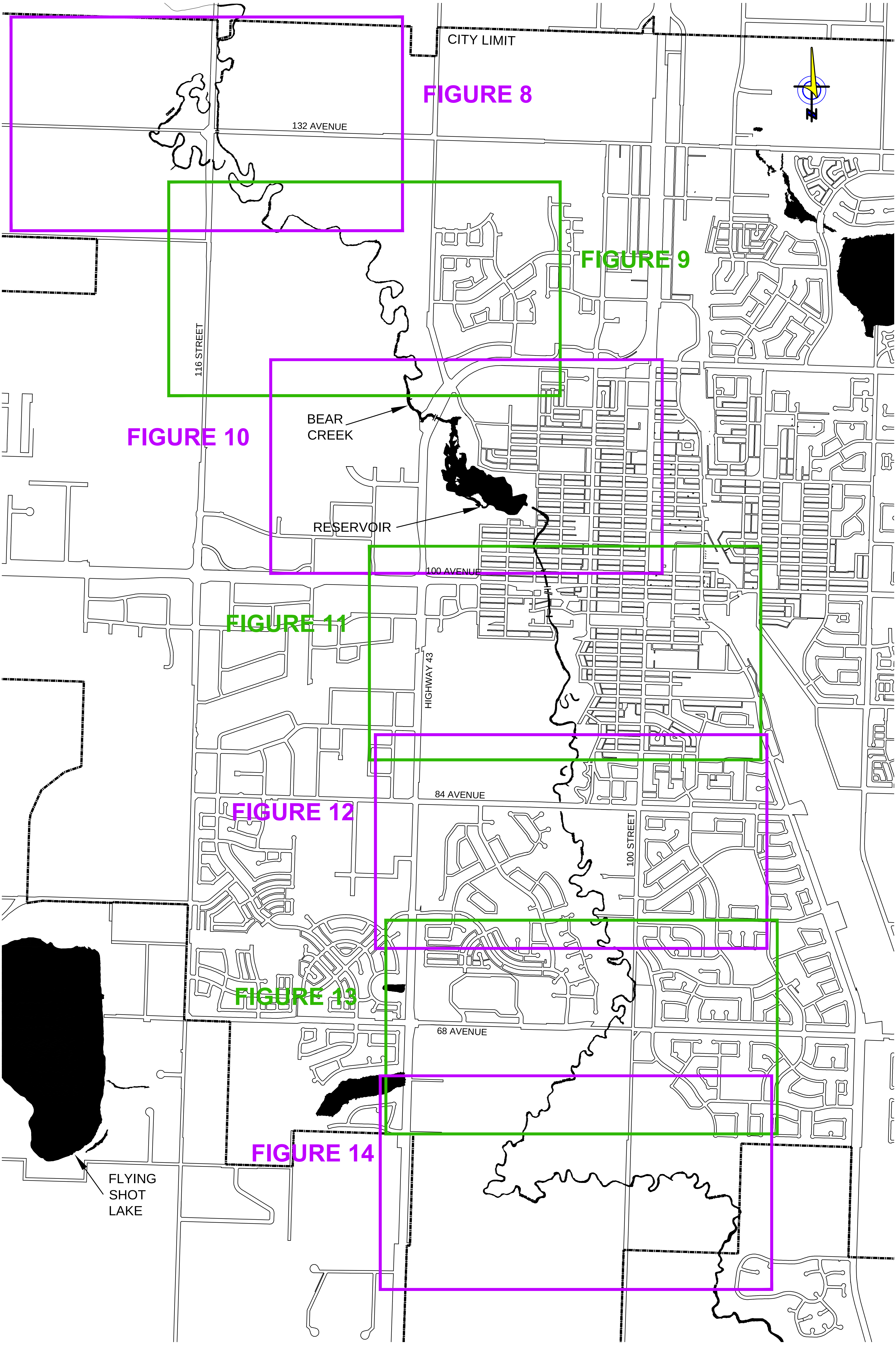
CLIENT:

THE CITY OF GRANDE PRAIRIE

LOCATION PLAN

BEAR CREEK CORRIDOR STUDY
GRANDE PRAIRIE, ALBERTA

SCALE: NOT TO SCALE | JOB NO. GP-1433 | DRAWING NO. FIGURE 1



REV #	DATE	DETAILS

DRAWN:	CHK'D.:	REV #:	DATE:
BK	MMc	0	DECEMBER 2010

ParklandGEO

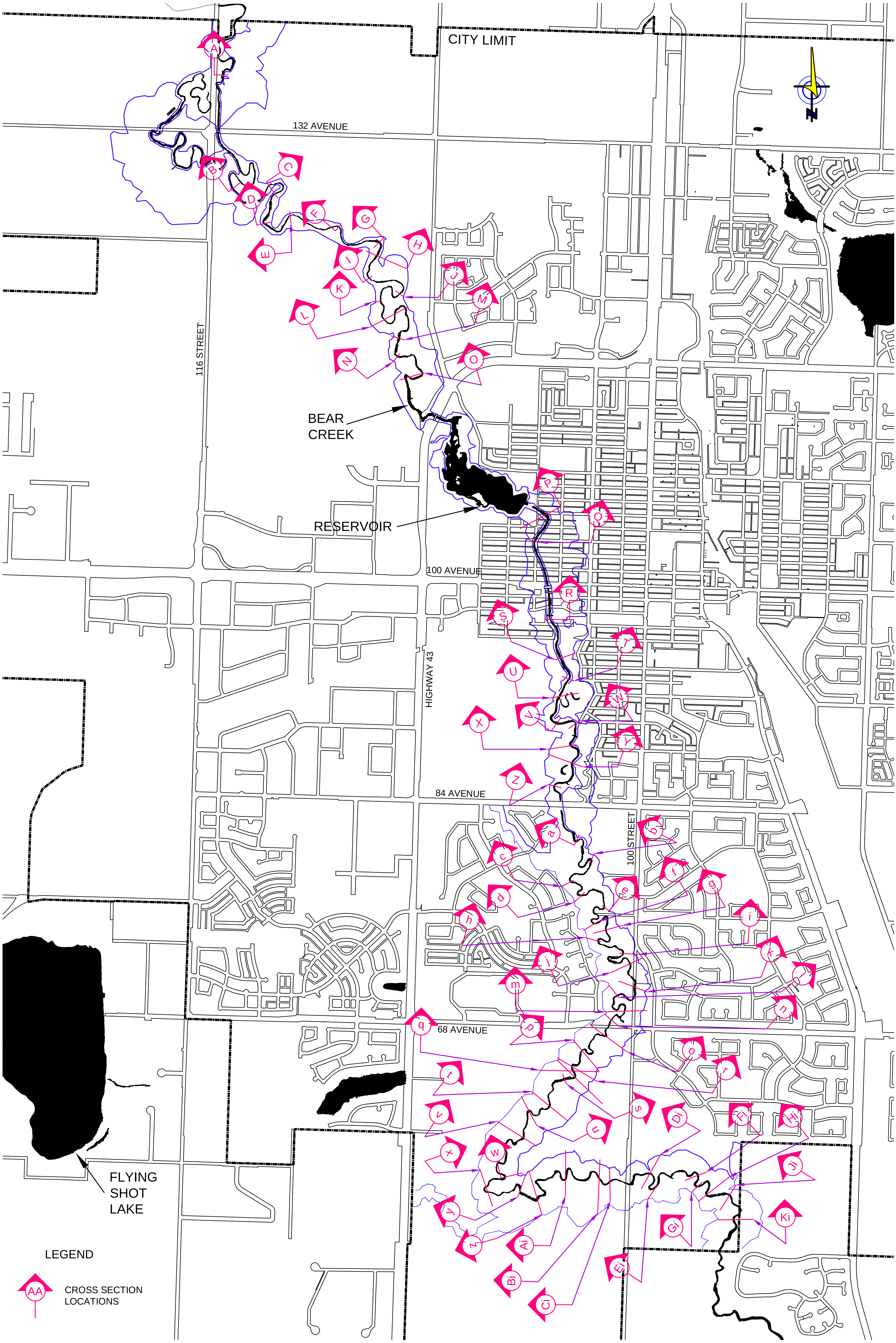
CLIENT:

THE CITY OF GRANDE PRAIRIE

KEY PLAN

BEAR CREEK CORRIDOR STUDY
GRANDE PRAIRIE, ALBERTA

SCALE:	JOB NO.	DRAWING NO.
1:25,000	GP-1433	FIGURE 2



REV #	DATE	DETAILS

DRAWN:	CHK'D.:	REV #:	DATE:
BK	MMc	0	DECEMBER 2010

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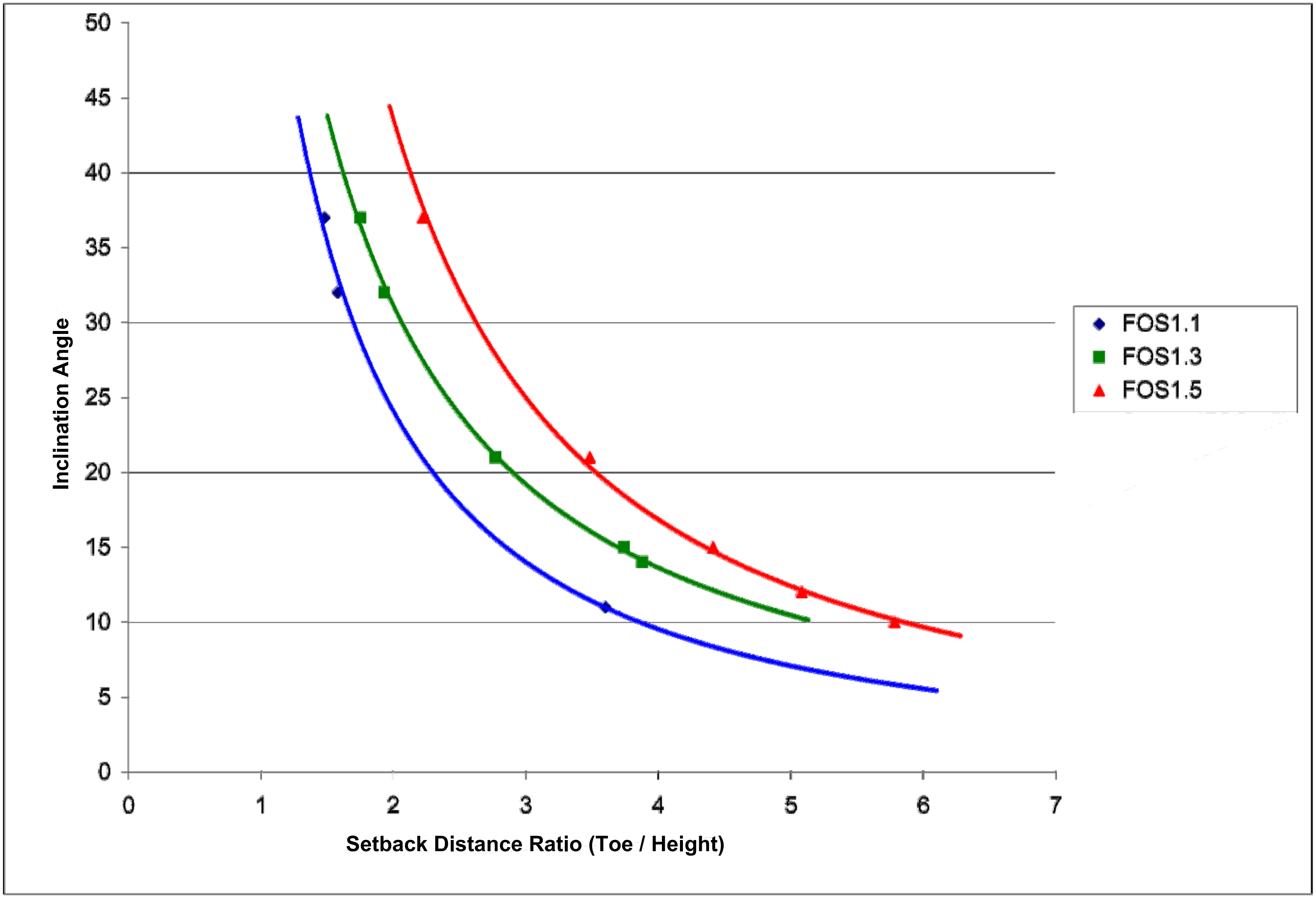
THE CITY OF GRANDE PRAIRIE

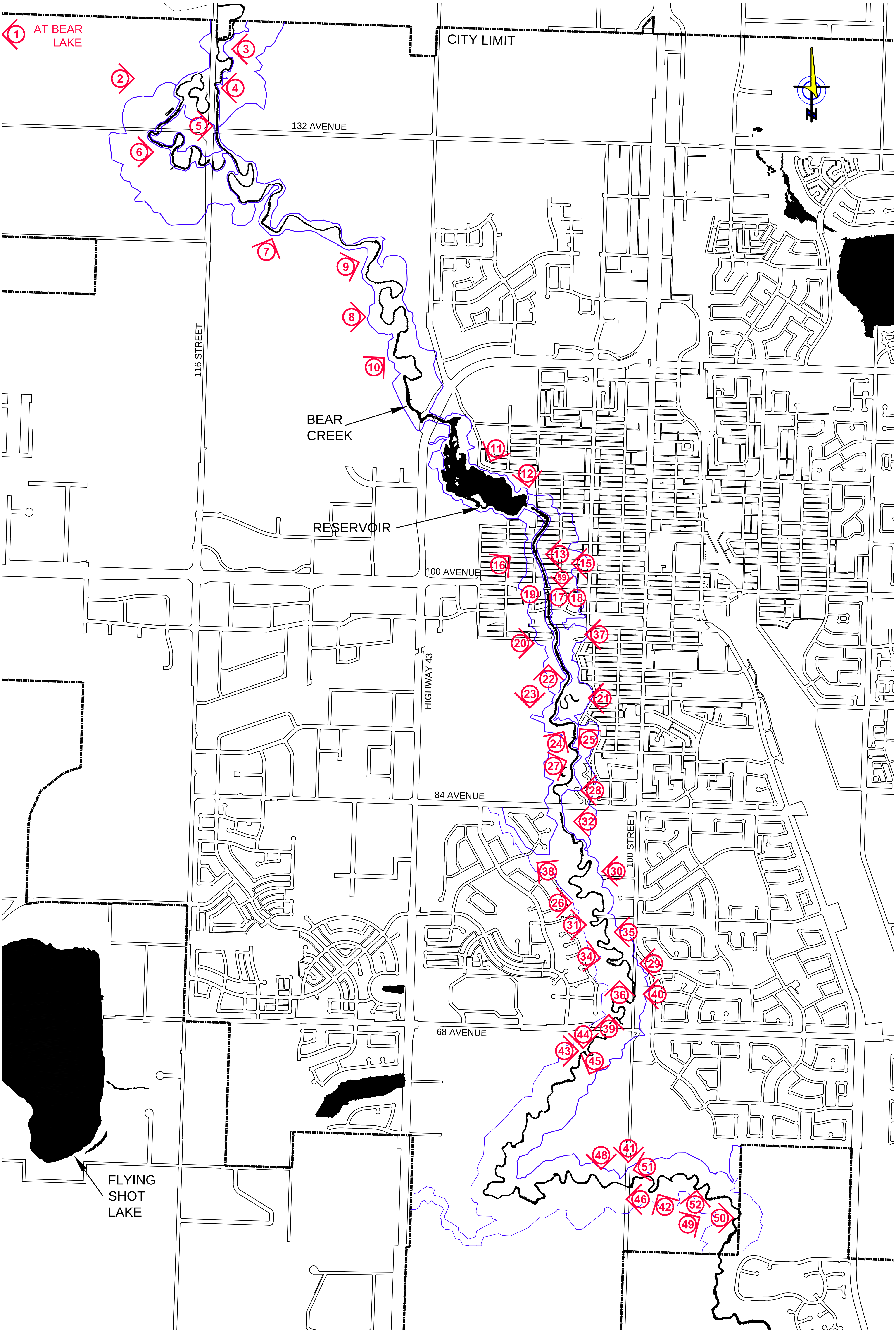
CROSS SECTION LOCATIONS

BEAR CREEK CORRIDOR STUDY
GRANDE PRAIRIE, ALBERTA

SCALE:	JOB NO.	DRAWING NO.
1:25,000	GP-1433	FIGURE 3



ParklandGEO	CLIENT: THE CITY OF GRANDE PRAIRIE	SETBACK DISTANCE vs. SLOPE INCLINATION			
		BEAR CREEK CORRIDOR STUDY GRANDE PRAIRIE, ALBERTA			
		DRAWN: JP	CHK'D.: MMc	REV #: 0	DATE: DECEMBER 2010
		SCALE: 1:1000	JOB NO. GP1433		DRAWING NO. FIGURE 4



REV #	DATE	DETAILS		CLIENT:	
DRAWN: BK	CHK'D.: MMc	REV #: 0	DATE: DECEMBER 2010	THE CITY OF GRANDE PRAIRIE	PHOTOGRAPH LOCATIONS BEAR CREEK CORRIDOR STUDY GRANDE PRAIRIE, ALBERTA
SCALE: 1:25,000	JOB NO. GP-1433	DRAWING NO. FIGURE 5			

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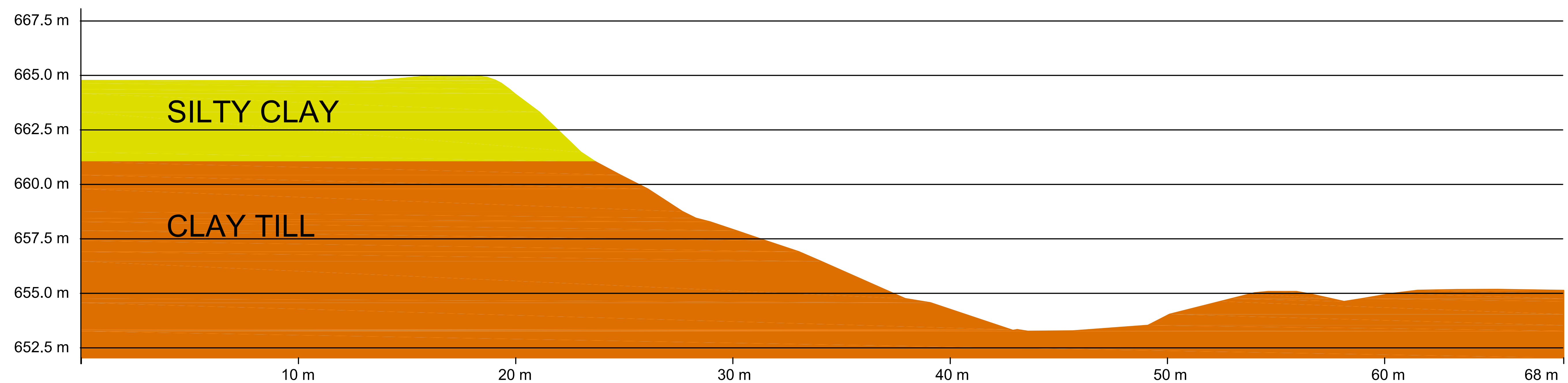
Cross Section K



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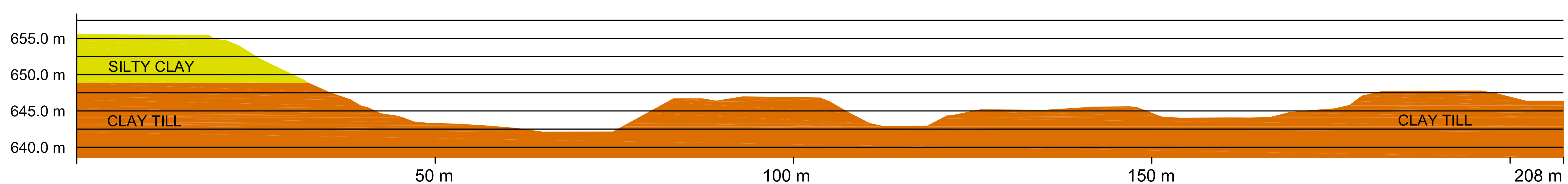

REV #	DATE	DETAILS

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JP	MMc	0	DECEMBER 2010

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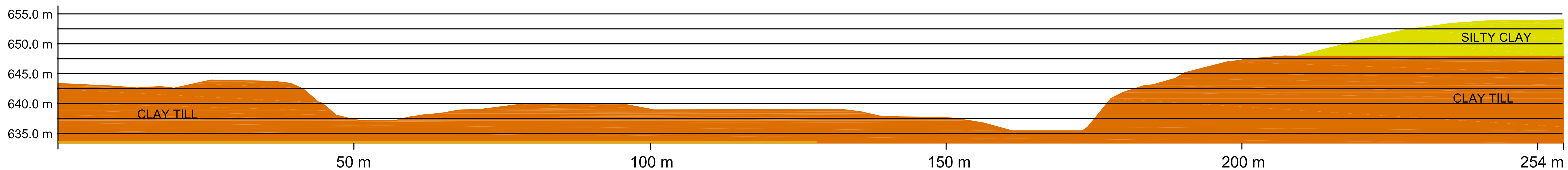
CLIENT:
THE CITY OF GRANDE PRAIRIE

TYPICAL SOIL PROFILES

BEAR CREEK CORRIDOR STUDY
GRANDE PRAIRIE, ALBERTA

SCALE:	JOB NO.	DRAWING NO.
AS SHOWN	GP1433	FIGURE 6

Cross Section j



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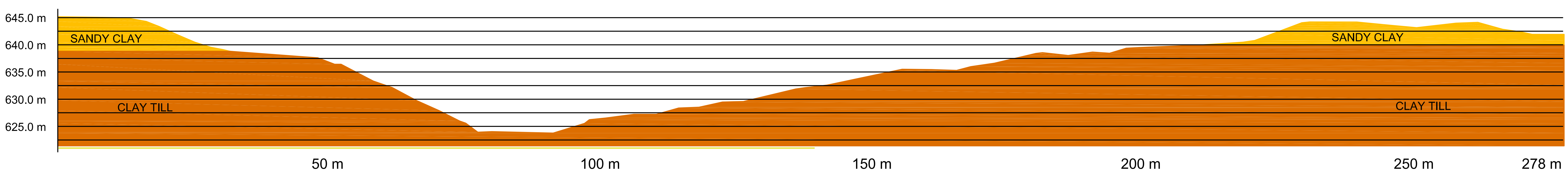

REV #	DATE	DETAILS

DRAWN:	CHK'D.:	REV #:	DATE:
JP	MMc	0	DECEMBER 2010

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CLIENT:
THE CITY OF GRANDE PRAIRIE

TYPICAL SOIL PROFILES

BEAR CREEK CORRIDOR STUDY
GRANDE PRAIRIE, ALBERTA

SCALE:	JOB NO.	DRAWING NO.
AS SHOWN	GP1433	FIGURE 7

SCALE (metres)

-120 -60 0 60 120 240

LEGEND

- Top of Bank (TOB)
- Estimated Development Line (EDL)
- TOB to EDL
- EDL to 40 Metre Setback Zone

REV #	DATE	DETAILS

DRAWN:	CHK'D.:	REV #:	DATE:
JP	MMc	0	DECEMBER 2010

Parkland GEO

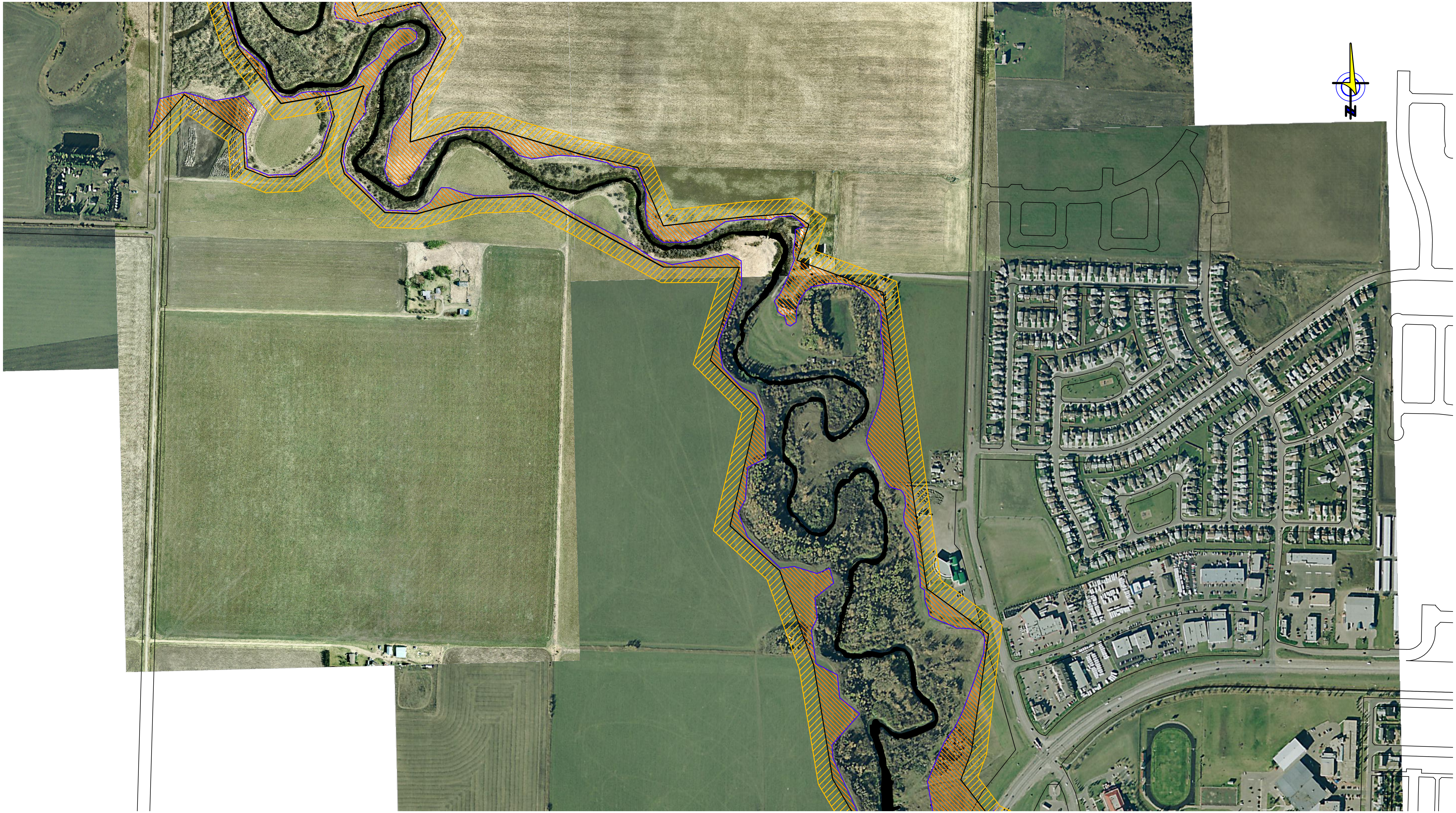
CLIENT:

THE CITY OF GRANDE PRAIRIE

SETBACK ZONES

BEAR CREEK CORRIDOR STUDY
GRANDE PRAIRIE, ALBERTA

SCALE:	JOB NO.	DRAWING NO.
1:7000	GP-1433	FIGURE 8



SCALE (metres)

-120 -60 0 60 120 240

LEGEND

- Top of Bank (TOB)
- Estimated Development Line (EDL)
- TOB to EDL
- EDL to 40 Metre Setback Zone

REV #	DATE	DETAILS

DRAWN:	CHK'D.:	REV #:	DATE:
JP	MMc	0	DECEMBER 2010

ParklandGEO

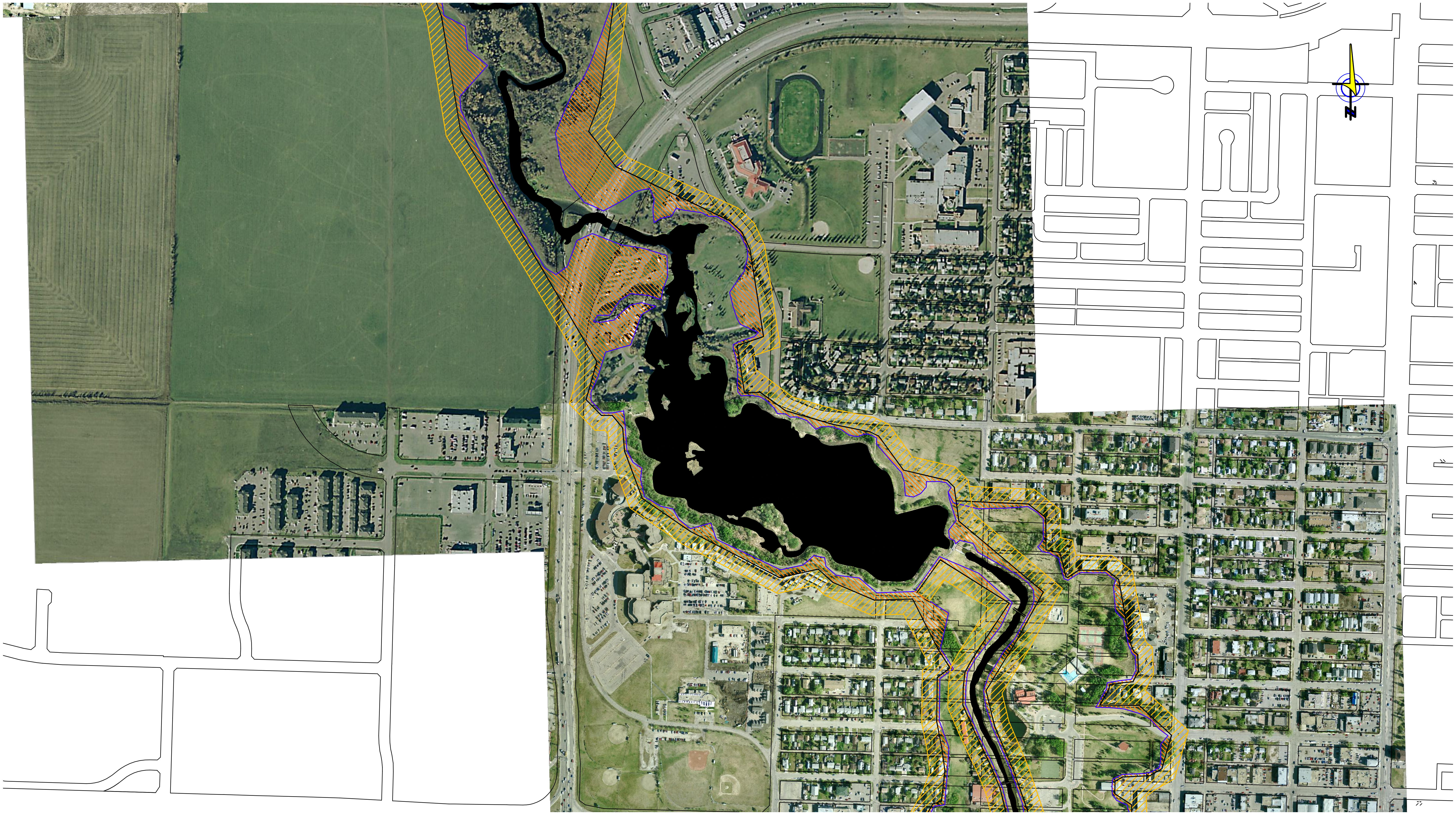
CLIENT:

THE CITY OF GRANDE PRAIRIE

SETBACK ZONES

BEAR CREEK CORRIDOR STUDY
GRANDE PRAIRIE, ALBERTA

SCALE:	JOB NO.	DRAWING NO.
1:7000	GP-1433	FIGURE 9



SCALE (metres)

-120 -60 0 60 120 240

LEGEND

- Top of Bank (TOB)
- Estimated Development Line (EDL)
- TOB to EDL
- EDL to 40 Metre Setback Zone

REV #	DATE	DETAILS

DRAWN:	CHK'D.:	REV #:	DATE:
JP	MMc	0	DECEMBER 2010

ParklandGEO

CLIENT:

THE CITY OF GRANDE PRAIRIE

SETBACK ZONES

BEAR CREEK CORRIDOR STUDY
GRANDE PRAIRIE, ALBERTA

SCALE:	JOB NO.	DRAWING NO.
1:7000	GP-1433	FIGURE 10

SCALE (metres)

-120 -60 0 60 120 240

LEGEND

- Top of Bank (TOB)
- Estimated Development Line (EDL)
- TOB to EDL
- EDL to 40 Metre Setback Zone

REV #	DATE	DETAILS

DRAWN:	CHK'D.:	REV #:	DATE:
JP	MMc	0	DECEMBER 2010

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CLIENT:

THE CITY OF GRANDE PRAIRIE

SETBACK ZONES

BEAR CREEK CORRIDOR STUDY
GRANDE PRAIRIE, ALBERTA

SCALE:	JOB NO.	DRAWING NO.
1:7000	GP-1433	FIGURE 11

LEGEND

- Top of Bank (TOB)
- Estimated Development Line (EDL)
- TOB to EDL
- EDL to 40 Metre Setback Zone

REV #	DATE	DETAILS

DRAWN:	CHK'D.:	REV #:	DATE:
JP	MMc	0	DECEMBER 2010

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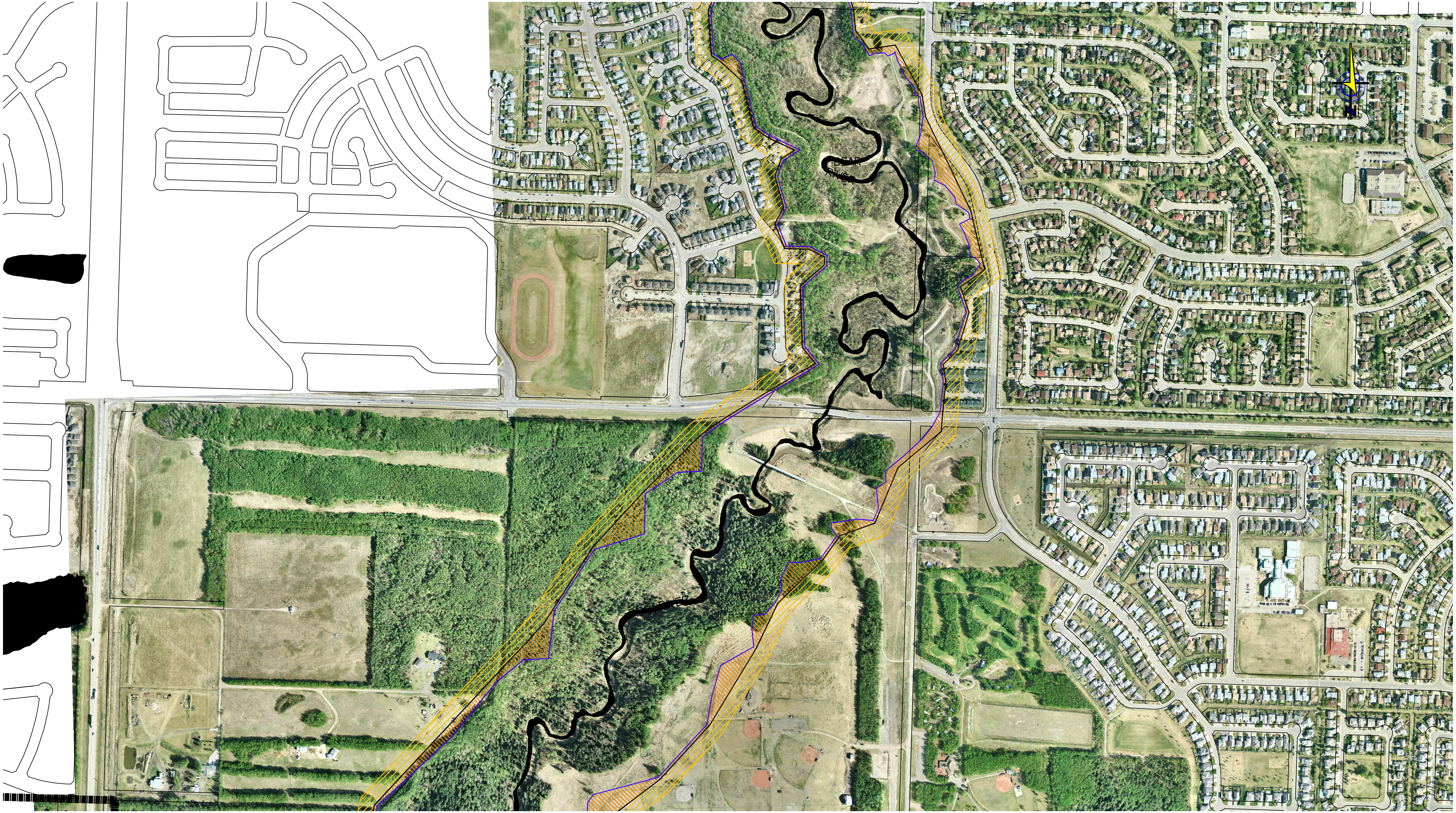
CLIENT:

THE CITY OF GRANDE PRAIRIE

SETBACK ZONES

BEAR CREEK CORRIDOR STUDY
GRANDE PRAIRIE, ALBERTA

SCALE:	JOB NO.	DRAWING NO.
1:7000	GP-1433	FIGURE 12



SCALE (metres)

-120 -60 0 60 120 240

LEGEND

- Top of Bank (TOB)
- Estimated Development Line (EDL)
- TOB to EDL
- EDL to 40 Metre Setback Zone

REV #	DATE	DETAILS

DRAWN:	CHK'D.:	REV #:	DATE:
JP	MMc	0	DECEMBER 2010

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CLIENT:

THE CITY OF GRANDE PRAIRIE

SETBACK ZONES

BEAR CREEK CORRIDOR STUDY
GRANDE PRAIRIE, ALBERTA

SCALE:	JOB NO.	DRAWING NO.
1:7000	GP-1433	FIGURE 13

SCALE (metres)

-120 -60 0 60 120 240

LEGEND

- Top of Bank (TOB)
- Estimated Development Line (EDL)
- TOB to EDL
- EDL to 40 Metre Setback Zone

REV #	DATE	DETAILS

DRAWN:	CHK'D.:	REV #:	DATE:
JP	MMc	0	DECEMBER 2010

ParklandGEO

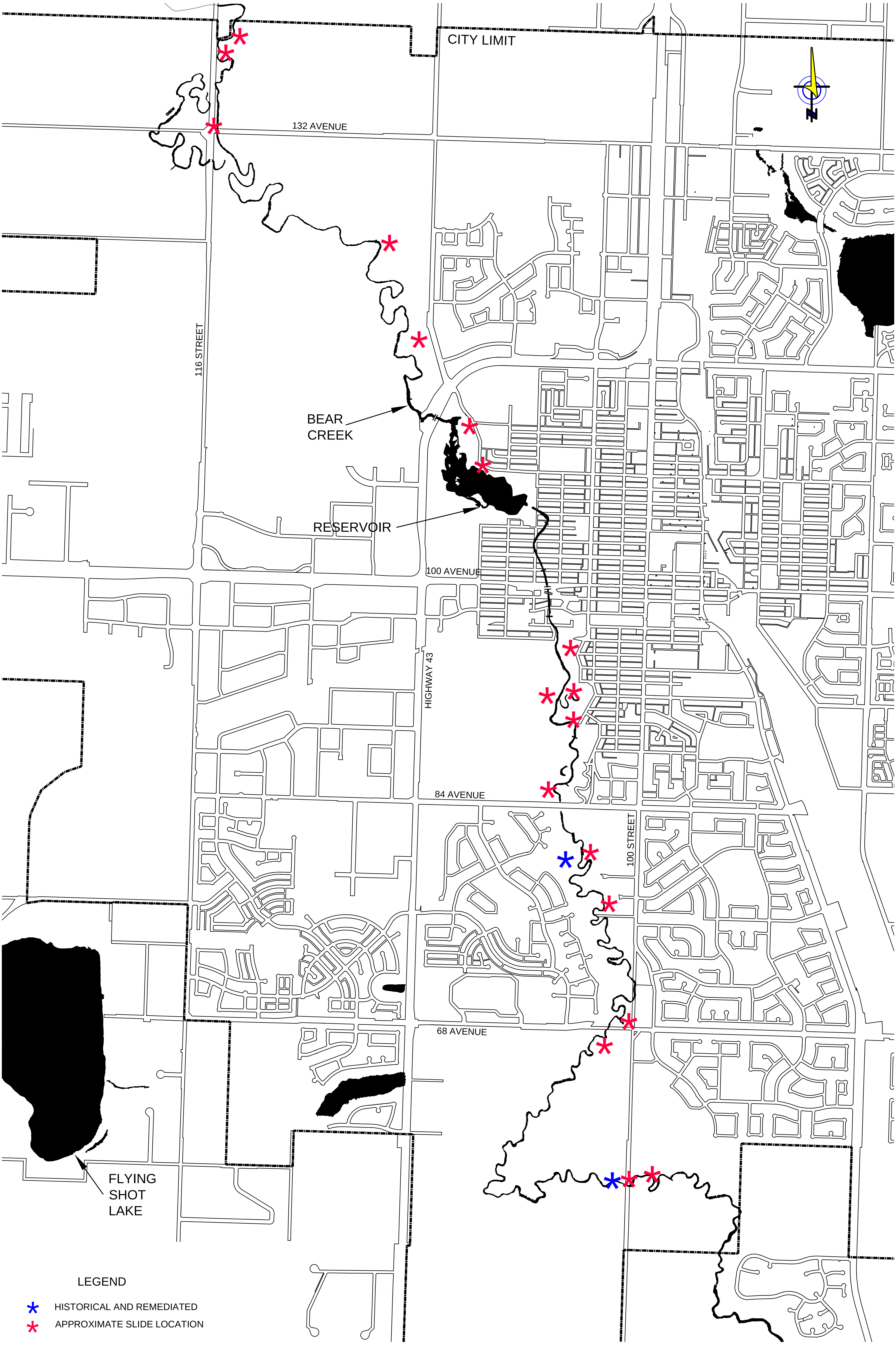
CLIENT:

THE CITY OF GRANDE PRAIRIE

SETBACK ZONES

BEAR CREEK CORRIDOR STUDY
GRANDE PRAIRIE, ALBERTA

SCALE:	JOB NO.	DRAWING NO.
1:7000	GP-1433	FIGURE 14



REV #	DATE	DETAILS

DRAWN:	CHK'D.:	REV #:	DATE:
BK	MMc	0	DECEMBER 2010

ParklandGEO

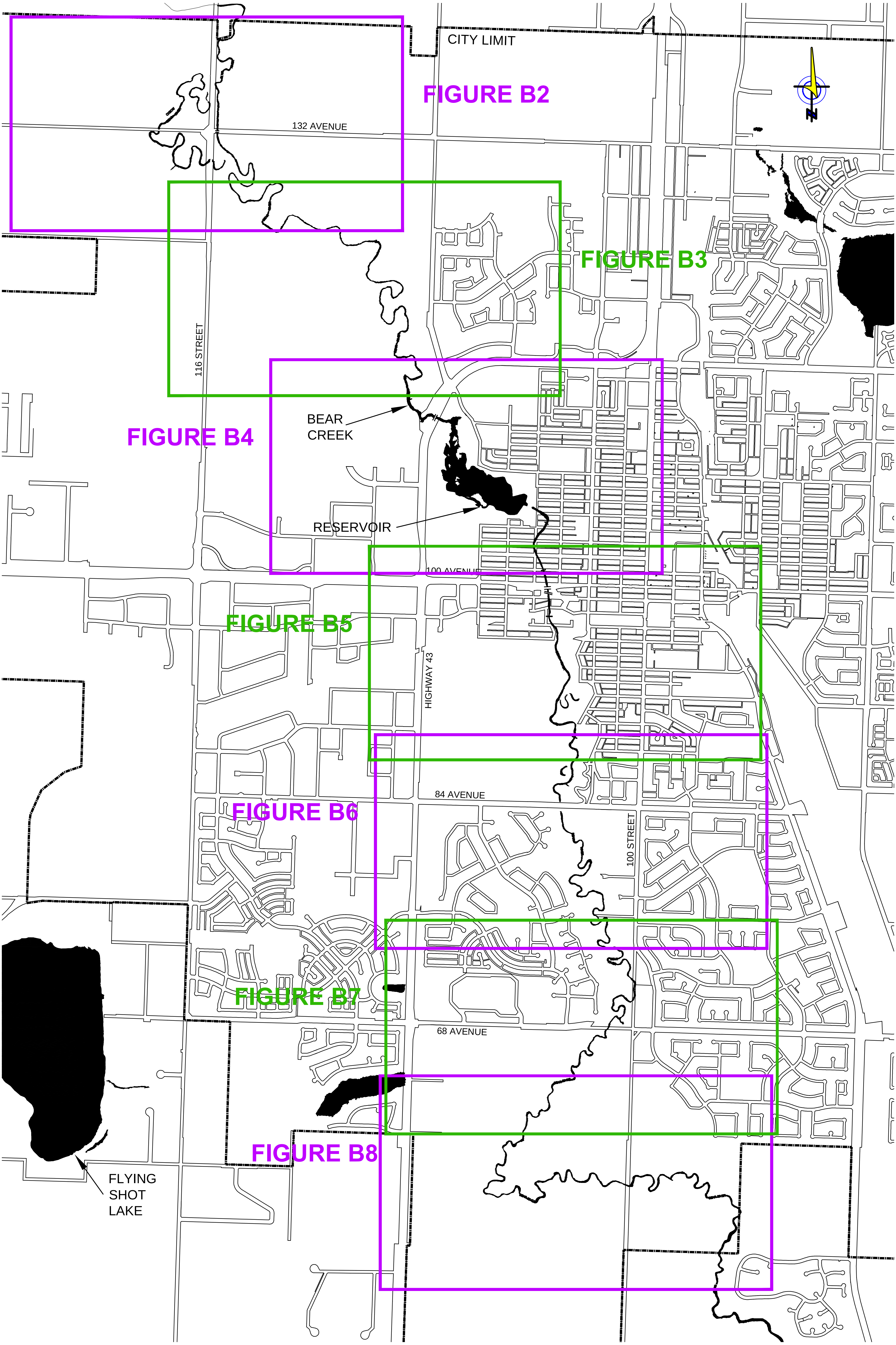
CLIENT:

THE CITY OF GRANDE PRAIRIE

LOCATIONS OF SIGNIFICANT SLIDES

BEAR CREEK CORRIDOR STUDY
GRANDE PRAIRIE, ALBERTA

SCALE:	JOB NO.	DRAWING NO.
1:25,000	GP-1433	FIGURE 15



REV #	DATE	DETAILS

DRAWN:	CHK'D.:	REV #:	DATE:
BK	MMc	0	DECEMBER 2010

ParklandGEO

CLIENT:

THE CITY OF GRANDE PRAIRIE

KEY PLAN - LiDAR IMAGERY

BEAR CREEK CORRIDOR STUDY
GRANDE PRAIRIE, ALBERTA

SCALE:	JOB NO.	DRAWING NO.
1:25,000	GP-1433	FIGURE B1

APPENDIX A

PHOTOGRAPHS

Photograph 1: Bear Creek at the east end of Bear Lake.

Photograph 2: Meandering oxbows (bottom portion of photo) along cut off portion of Bear Creek just south of the north City Limit. The active Bear Creek is located east of 116 Street (top portion of photograph - north is to the left).

Photograph 3: Typical slumps along creek along the entire creek from 132 Avenue to the northern City Limit. The typical valley depth from upland to water elevation is typically less than 3 m along much of this section. Some beaver activity observed.

Photograph 4: Beaver activity and erosion near 116 Street. Failure scarp noted with arrow. Beaver activity is causing increased water velocity in some areas, resulting in slope instability; however, this is not a major cause of failures in this area.

Photograph 5: Bridge at 132 Avenue looking east. Minor tension cracks indicative of slope movement were observed adjacent to the east and west abutments, on the north side of the bridge. This areas should be monitored for future movements.

Photograph 6: Looking east at dead oxbows west of 116 Street and the active and creek channel with low areas to the east. Bear Creek becomes progressively deeper towards the southeast (the Royal Oaks district is in the background).

Photograph 7: Typical meanders and low-lying area south of 132 Avenue on private farm west of Royal Oaks and north of Bypass Road.

Photograph 8: Meanders and two distinct over-steepened areas immediately northwest of the People's Church development. A detailed setback study would be required for the entire length of Bear Creek through this quarter section prior to development.

Photograph 9: Slope failure by the barn located on the farm west of 108 Street and 200 m south of 132 Avenue. Two failure scarps were present with the closest failure within 5 m of the barn.

Photograph 10: Relatively stable slopes near the Peoples Church facility, north of the by-pass road (Highway 43) and west of 108 Street. Infilling of the old channel pushed Bear Creek further west, which has contributed to the overall stability and lack of erosion near the developed area.

Photograph 11: Looking south across the Reservoir with Grande Prairie Regional College in the background. The reservoir is very shallow throughout much of the area, with the water depth being typically less than 300 mm. A slightly deeper channel is located running the length of the reservoir, located at the bottom of the photo.

Photograph 12: Discharge from the reservoir is through a weir located at the east end near 104 Street, within Muskoseepi Park. The creek and land elevation downstream of the weir is about 4 m lower than upstream.

Photograph 13: Straight section of Bear Creek, looking northwest at the Museum. A few minor slope failures (arrow) were located along this section of the creek towards the 100 Avenue bridge.

Photograph 14: Looking south, downstream of the Museum at the 100 Avenue bridge.

Photograph 15: Aerial view looking west, showing Bear Creek and a stocked recreational fishing pond (bottom of photo) on the east side of the creek. The Museum facility is to the west.

Photograph 16: Looking northeast along creek with pedestrian footbridge.

Photograph 17: Gabions at the 100 Avenue bridge, located upslope of the bike path (bottom of photograph). The gabions are in good condition but subject to some vandalism, as large rocks have been removed from the baskets.

Photograph 18: Tension crack at 100 Avenue bridge in the paved bike trail (east side of creek). The tension cracks are indicative of slow creeping slope movement and are a maintenance issue. Cracks should be filled to minimize water infiltration and for safety purposes.

Photograph 19: Looking east across the Bear Creek at the rip-rap covered abutment for the two bridges at 100 Avenue.

Photograph 20: Aerial view looking east at the old wood trestle train bridge. The valley depth has increased significantly south (downstream) of the 100 Avenue bridges.

Photograph 21: Utilidor Bridge crossing the Bear Creek. A large oxbow is visible in the picture foreground. The straight alignment of the creek indicates that this portion of the channel had been straightened, likely to avoid instability issues.

Photograph 22: Looking north along Bear Creek. Grass covered landslide debris indicates that this portion of the stream has stabilized within the recent past, likely due to reduced stream flows allowing vegetation to establish. A more recent slope failure is visible in the background (arrow).

Photograph 23: Typical vegetated section between 96 and 90 Avenue, with oversteepened unvegetated slopes at the outside creek bends, particularly evident where topographic high points occur along the creek.

Photograph 24: Slopes at inclinations of about 2.5 (H) to 1(V) are more stable due to better vegetative cover, but are still susceptible to toe erosion induced failures. This is a surficial failure that does not extend significantly back from the slope face. With the eventual loss of the vegetation, this slope would be prone to a larger regressive rotational failure that would extent much further back.

Photograph 25: Lateral migration of the slope face is occurring due to weathering and toe erosion. Most areas have residential developments further back from the slope to not be at risk from large failures, particularly along 102 Street between 86 and 100 Avenue.

Photograph 26: Typical undeveloped areas within the Bear Creek valley.

Photograph 27: Over-steepened slope coincident with a topographic rise and an outside bed along Bear Creek.

Photograph 28: Failure located east of Canfor along the north side of 84 Avenue. The creek has been straightened from immediately north of the bridge to at least 60 m south. Although vegetation is starting to establish on the slope face within the failure zone, continued erosion by the creek due to the very sharp bend will likely result in further regression until a more stable angle is reached.

Photograph 29: Typical sinusoidal creek path with oxbow feature, looking west near 72B Avenue and 102 Street.

Photograph 30: Looking west at Bear Creek, with typical parkland trails. A drainage channel extends from the west to flow into Bear Creek. Located north of 79 Avenue and east of 102 Street.

Photograph 31: Typical creek section south of 84 Avenue, looking east at 75 Avenue.

Photograph 32: South of 84 Avenue Bridge showing straight section of the creek and paved walking trail to the west side of the creek.

Photograph 33: Stable section of Bear Creek, with relatively gentle valley slopes and minimal erosion.

Photograph 34: Typical over-steepened outside bend along creek. The creek has cut through the upper lacustrine deposits (upper light brown soil) and is within the deeper clay till (darker soil) which is relatively stronger than the upper material.

Photograph 35: Relatively stable section of the creek, with thick grass vegetation minimizing erosion. Minor erosion at the water line is evident but lateral migration of the channel is minimized. The hummocky terrain indicates that this area was likely a historic landslide area.

Photograph 36: Looking along Bear Creek from a footbridge crossing around 71 Avenue. Relatively low stream velocities have allowed thicker vegetation to establish in this area. There were generally fewer tight bends in the channel which minimized outside bends.

Photograph 37: Looking south from a footbridge. A storm outfall was located to the right side of the photograph. The gravel in the river appears to be rip-rap placed to minimize erosion due to storm flows.

Photograph 38: A stormwater drainage channel leading into Bear Creek. The thick vegetation will minimize sediment transport into the creek, and will also minimize erosion within the drainage channel.

Photograph 39: Looking southwest at the creek immediately north of the 68 Avenue bridge, showing very tight bends that will likely result in new oxbow formations. The new bridge crossing at 68 Avenue displays less obvious signs of straightening or stream alteration.

Photograph 40: Typical section of creek in the areas north of 68 Avenue, with wide natural areas between the creek and the residential developments allowing an adequate buffer to minimize the impacts of potential slope failures.

Photograph 41: Looking north at the utilidor at 100 Street, carrying potable water lines from the adjacent treatment plant, located to the south. The treatment plant obtains its water from the Wapiti River, further to the southeast.

Photograph 42: Looking north. The ball diamonds east of 100 Street are in the background. The valley is deeper in this area, with steeper slopes, with evidence of current and historical landslide activity being observed. No developments were located immediately adjacent to this portion of Bear Creek.

Photograph 43: Utility crossing with pedestrian access south of 68 Avenue, looking east. The gravel lines the stream bed, as erosion of the clay till has removed all clay and silt materials.

Photograph 44: Rip-rap on the outside bend upstream of the utility bridge. The rip-rap has been effective on the west side of the creek, but significant erosion is present on the east side.

Photograph 45: Typical stream south of 68 Avenue, with more gravel and cobbles along the stream bed. There is minimal residential development south of this area. The valley becomes deeper, further to the south and to the east. Bear Creek is downcutting through clay till and clayshale bedrock in these areas which is a change in geology and will result in different slope profiles and behavior.

Photograph 46: Typical slope section along far south extent of Bear Creek before turning east.

Photograph 47: Surficial sloughing failure at relatively shallow slope inclination, likely triggered by toe erosion.

Photograph 48: Oxbow lake located 3 to 4 metres above river elevation. The water treatment plant is in the background. The relatively straight portion of the main creek, along with the significant elevation difference between the oxbow lake and the creek, indicates that this portion of the river may have been straightened and lowered.

Photograph 49: Beaver activity was more prevalent along the east-west portion of Bear Creek, particularly east of the water treatment plant.

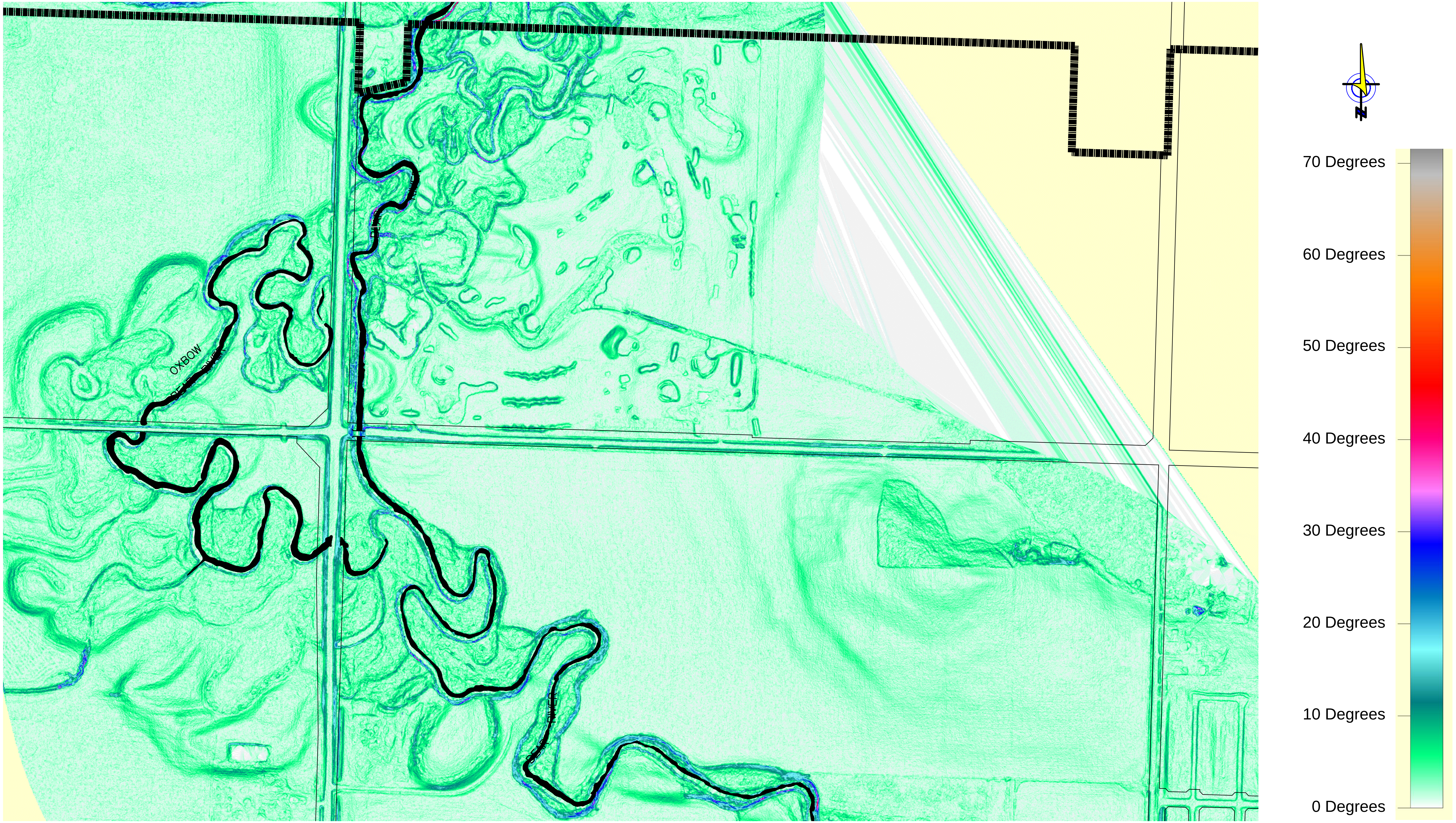
Photograph 50: Residential development in the County of Grande Prairie near creek at the eastern end of the study area. This area has a relatively shallow valley and modest slopes.

Photograph 51: Slope failure in the northeast abutment fill of the utilidor bridge located along 100 Street, likely caused by toe erosion.

Photograph 52: Over-steepened slopes and side cutting which will form an oxbow. The slopes east of 100 Street were generally stable at steep inclinations than slopes further west and north, as the exposed soils were likely clay shale bedrock, and less susceptible to erosion.

APPENDIX B

LiDAR IMAGERY



SCALE (metres)

-120 -60 0 60 120 240

REV #	DATE	DETAILS

DRAWN:	CHK'D.:	REV #:	DATE:
JP	MMc	0	DECEMBER 2010

ParklandGEO

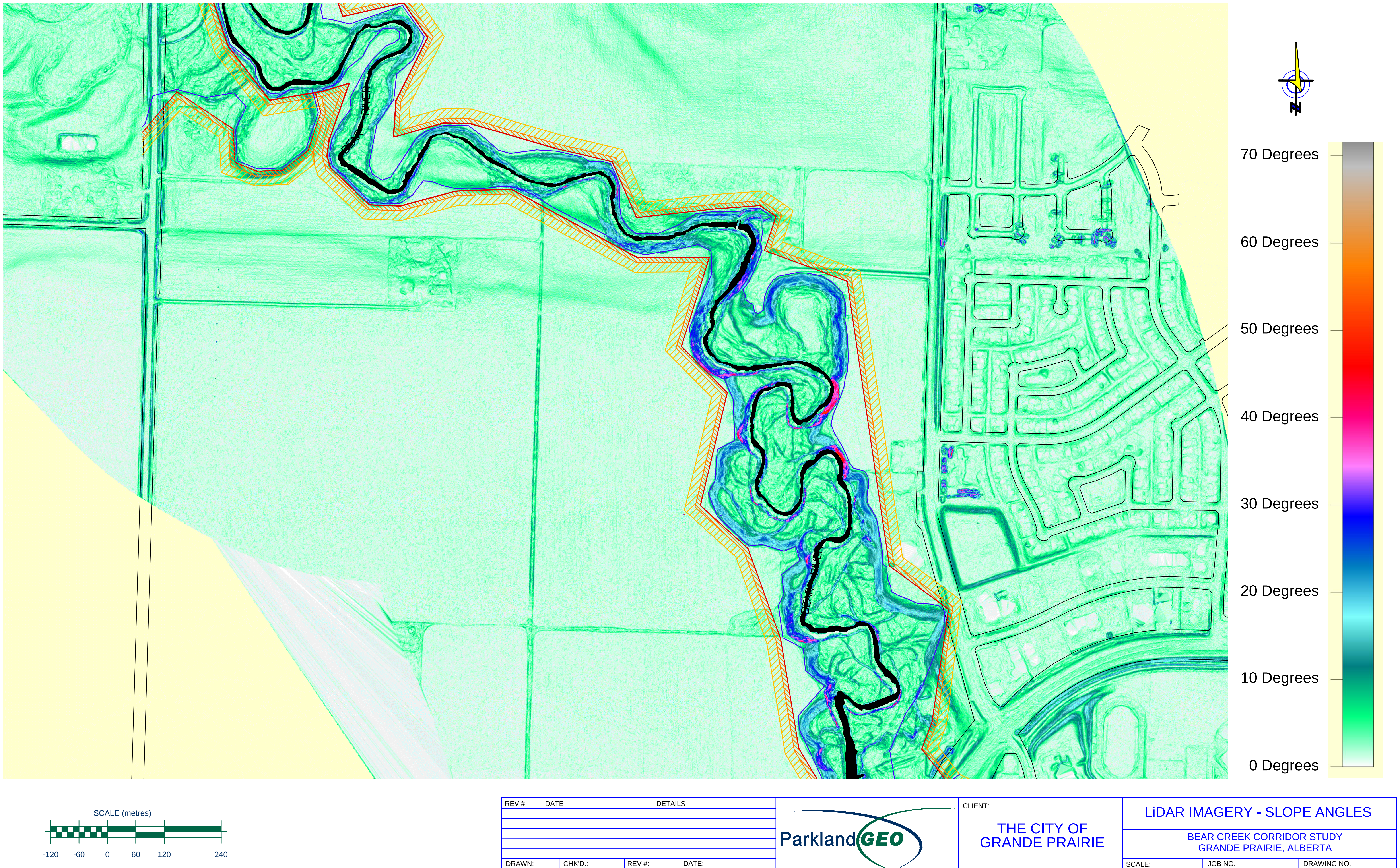
CLIENT:

THE CITY OF GRANDE PRAIRIE

LiDAR IMAGERY - SLOPE ANGLES

BEAR CREEK CORRIDOR STUDY
GRANDE PRAIRIE, ALBERTA

SCALE:	JOB NO.	DRAWING NO.
1:7000	GP-1433	FIGURE B2



REV #	DATE	DETAILS		
DRAWN: JP	CHK'D.: MMc	REV #: 0	DATE: DECEMBER 2010	

Parkland GEO

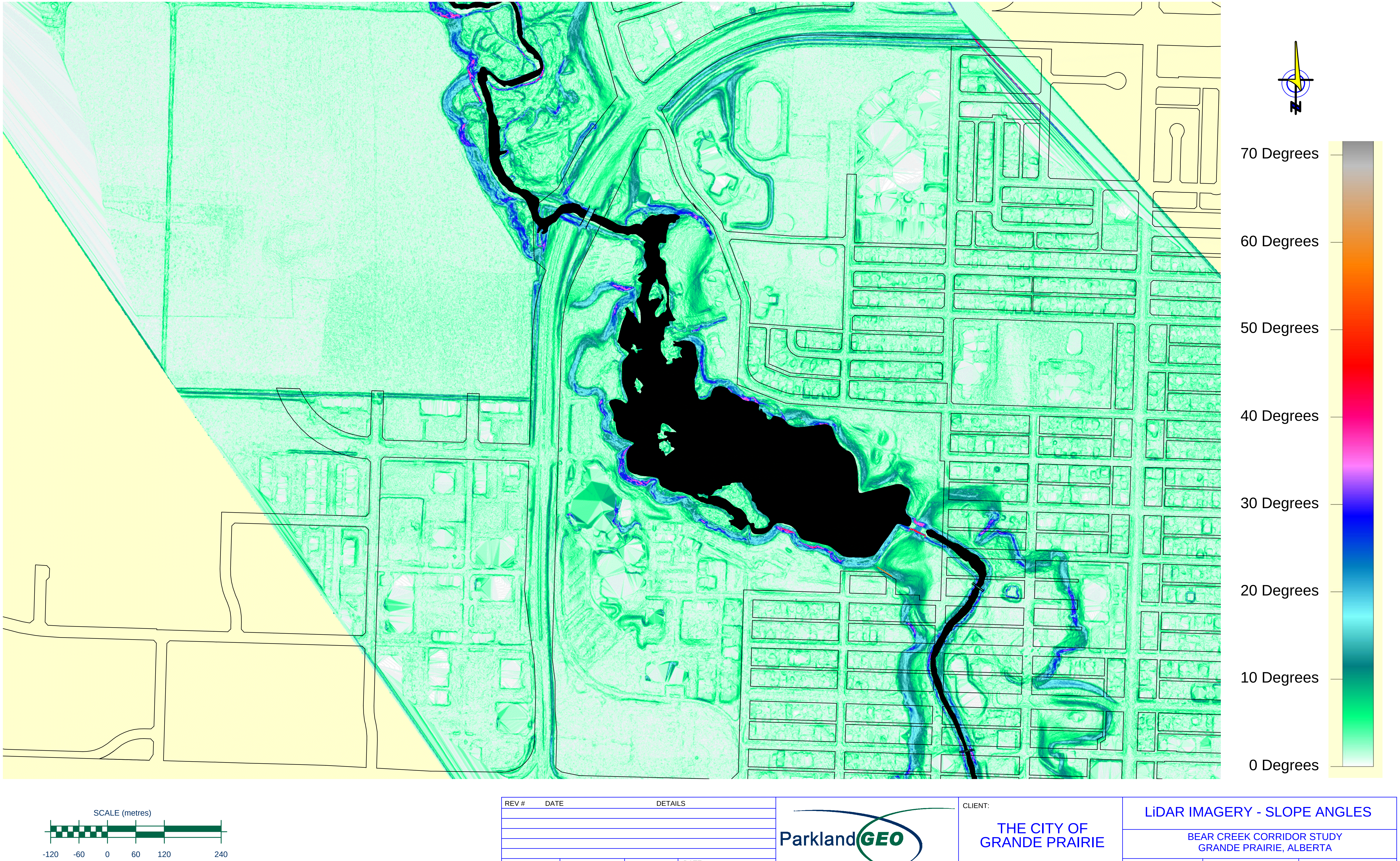
CLIENT:

THE CITY OF GRANDE PRAIRIE

LiDAR IMAGERY - SLOPE ANGLES

BEAR CREEK CORRIDOR STUDY
GRANDE PRAIRIE, ALBERTA

SCALE:	JOB NO.	DRAWING NO.
1:7000	GP-1433	FIGURE B3



REV #	DATE	DETAILS

DRAWN:	CHK'D.:	REV #:	DATE:
JP	MMc	0	DECEMBER 2010

Parkland GEO

CLIENT:

THE CITY OF GRANDE PRAIRIE

LiDAR IMAGERY - SLOPE ANGLES

BEAR CREEK CORRIDOR STUDY
GRANDE PRAIRIE, ALBERTA

SCALE:	JOB NO.	DRAWING NO.
1:7000	GP-1433	FIGURE B4

SCALE (metres)

-120 -60 0 60 120 240

REV #	DATE	DETAILS

DRAWN:	CHK'D.:	REV #:	DATE:
JP	MMc	0	DECEMBER 2010

ParklandGEO

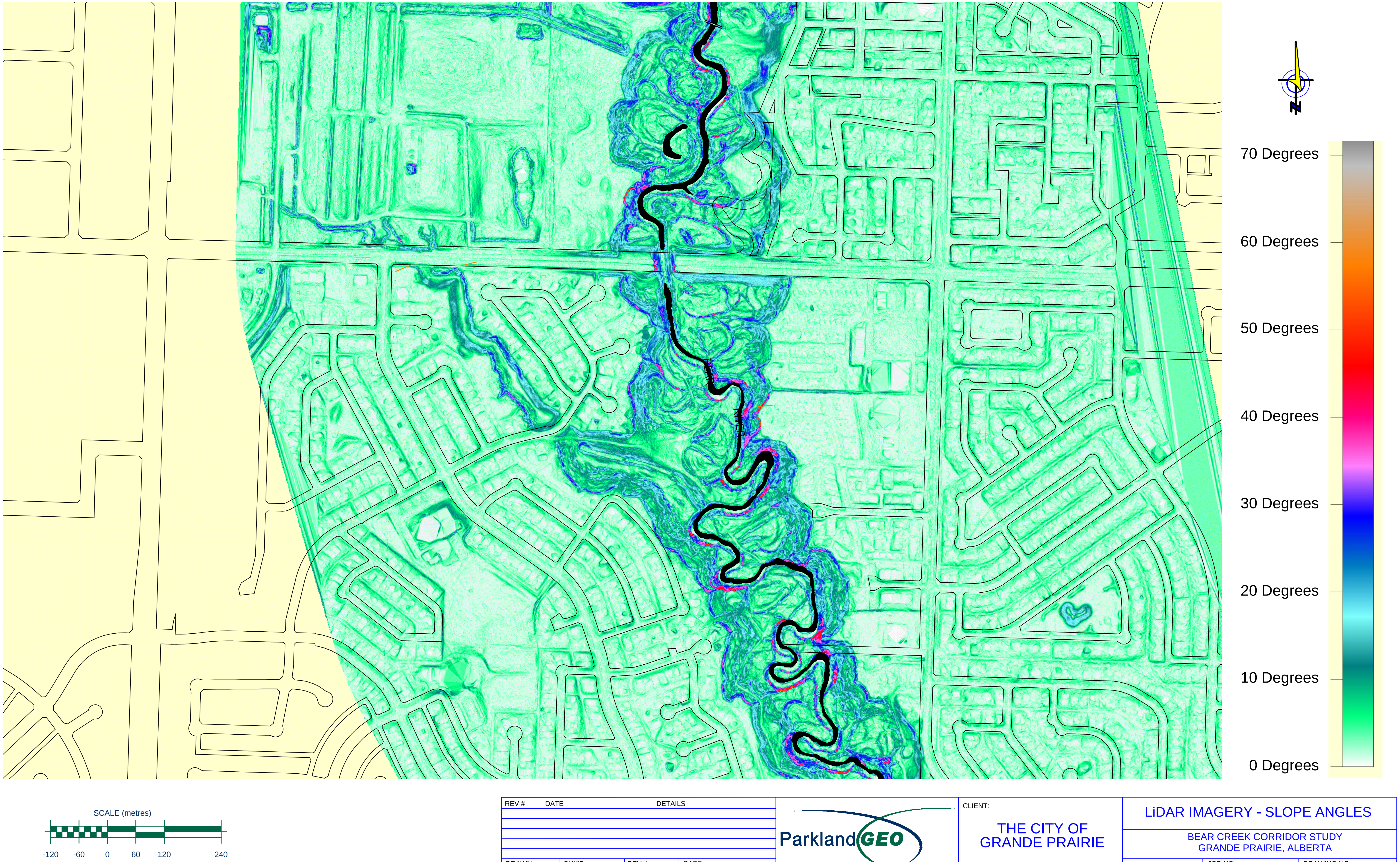
CLIENT:

THE CITY OF GRANDE PRAIRIE

LiDAR IMAGERY - SLOPE ANGLES

BEAR CREEK CORRIDOR STUDY
GRANDE PRAIRIE, ALBERTA

SCALE:	JOB NO.	DRAWING NO.
1:7000	GP-1433	FIGURE B5



REV #	DATE	DETAILS

DRAWN:	CHK'D.:	REV #:	DATE:
JP	MMc	0	DECEMBER 2010

ParklandGEO

CLIENT:

THE CITY OF GRANDE PRAIRIE

LiDAR IMAGERY - SLOPE ANGLES

BEAR CREEK CORRIDOR STUDY
GRANDE PRAIRIE, ALBERTA

SCALE:	JOB NO.	DRAWING NO.
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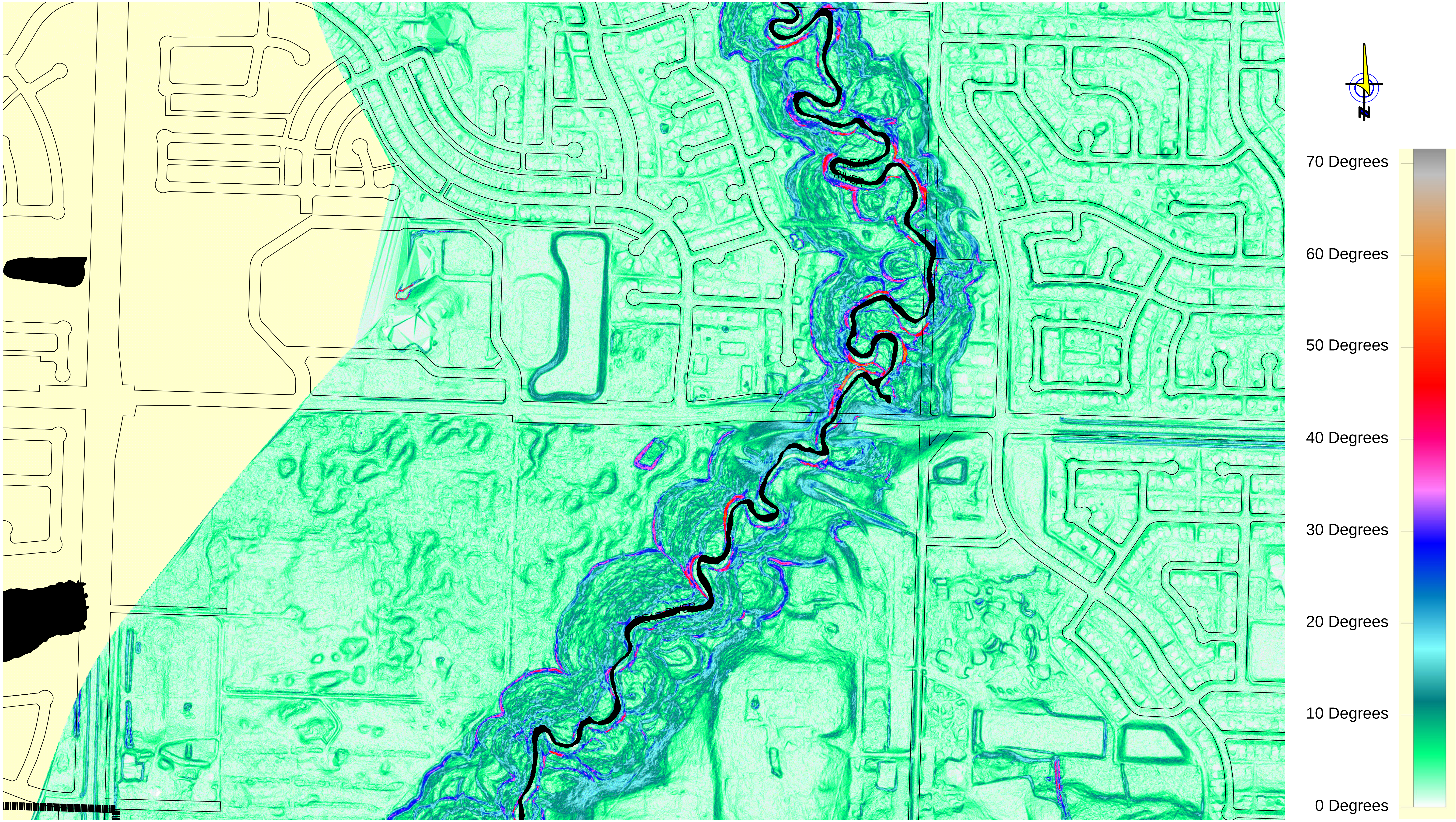

SCALE (metres)

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REV #	DATE	DETAILS

DRAWN:	CHK'D.:	REV #:	DATE:
JP	MMc	0	DECEMBER 2010

Parkland GEO

CLIENT:

THE CITY OF GRANDE PRAIRIE

LiDAR IMAGERY - SLOPE ANGLES

BEAR CREEK CORRIDOR STUDY
GRANDE PRAIRIE, ALBERTA

SCALE:	JOB NO.	DRAWING NO.
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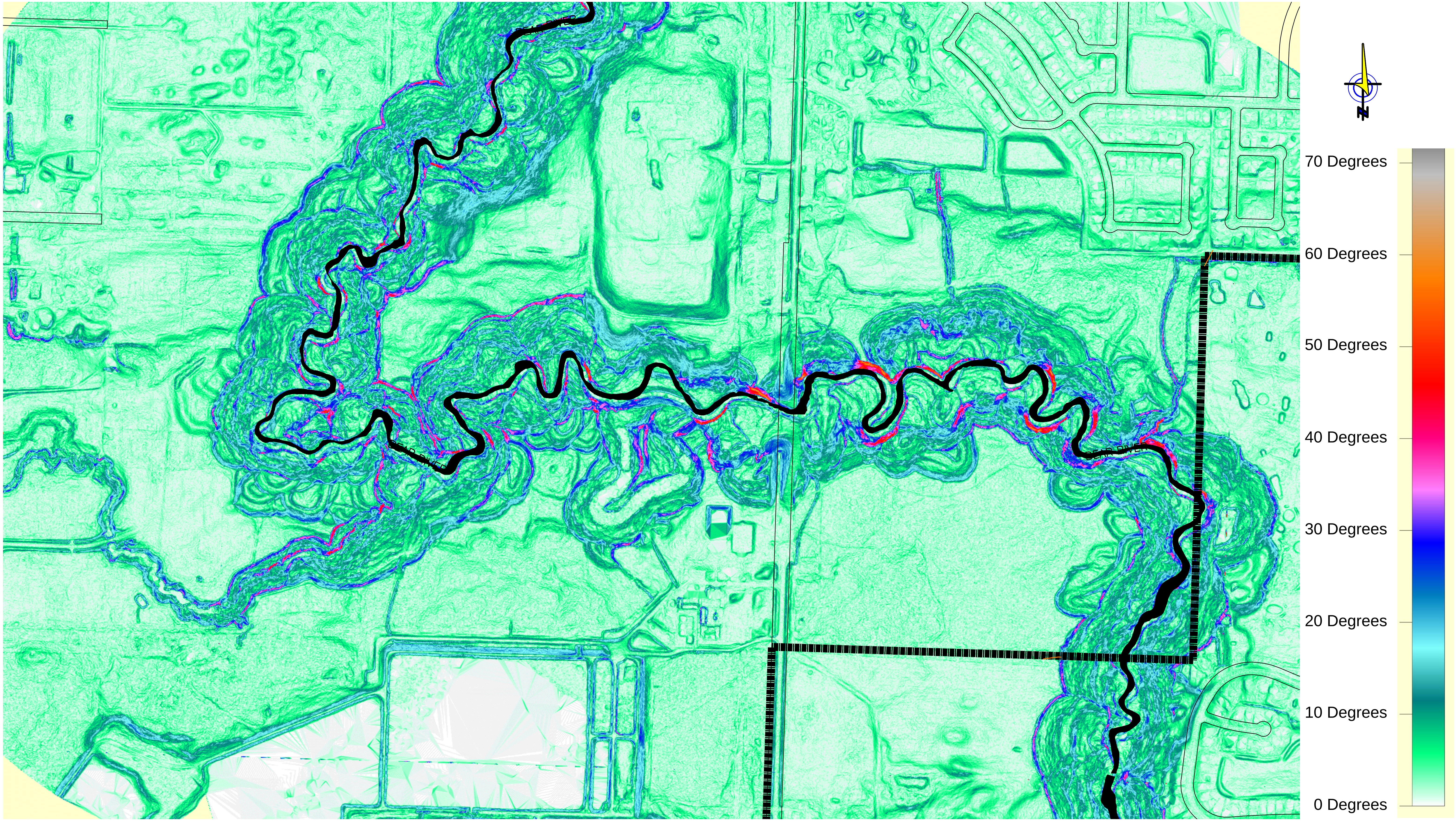

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JP	MMc	0	DECEMBER 2010

Parkland GEO

CLIENT:

THE CITY OF GRANDE PRAIRIE

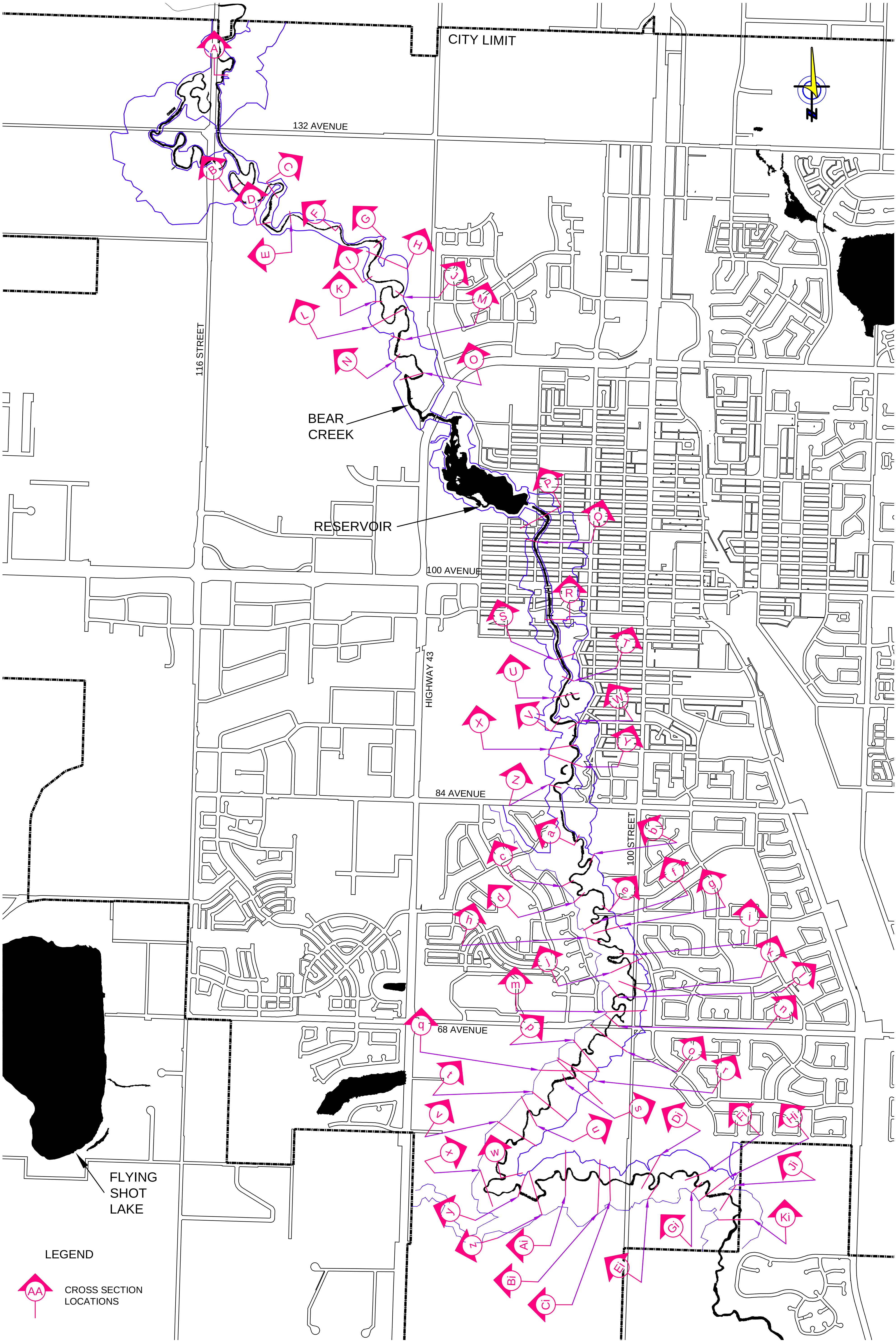
LiDAR IMAGERY - SLOPE ANGLES

BEAR CREEK CORRIDOR STUDY
GRANDE PRAIRIE, ALBERTA

SCALE:	JOB NO.	DRAWING NO.
1:7000	GP-1433	FIGURE B8

APPENDIX C

SLOPE CROSS SECTIONS



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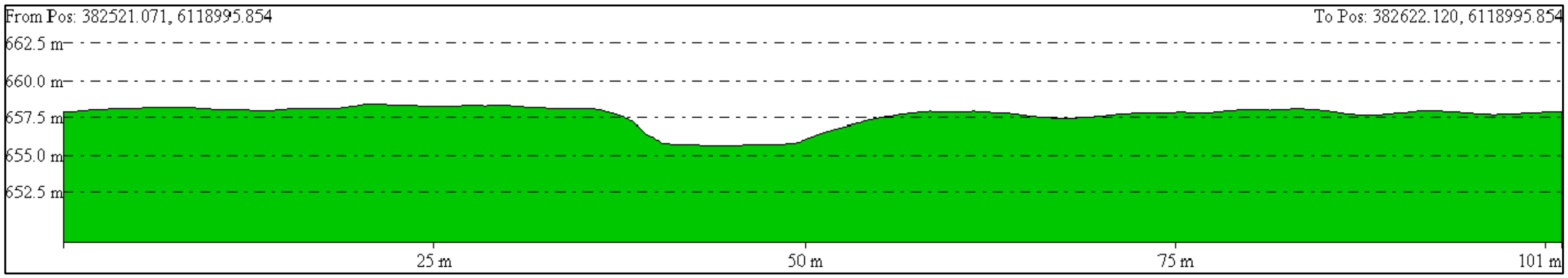
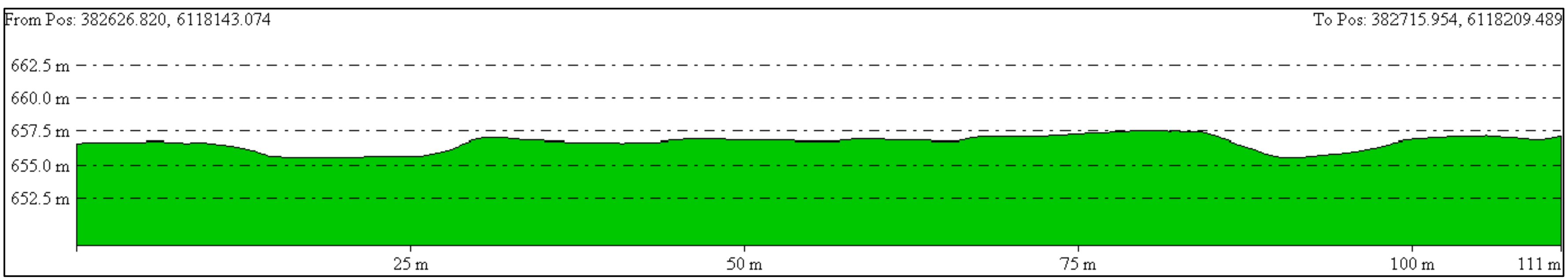
DRAWN: BK	CHK'D.: MMc	REV #: 0	DATE: DECEMBER 2010	THE CITY OF GRANDE PRAIRIE	BEAR CREEK CORRIDOR STUDY GRANDE PRAIRIE, ALBERTA		
					SCALE: 1:25,000	JOB NO. GP-1433	DRAWING NO. FIGURE 3

ParklandGEO

Cross Section A



Cross Section B



ParklandGEO

CLIENT: City of Grande Prairie

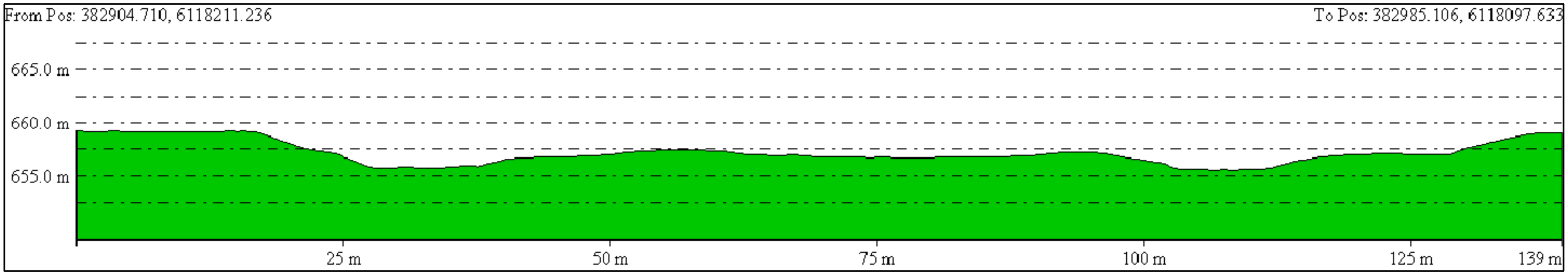
Cross Sections A and B

Bear Creek Corridor Study
Grande Prairie, Alberta

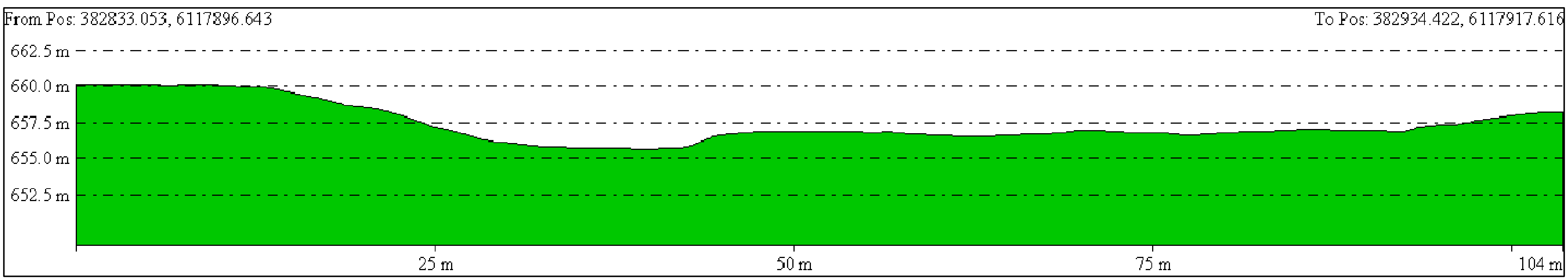
DRAWN:	CHK'D.:	REV #:	DATE:
NT	JP	0	December, 2010

SCALE:	JOB NO.	DRAWING NO.
As shown	GP 1433	Figure C - 1

Cross Section C



Cross Section D

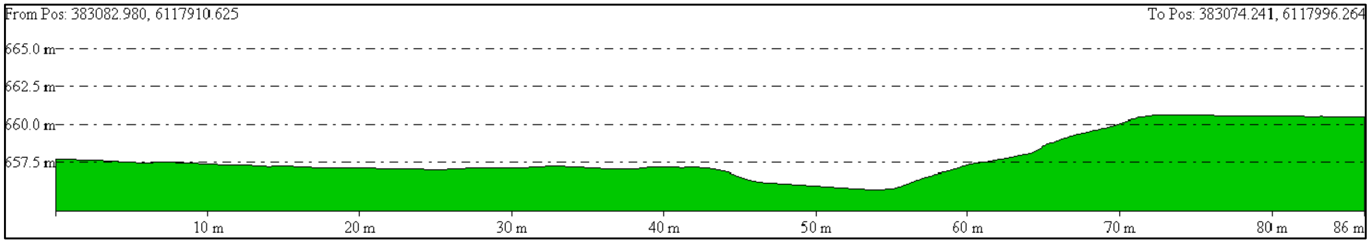


ParklandGEO	CLIENT: City of Grande Prairie	**Cross Sections C and D** Bear Creek Corridor Study Grande Prairie, Alberta

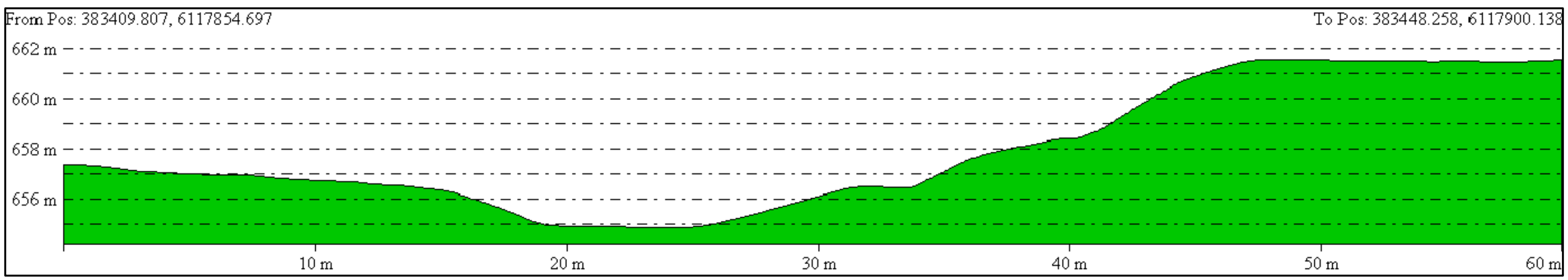
DRAWN:	CHK'D.:	REV #:	DATE:
NT	JP	0	December, 2010

SCALE:	JOB NO.	DRAWING NO.
As shown	GP 1433	Figure C - 2

Cross Section E



Cross Section F

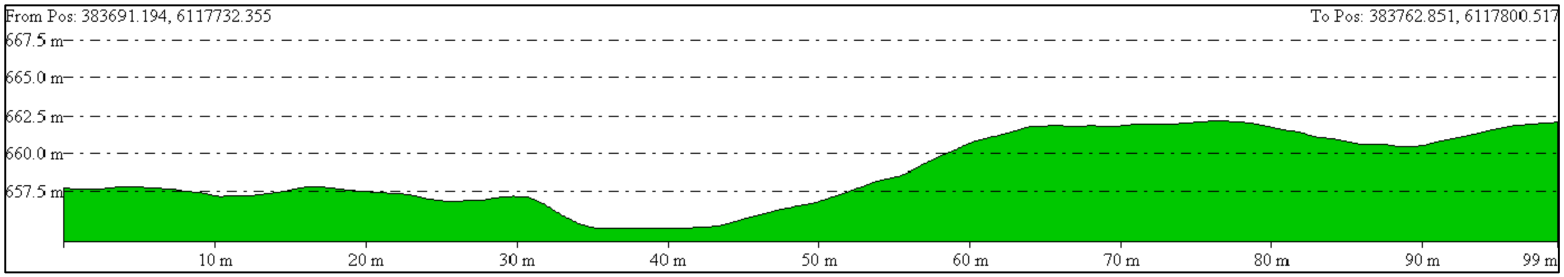


ParklandGEO	CLIENT: City of Grande Prairie	Cross Sections E and F Bear Creek Corridor Study Grande Prairie, Alberta

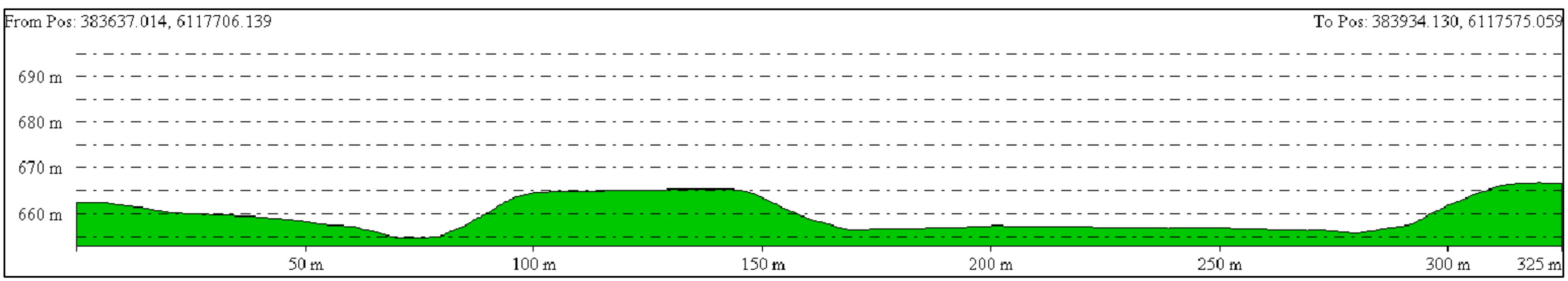
DRAWN:	CHK'D.:	REV #:	DATE:
NT	JP	0	December, 2010

SCALE:	JOB NO.	DRAWING NO.
As shown	GP 1433	Figure C - 3

Cross Section G



Cross Section H

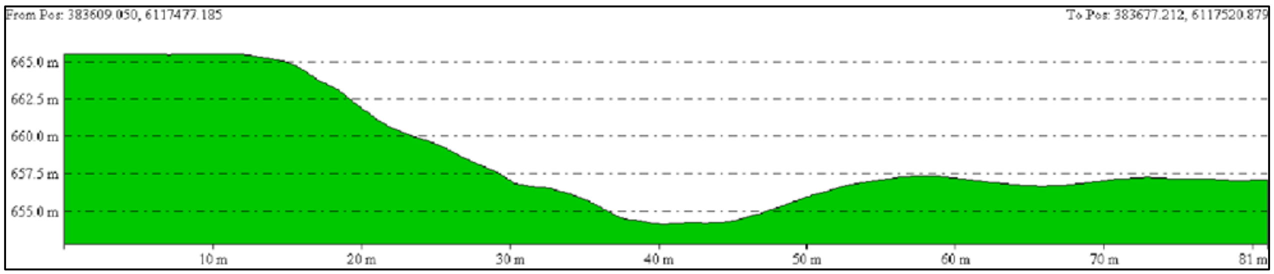


Parkland GEO	CLIENT: City of Grande Prairie	Cross Sections G and H
		Bear Creek Corridor Study Grande Prairie, Alberta

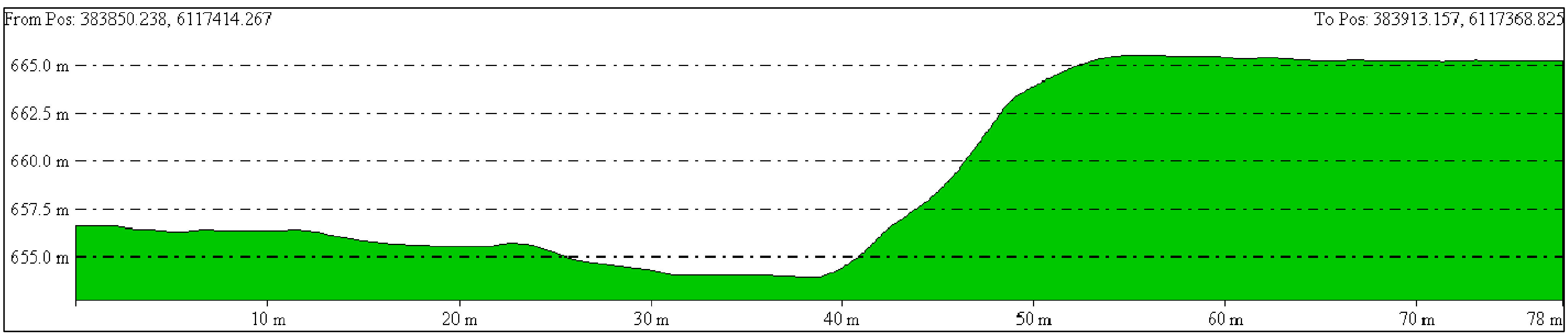
DRAWN:	CHK'D.:	REV #:	DATE:
NT	JP	0	December, 2010

SCALE:	JOB NO.	DRAWING NO.
As shown	GP 1433	Figure C - 4

Cross Section I

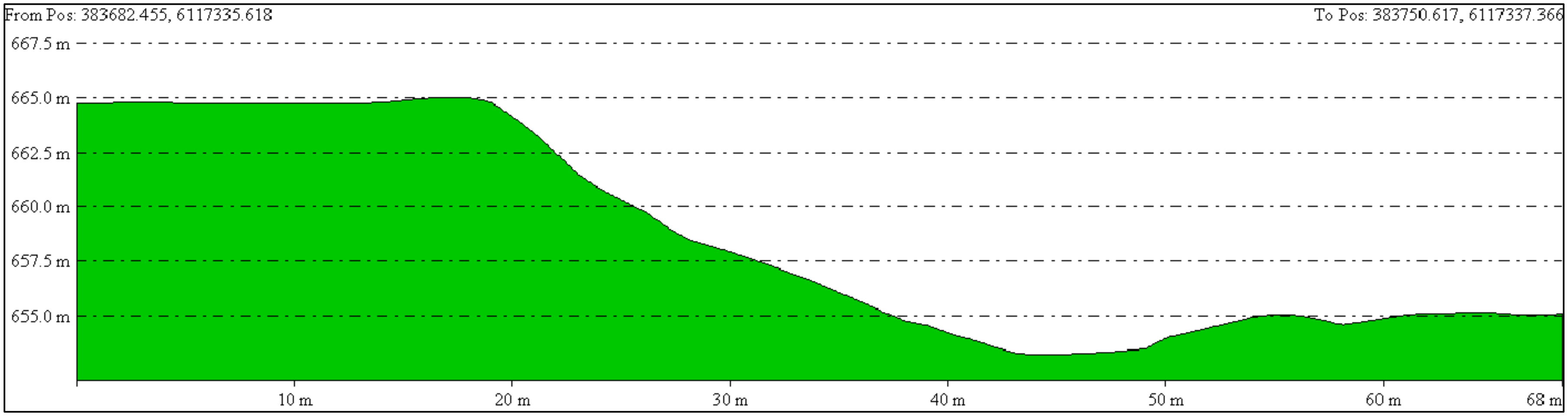


Cross Section J

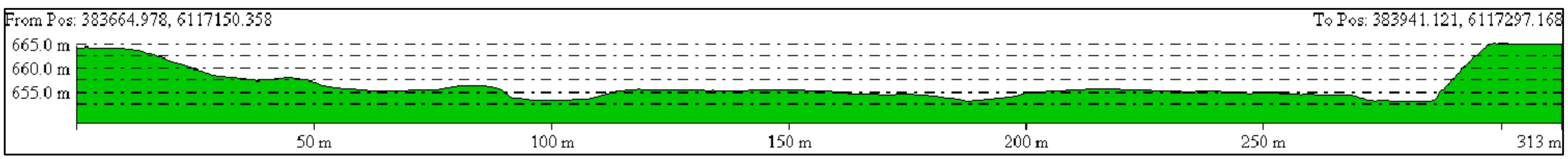


ParklandGEO	CLIENT: City of Grande Prairie	Cross Sections I and J			
		Bear Creek Corridor Study Grande Prairie, Alberta			
		DRAWN: NT	CHK'D.: JP	REV #: 0	DATE: December, 2010
		SCALE: As shown	JOB NO. GP 1433		DRAWING NO. Figure C - 5

Cross Section K



Cross Section L



ParklandGEO

CLIENT:

City of Grande Prairie

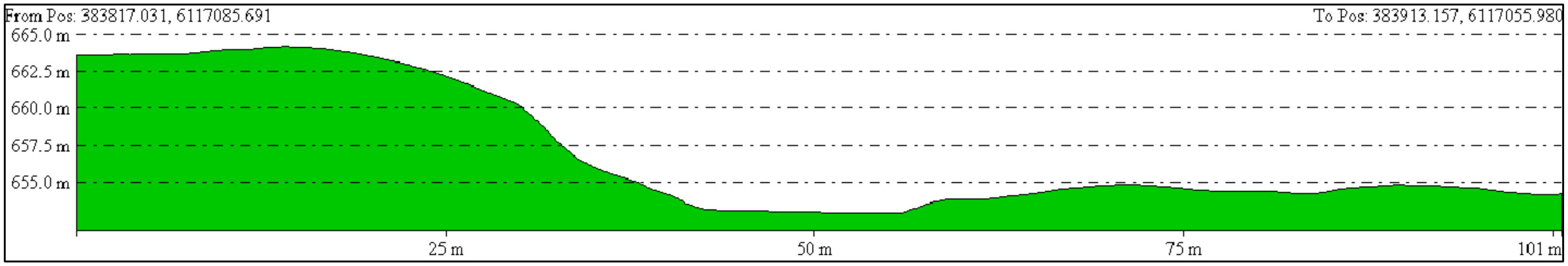
Cross Sections K and L

Bear Creek Corridor Study
Grande Prairie, Alberta

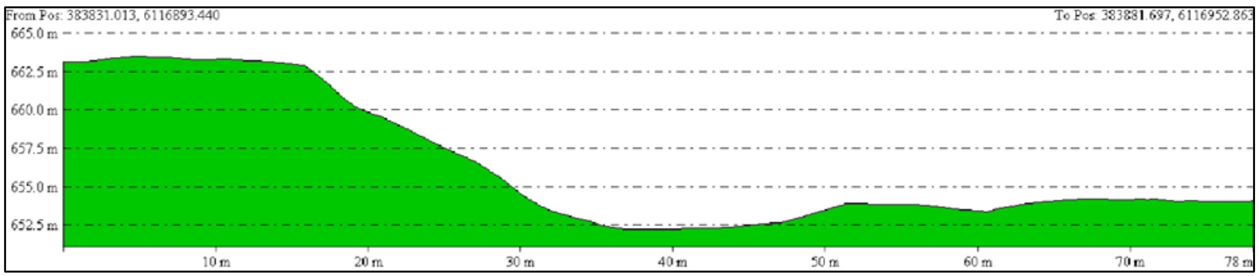
DRAWN:	CHK'D.:	REV #:	DATE:
NT	JP	0	December, 2010

SCALE:	JOB NO.	DRAWING NO.
As shown	GP 1433	Figure C - 6

Cross Section M



Cross Section N

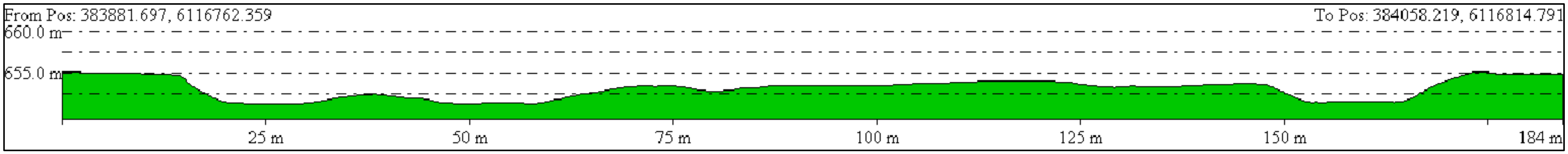


ParklandGEO	CLIENT: City of Grande Prairie	Cross Sections M and N
		Bear Creek Corridor Study Grande Prairie, Alberta

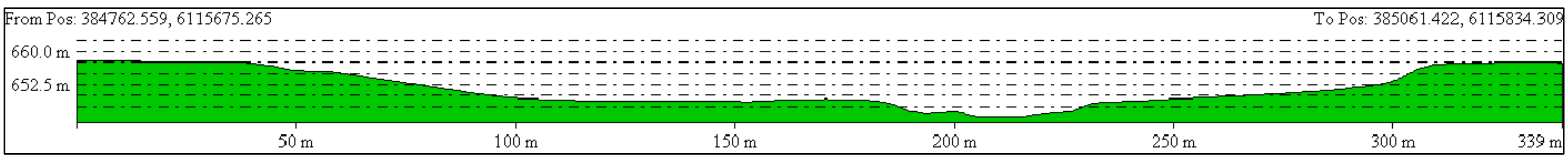
DRAWN:	CHK'D.:	REV #:	DATE:
NT	JP	0	December, 2010

SCALE:	JOB NO.	DRAWING NO.
As shown	GP 1433	Figure C - 7

Cross Section O



Cross Section P



ParklandGEO

CLIENT:

City of Grande Prairie

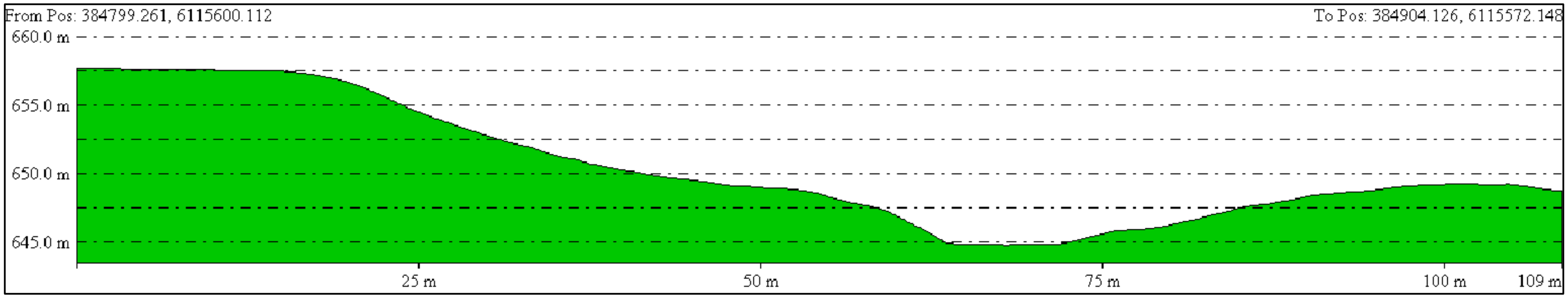
Cross Sections O and P

Bear Creek Corridor Study
Grande Prairie, Alberta

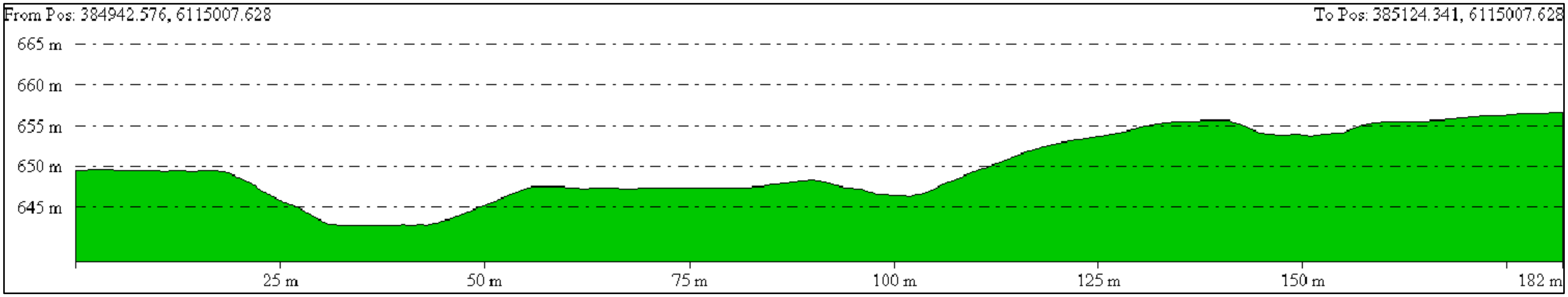
DRAWN:	CHK'D.:	REV #:	DATE:
NT	JP	0	December, 2010

SCALE:	JOB NO.	DRAWING NO.
As shown	GP 1433	Figure C - 8

Cross Section Q



Cross Section R



ParklandGEO	CLIENT: City of Grande Prairie	Cross Sections Q and R			
		Bear Creek Corridor Study Grande Prairie, Alberta			
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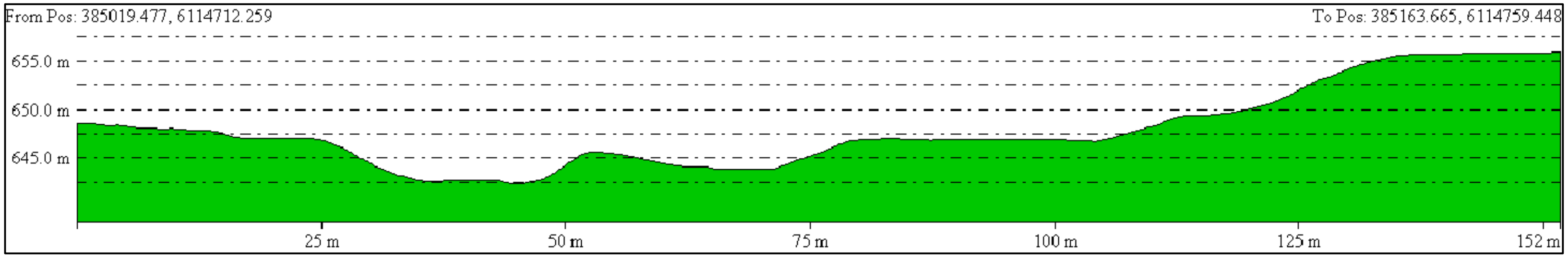
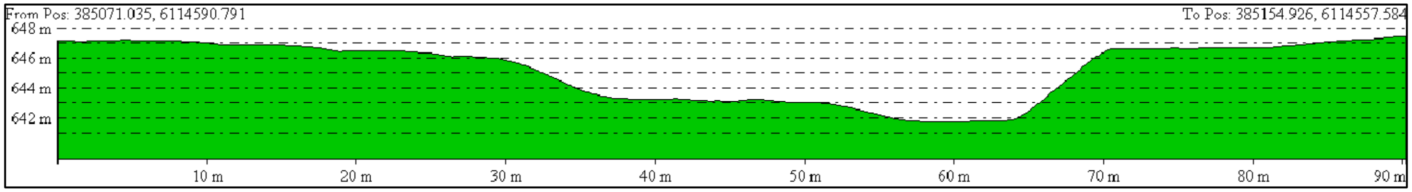
		SCALE: As shown	JOB NO. GP 1433		DRAWING NO. Figure C - 9

Cross Section S



Cross Section T



ParklandGEO	CLIENT: City of Grande Prairie	Cross Sections S and T			
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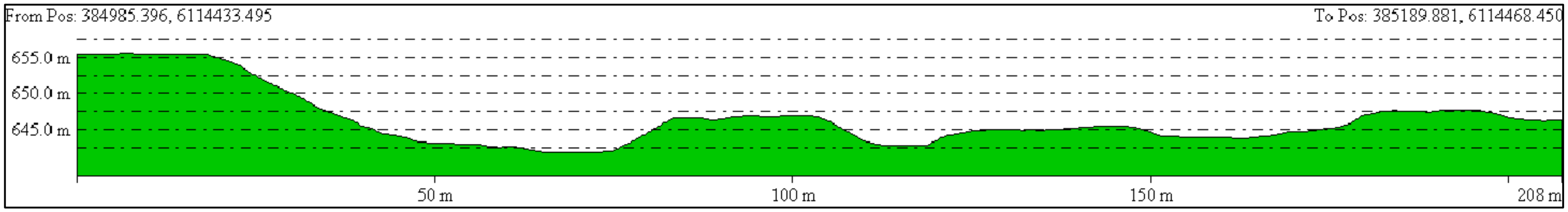
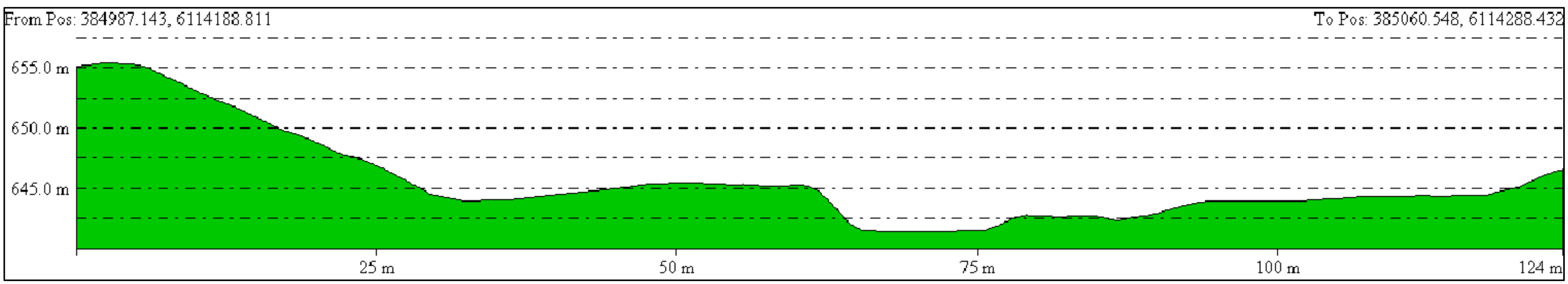
		SCALE: As shown	JOB NO. GP 1433		DRAWING NO. Figure C - 10

Cross Section U



Cross Section V



ParklandGEO	CLIENT: City of Grande Prairie	Cross Sections U and V			
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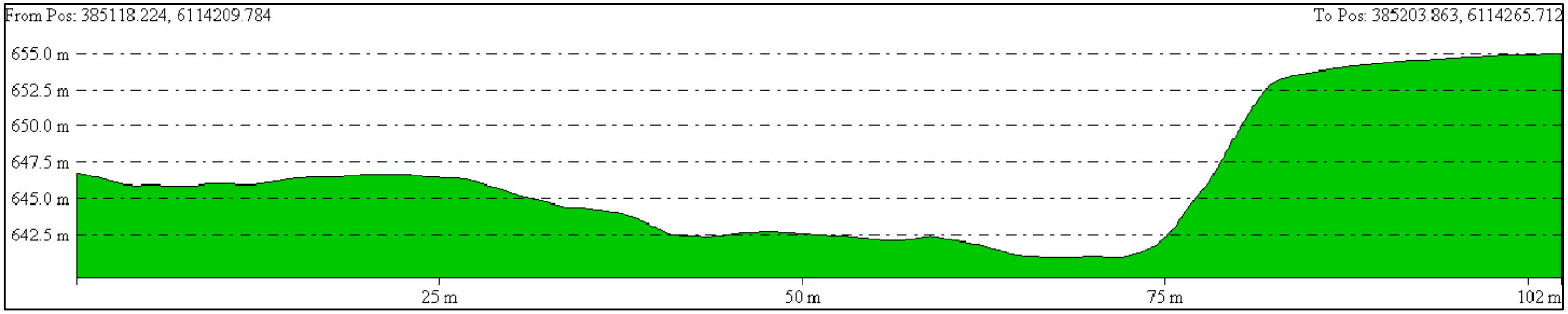
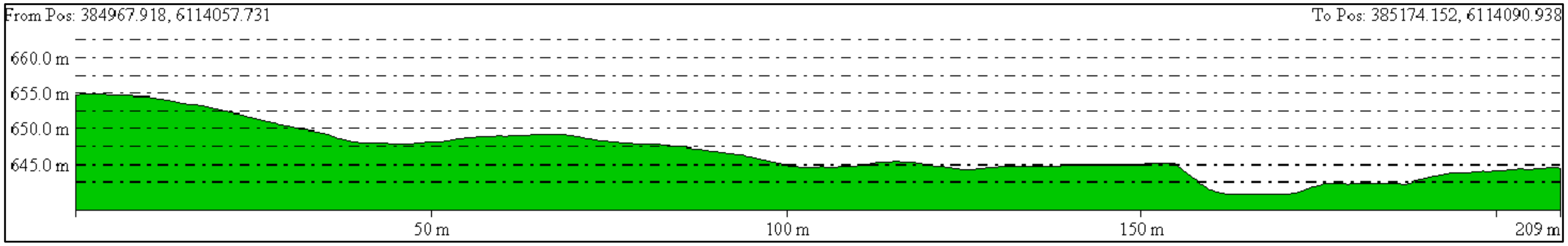
Cross Section W



Cross Section X



	CLIENT:	Cross Sections W and X			
ParklandGEO	City of Grande Prairie	Bear Creek Corridor Study Grande Prairie, Alberta			
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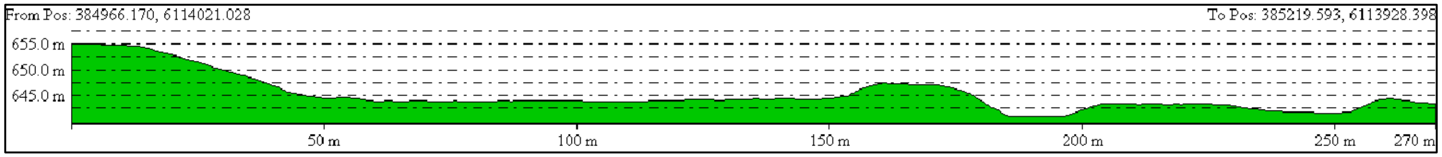
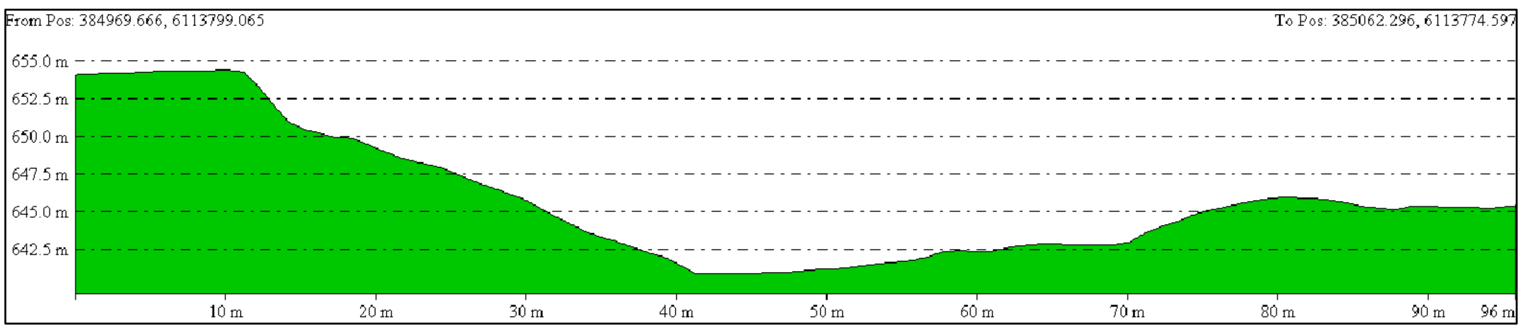
		SCALE: As shown	JOB NO. GP 1433		DRAWING NO. Figure C - 12

Cross Section Y



Cross Section Z



ParklandGEO	CLIENT: City of Grande Prairie	Cross Sections Y and Z			
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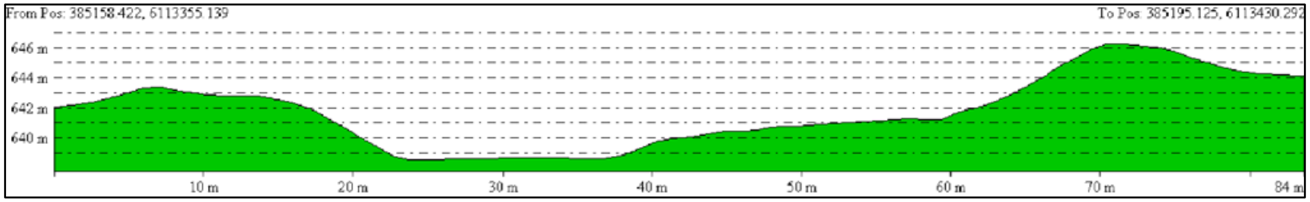
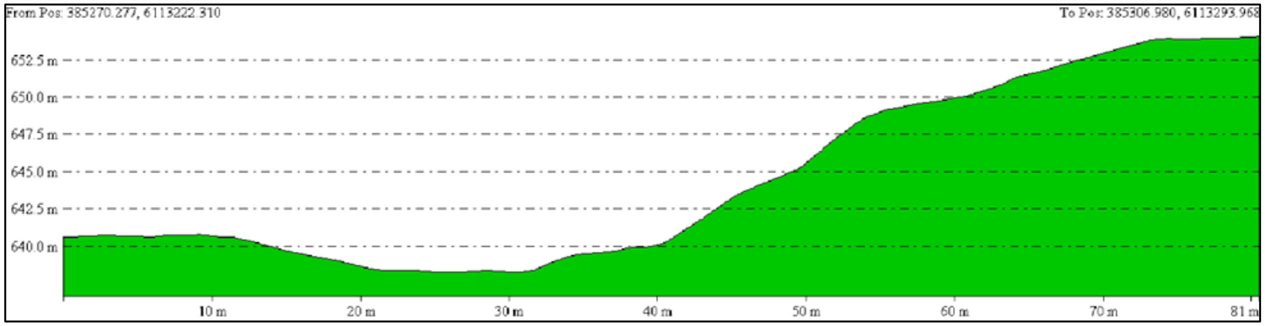
		SCALE: As shown	JOB NO. GP 1433		DRAWING NO. Figure C - 13

Cross Section a



Cross Section b



ParklandGEO	CLIENT: City of Grande Prairie	Cross Sections a and b			
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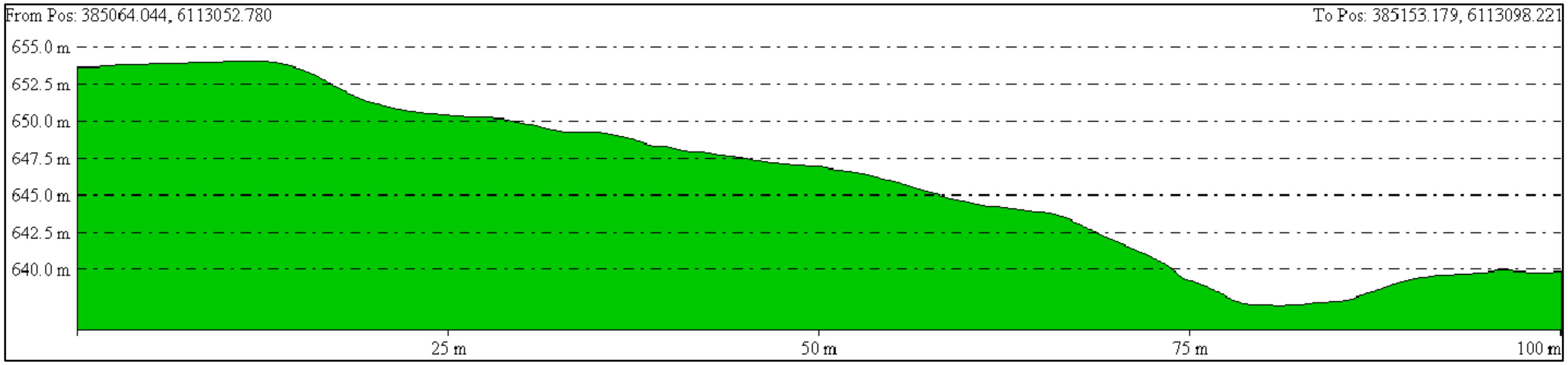
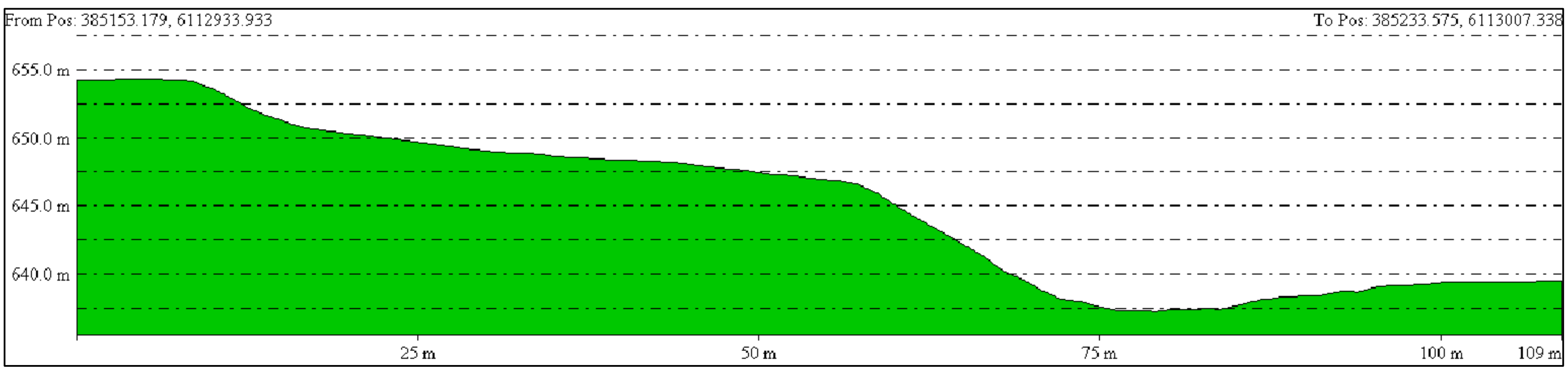
		SCALE: As shown	JOB NO. GP 1433		DRAWING NO. Figure C - 14

Cross Section c



Cross Section d



ParklandGEO

CLIENT:

City of Grande Prairie

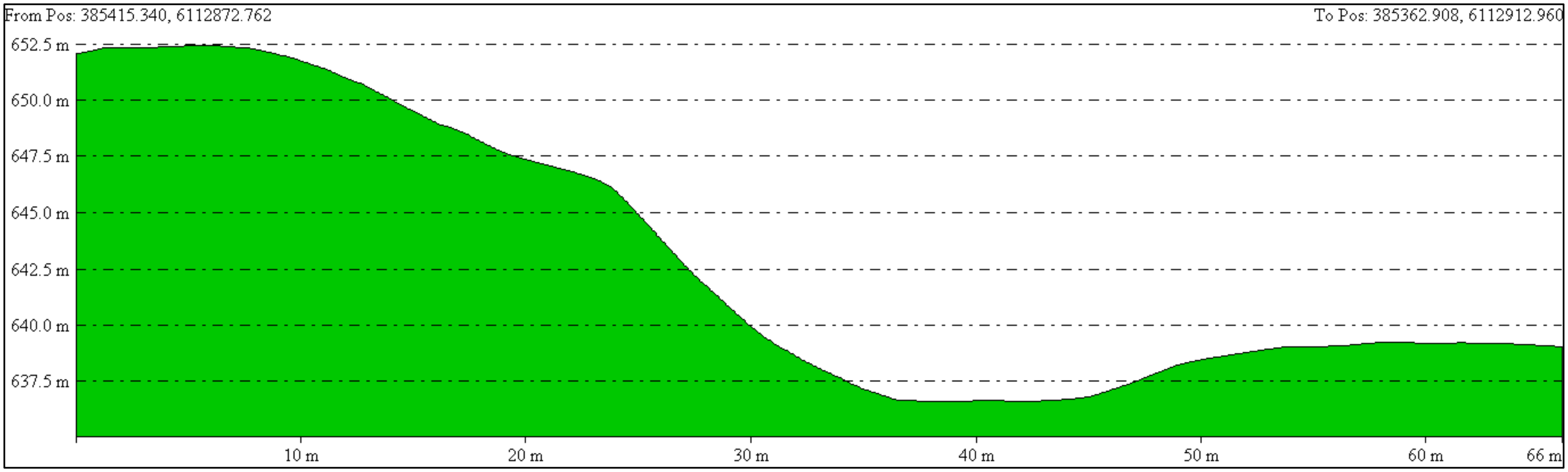
Cross Sections c and d

Bear Creek Corridor Study
Grande Prairie, Alberta

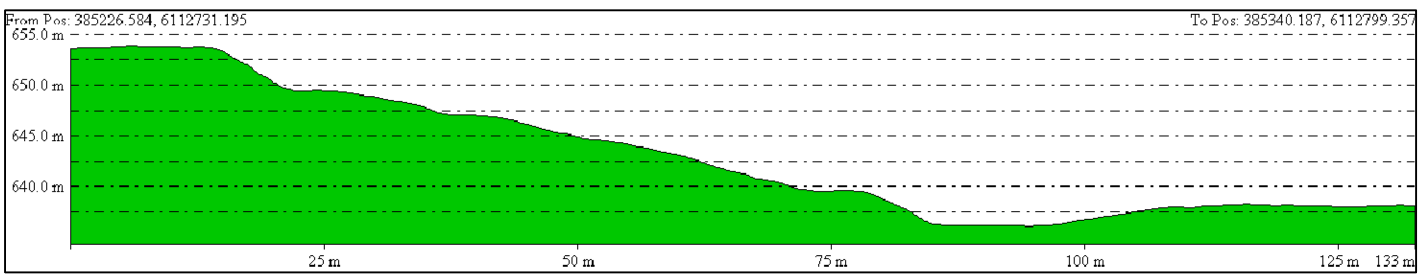
DRAWN:	CHK'D.:	REV #:	DATE:
NT	JP	0	December, 2010

SCALE:	JOB NO.	DRAWING NO.
As shown	GP 1433	Figure C - 15

Cross Section e



Cross Section f



ParklandGEO

CLIENT:

City of Grande Prairie

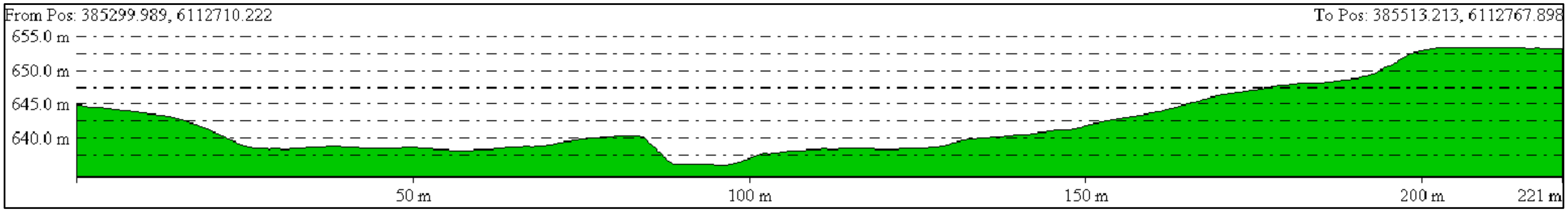
Cross Sections e and f

Bear Creek Corridor Study
Grande Prairie, Alberta

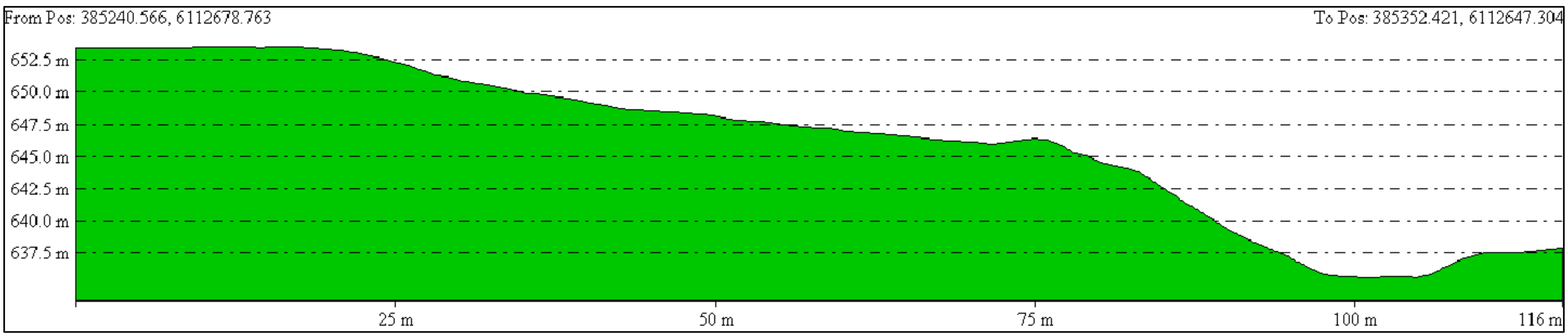
DRAWN:	CHK'D.:	REV #:	DATE:
NT	JP	0	December, 2010

SCALE:	JOB NO.	DRAWING NO.
As shown	GP 1433	Figure C - 16

Cross Section g



Cross Section h



ParklandGEO	CLIENT: City of Grande Prairie	Cross Sections g and h			
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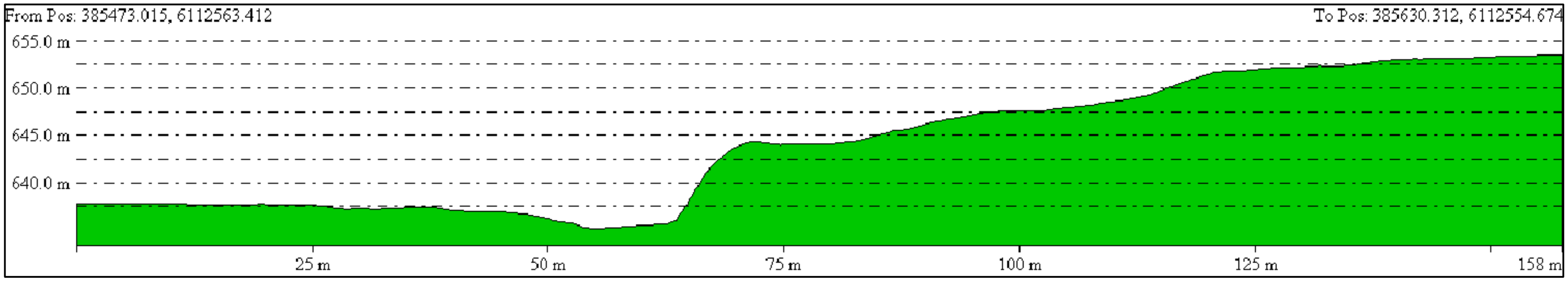
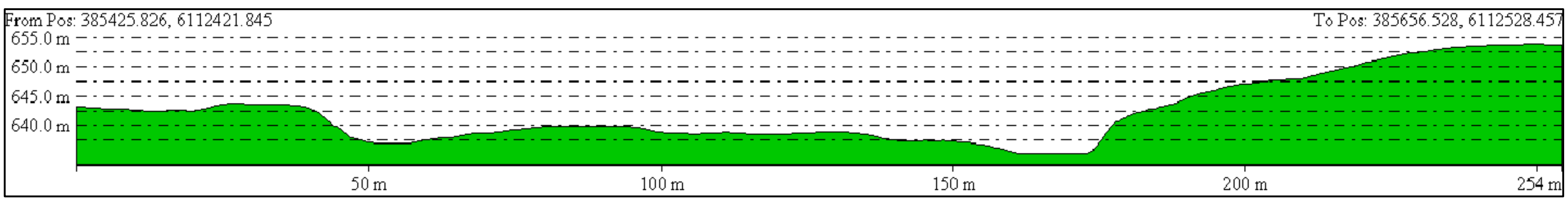
		SCALE: As shown	JOB NO. GP 1433		DRAWING NO. Figure C - 17

Cross Section i



Cross Section j



ParklandGEO	CLIENT: City of Grande Prairie	Cross Sections i and j			
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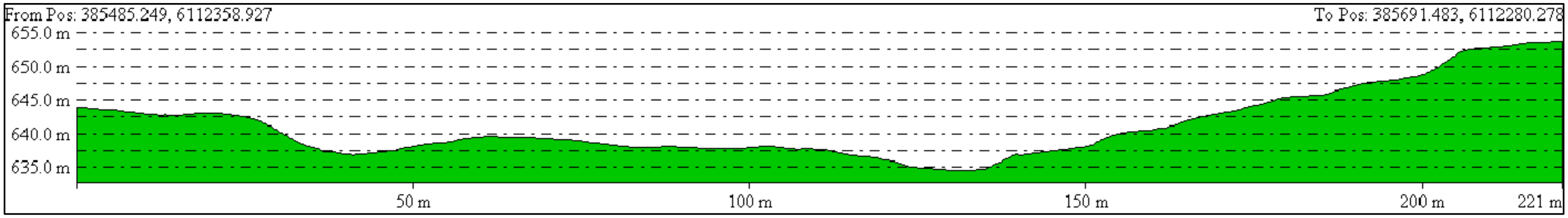
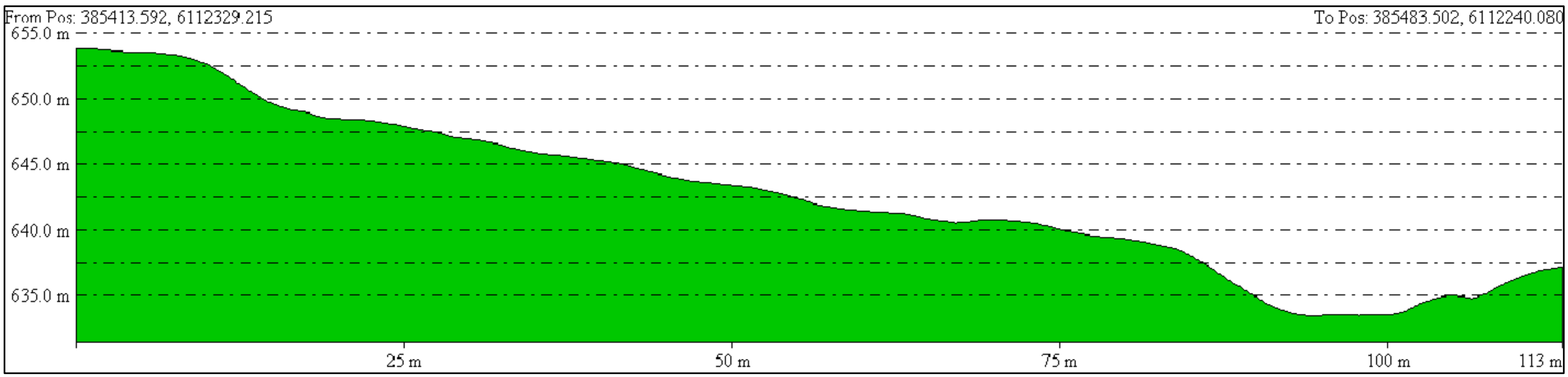
		SCALE: As shown	JOB NO. GP 1433		DRAWING NO. Figure C - 18

Cross Section k



Cross Section l



ParklandGEO	CLIENT: City of Grande Prairie	Cross Sections kand l			
		Bear Creek Corridor Study Grande Prairie, Alberta			
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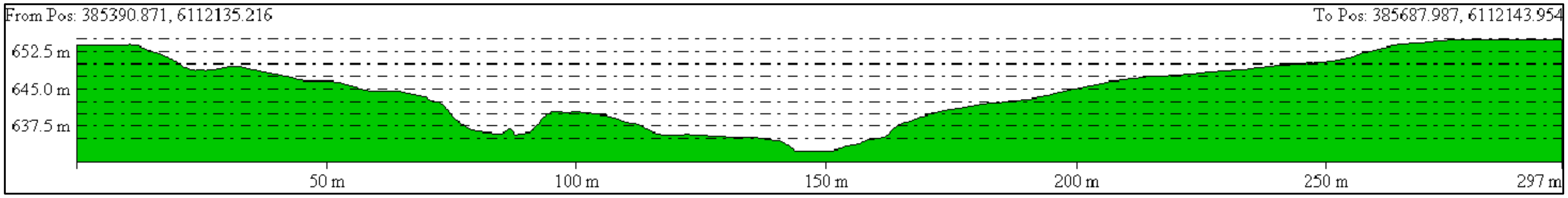
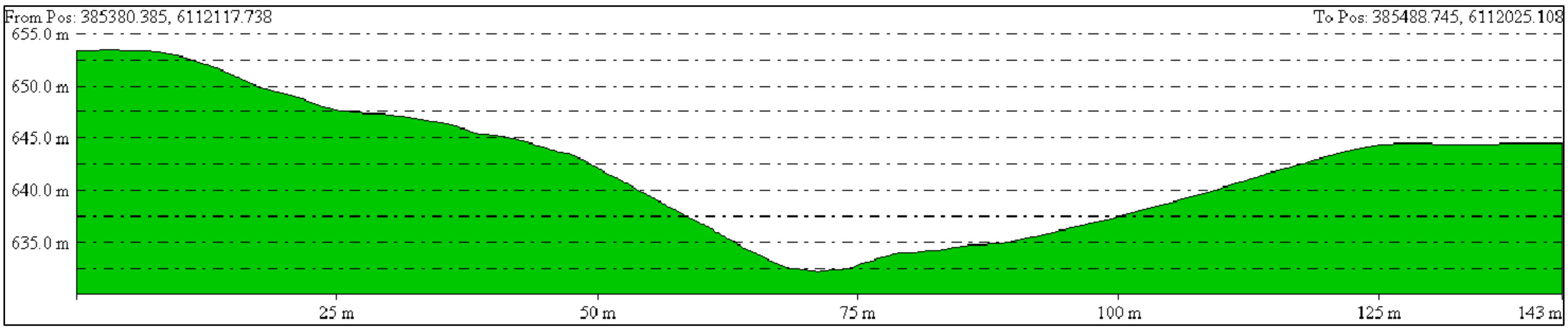
		SCALE: As shown	JOB NO. GP 1433		DRAWING NO. Figure C - 19

Cross Section m



Cross Section n



ParklandGEO

CLIENT:

City of Grande Prairie

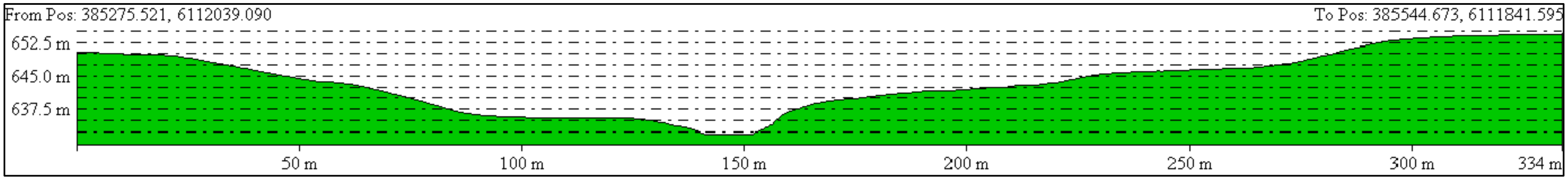
Cross Sections m and n

Bear Creek Corridor Study
Grande Prairie, Alberta

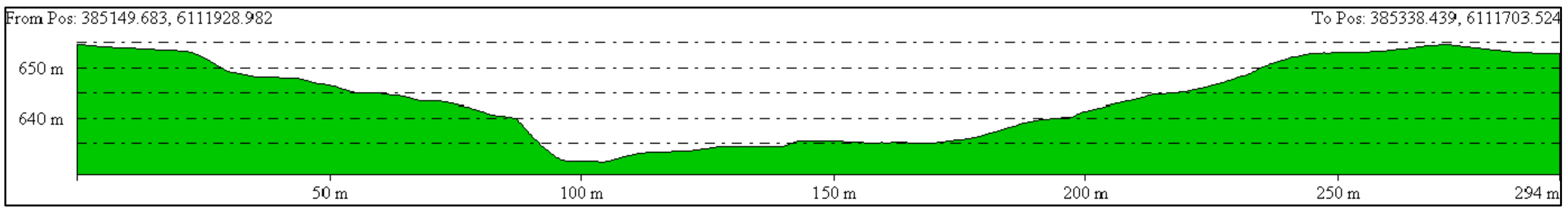
DRAWN:	CHK'D.:	REV #:	DATE:
NT	JP	0	December, 2010

SCALE:	JOB NO.	DRAWING NO.
As shown	GP 1433	Figure C - 20

Cross Section o



Cross Section p



ParklandGEO

CLIENT:

City of Grande Prairie

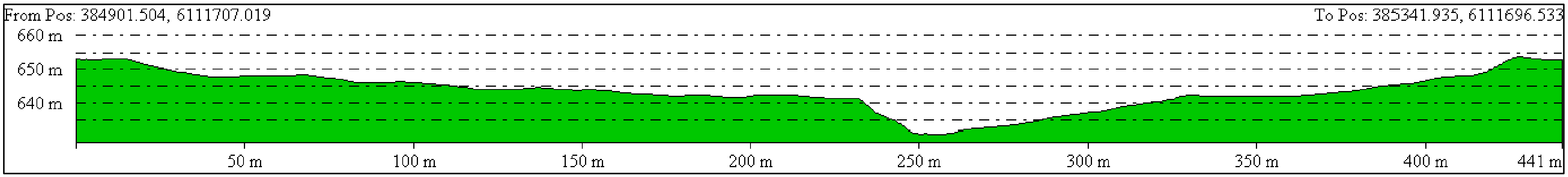
Cross Sections o and p

Bear Creek Corridor Study
Grande Prairie, Alberta

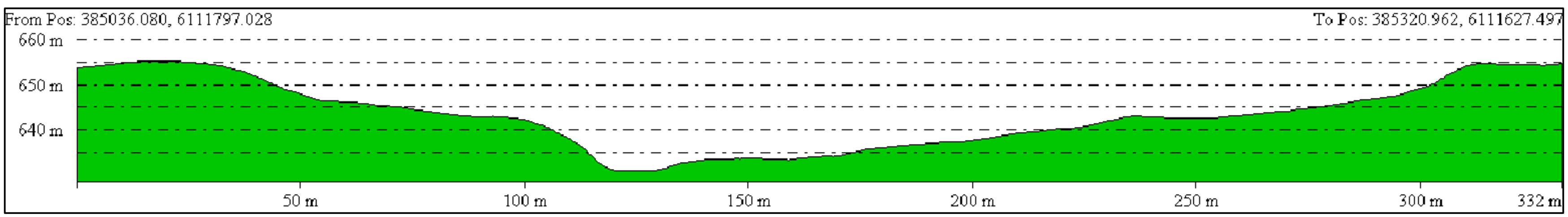
DRAWN:	CHK'D.:	REV #:	DATE:
NT	JP	0	December, 2010

SCALE:	JOB NO.	DRAWING NO.
As shown	GP 1433	Figure C - 21

Cross Section q



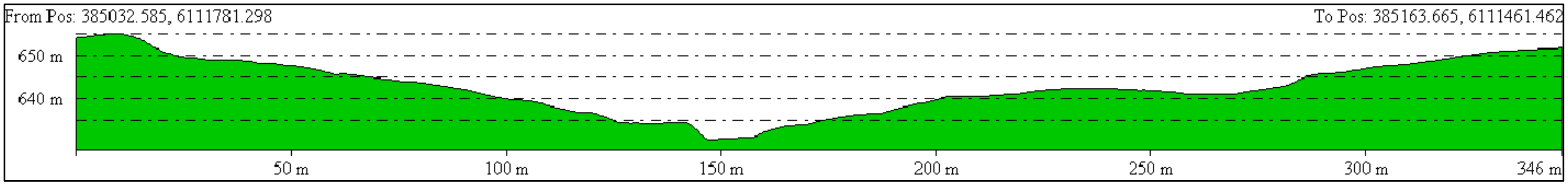
Cross Section r



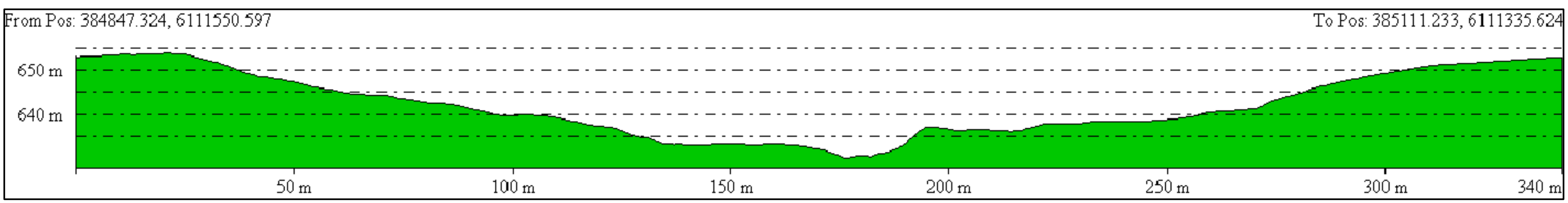
ParklandGEO

CLIENT:	Cross Sections q and r			
City of Grande Prairie	Bear Creek Corridor Study Grande Prairie, Alberta			
	DRAWN: NT	CHK'D.: JP	REV #: 0	DATE: December, 2010
	SCALE: As shown	JOB NO. GP 1433		DRAWING NO. Figure C - 22

Cross Section s



Cross Section t



ParklandGEO

CLIENT:

City of Grande Prairie

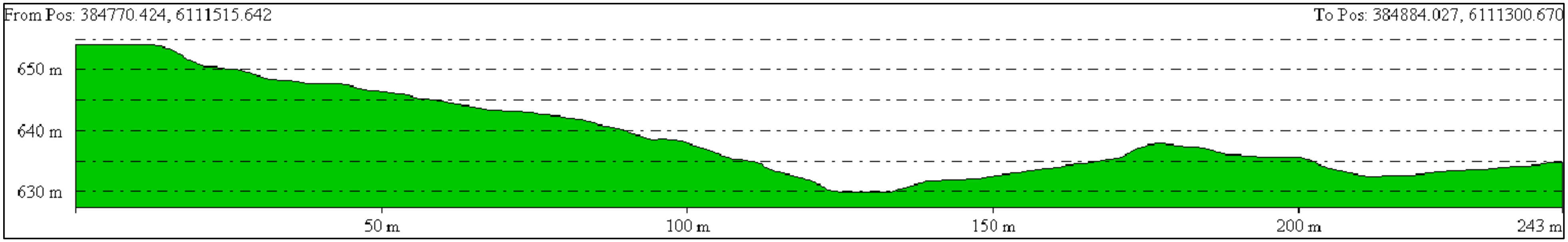
Cross Sections s and t

Bear Creek Corridor Study
Grande Prairie, Alberta

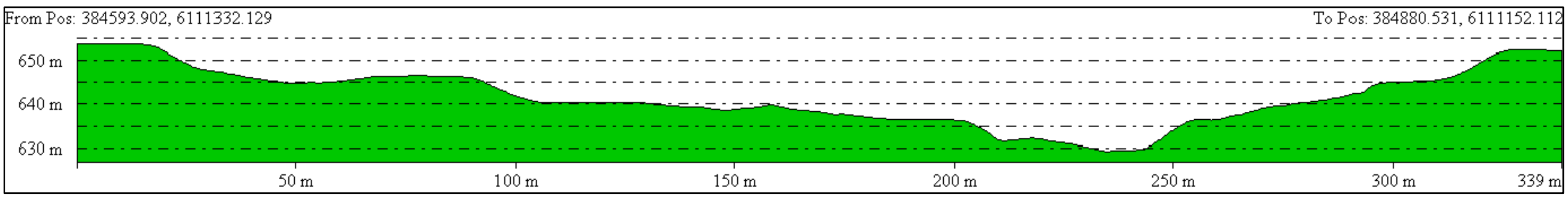
DRAWN:	CHK'D.:	REV #:	DATE:
NT	JP	0	December, 2010

SCALE:	JOB NO.	DRAWING NO.
As shown	GP 1433	Figure C - 23

Cross Section u

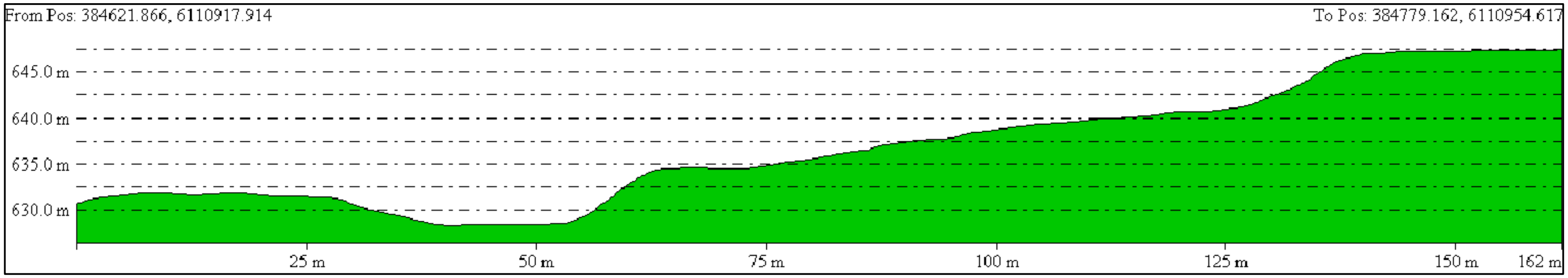


Cross Section v

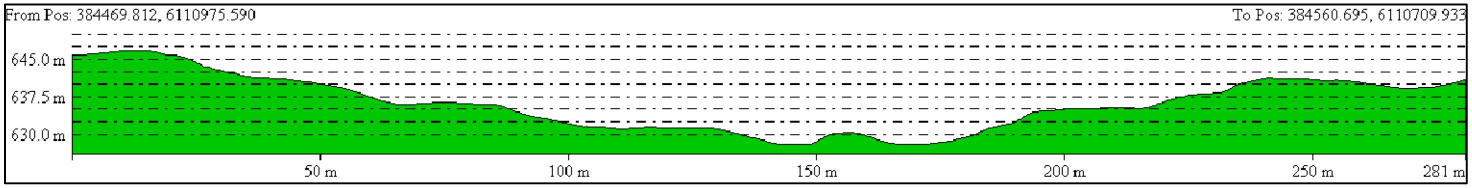


ParklandGEO	CLIENT: City of Grande Prairie	Cross Sections u and v Bear Creek Corridor Study Grande Prairie, Alberta
DRAWN: NT	CHK'D.: JP	REV #: 0
DATE: December, 2010	SCALE: As shown	JOB NO. GP 1433
DRAWING NO. Figure C - 24		

Cross Section w



Cross Section x

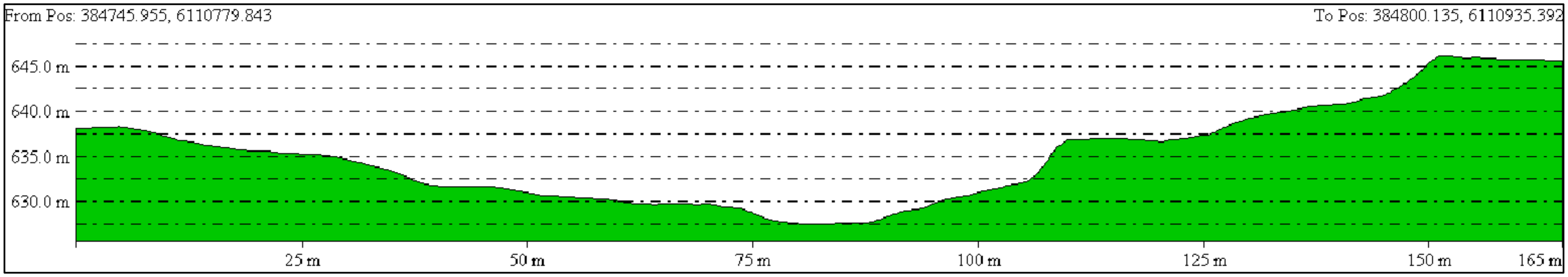


ParklandGEO	CLIENT: City of Grande Prairie	Cross Sections w and x Bear Creek Corridor Study Grande Prairie, Alberta

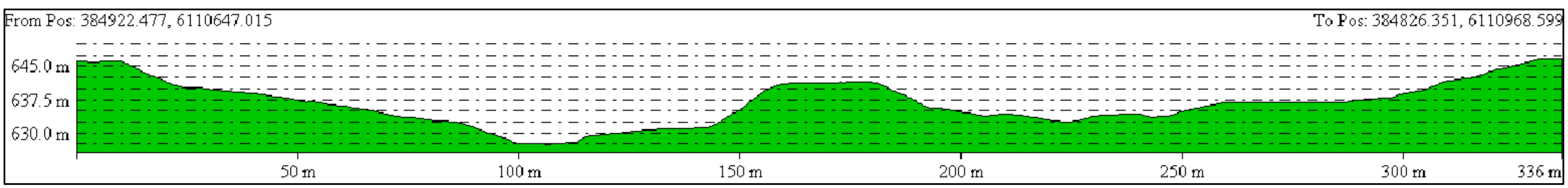
DRAWN:	CHK'D.:	REV #:	DATE:
NT	JP	0	December, 2010

SCALE:	JOB NO.	DRAWING NO.
As shown	GP 1433	Figure C - 25

Cross Section y



Cross Section z



ParklandGEO

CLIENT:

City of Grande Prairie

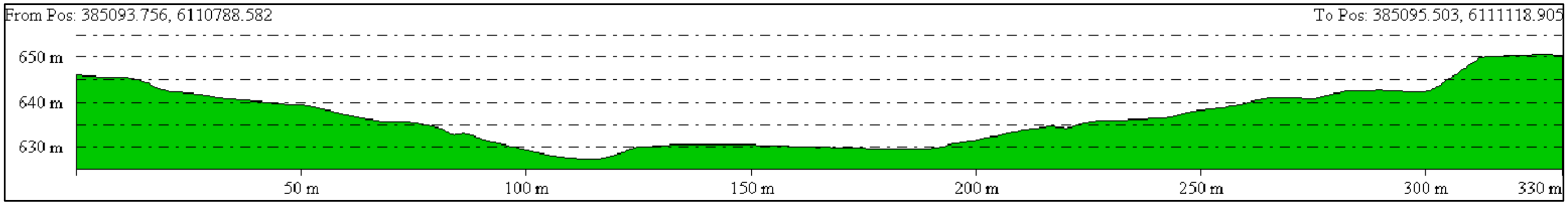
Cross Sections y and z

Bear Creek Corridor Study
Grande Prairie, Alberta

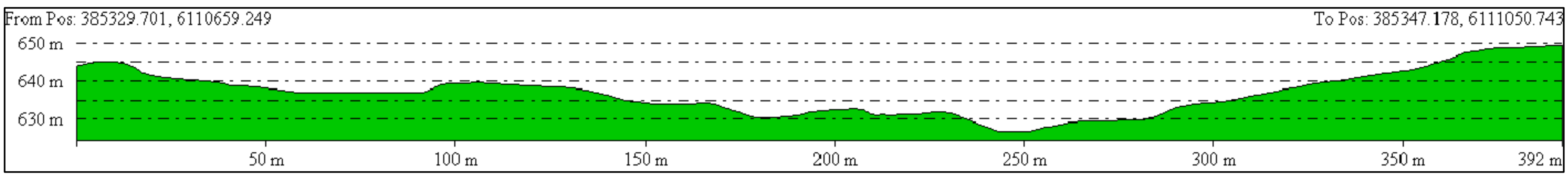
DRAWN:	CHK'D.:	REV #:	DATE:
NT	JP	0	December, 2010

SCALE:	JOB NO.	DRAWING NO.
As shown	GP 1433	Figure C - 26

Cross Section Ai



Cross Section Bi



ParklandGEO

CLIENT:

City of Grande Prairie

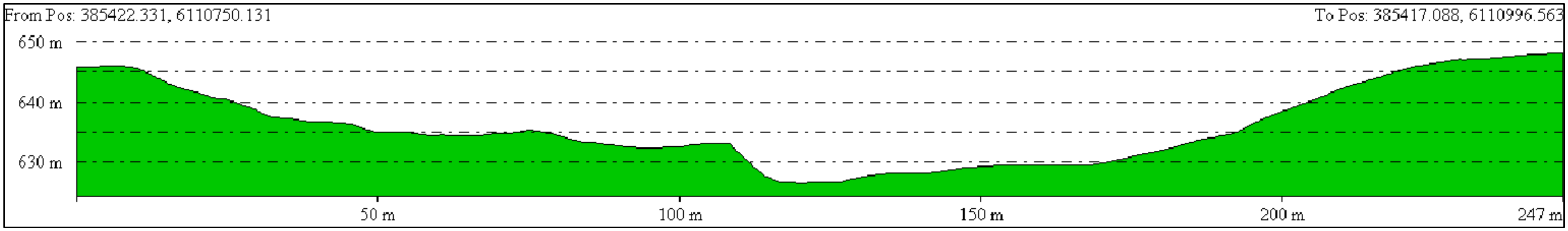
Cross Sections Ai and Bi

Bear Creek Corridor Study
Grande Prairie, Alberta

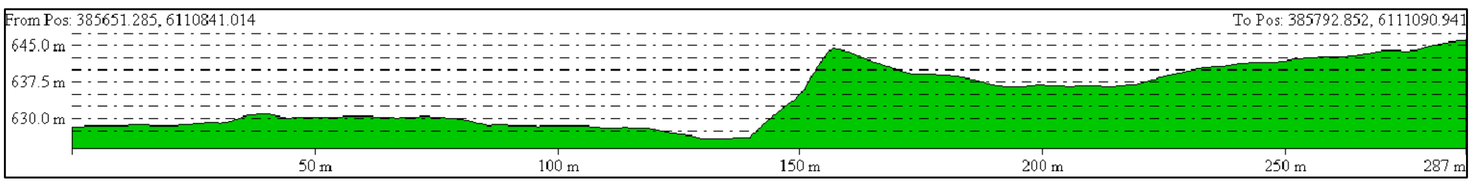
DRAWN:	CHK'D.:	REV #:	DATE:
NT	JP	0	December, 2010

SCALE:	JOB NO.	DRAWING NO.
As shown	GP 1433	Figure C - 27

Cross Section Ci



Cross Section Di



ParklandGEO	CLIENT: City of Grande Prairie	Cross Sections Ci and Di		
		Bear Creek Corridor Study Grande Prairie, Alberta		
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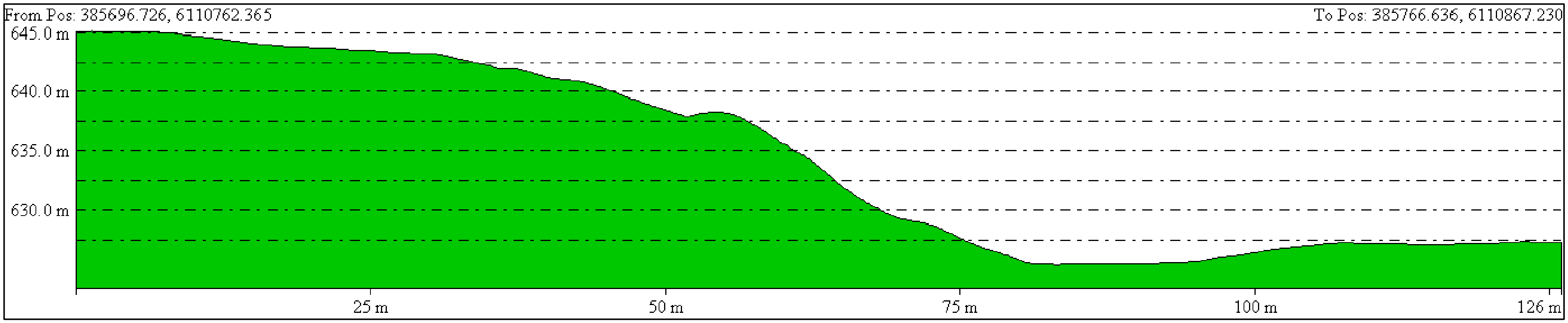
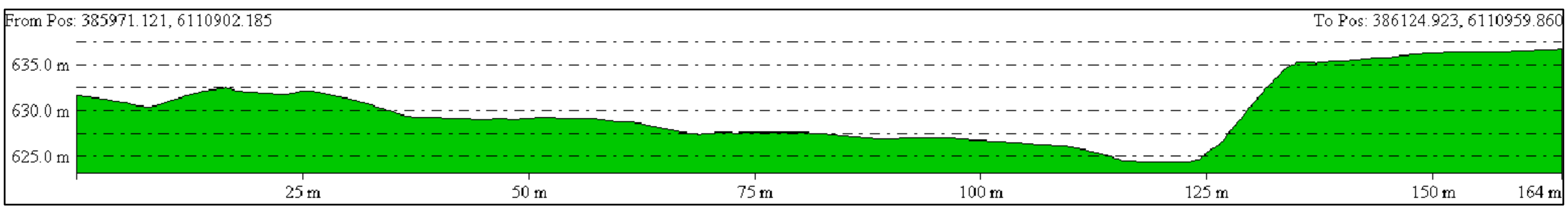
		SCALE: As shown	JOB NO. GP 1433	DRAWING NO. Figure C - 28

Cross Section Ei



Cross Section Fi



CLIENT:

City of Grande Prairie

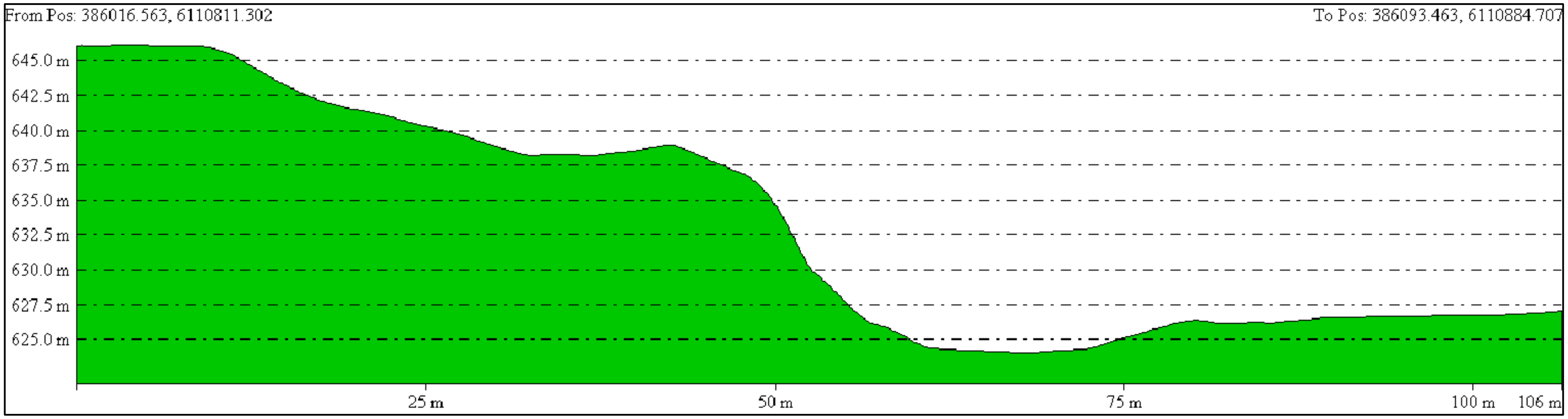
Cross Sections Ei and Fi

Bear Creek Corridor Study
Grande Prairie, Alberta

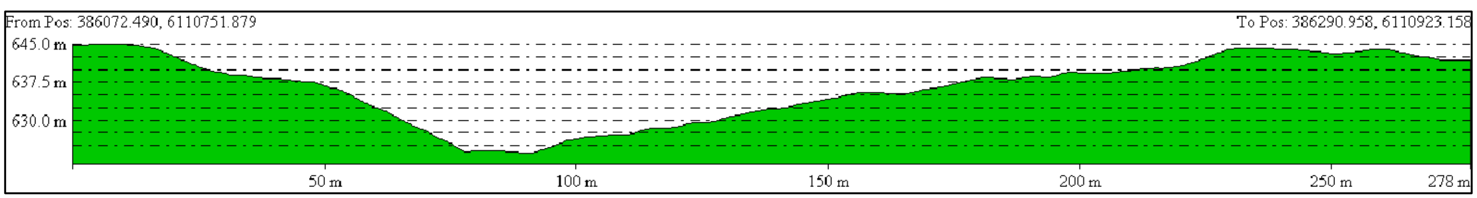
DRAWN:	CHK'D.:	REV #:	DATE:
NT	JP	0	December, 2010

SCALE:	JOB NO.	DRAWING NO.
As shown	GP 1433	Figure C - 29

Cross Section Gi

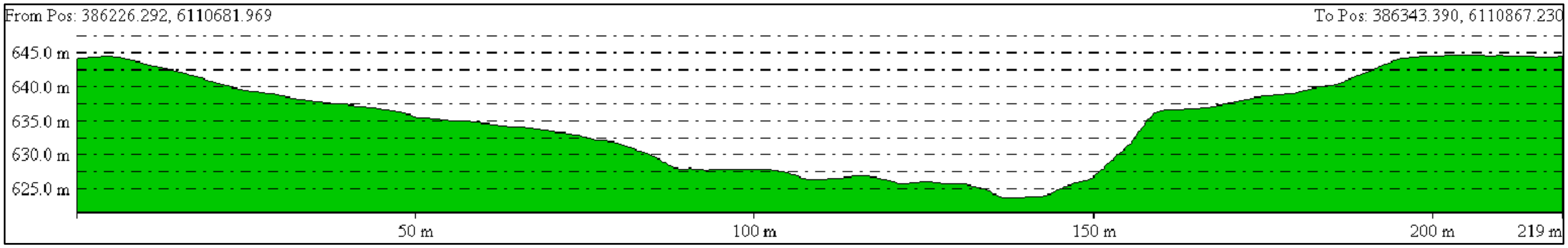


Cross Section Hi

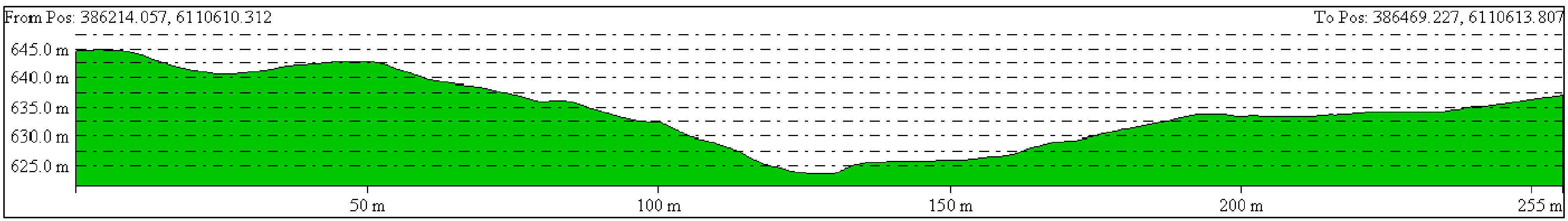


ParklandGEO	CLIENT: City of Grande Prairie	Cross Sections Gi and Hi
		Bear Creek Corridor Study Grande Prairie, Alberta
		DRAWN: NT / CHK'D.: JP / REV #: 0 / DATE: December, 2010
		SCALE: As shown / JOB NO. GP 1433 / DRAWING NO. Figure C - 30

Cross Section Ji



Cross Section Ki



ParklandGEO

CLIENT:

City of Grande Prairie

Cross Sections Ji and Ki

Bear Creek Corridor Study
Grande Prairie, Alberta

DRAWN:	CHK'D.:	REV #:	DATE:
NT	JP	0	December, 2010

SCALE:	JOB NO.	DRAWING NO.
As shown	GP 1433	Figure C - 31

APPENDIX D

SLOPE STABILITY ANALYSES

METHODOLOGY

TYPICAL SLOPE /W ANALYSES
SUPPORTING INFORMATION

D.0 SLOPE STABILITY ASSESSMENT

D.1 GENERAL

A slope stability analysis was conducted to assess potential impacts of the local slope on the City of Grande Prairie infrastructure in the vicinity as well as upland developments. Slope stability is described in terms of the factor of safety (FOS) against slope failure which is the ratio of total forces resisting failure divided by the sum of forces promoting or driving failure. In general, a FOS of less than 1.0 indicates that failure is expected and a FOS greater than 1 indicates that the slope is stable. A steepened slope will slump back over time to establish a stable profile for the existing soil and groundwater conditions. The FOS of a slope will increase slightly as vegetation is established on the face to protect the subgrade soil from erosion and weathering. Given the possibility of soil variation, groundwater fluctuation, erosion and other factors, slopes with FOS ranging between 1.0 and 1.3 are considered to be marginally stable and a "long term" stable slope is considered to have a FOS over 1.3.

The critical failure surface is the failure surface with the lowest calculated FOS intersecting the proposed development of concern. For service development on the slope face, the recommended FOS is at least 1.3. For lot developments at the crest of a slope, a recommended setback distance should be set so that the FOS at the closest property line is at least 1.3. A higher FOS would be recommended for permanent structures such as houses or other occupied buildings.

ParklandGEO undertook a general slope stability assessment using various borehole log data, surface profile information, and soil parameters estimated from field and laboratory tests, as well as available literature.

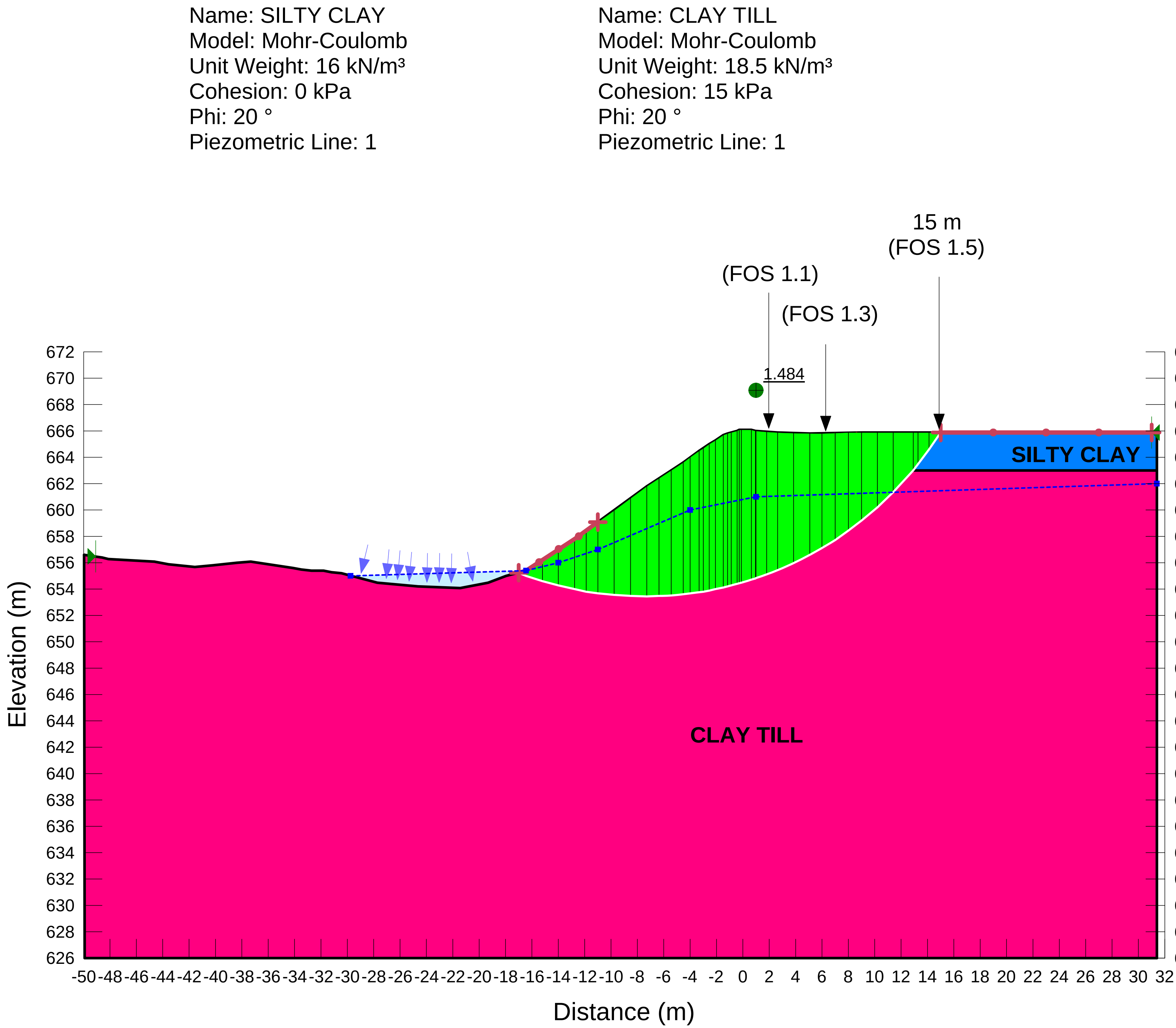
D.2 STABILITY ANALYSIS

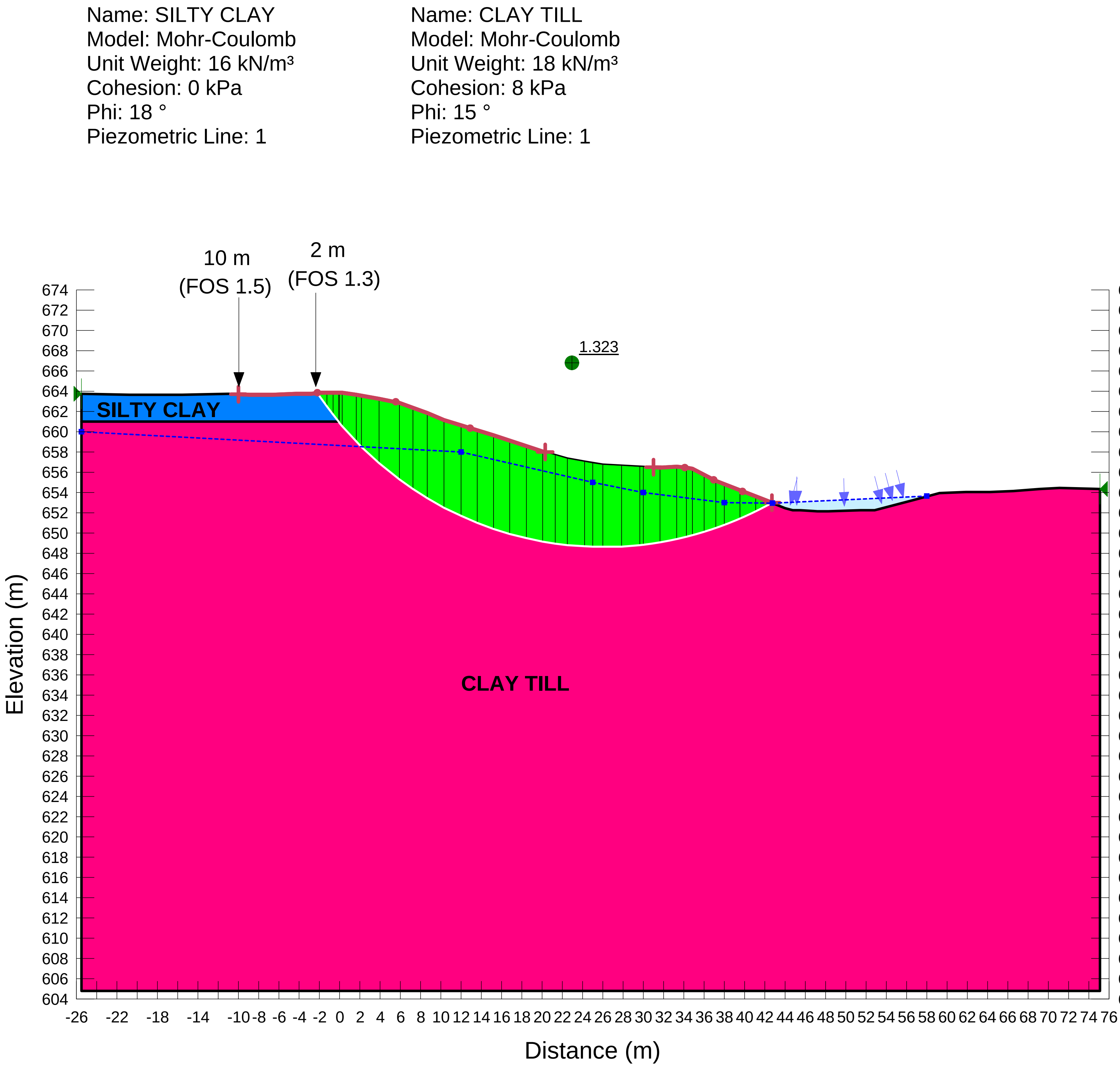
Limit equilibrium analysis was carried out using the Slope/W software program to evaluate the factor of safety (FOS) for the representative slope profile. The (FOS) was calculated using the Morgenstern-Price Method.

To evaluate slope stability, information on the shear strength of the earth materials, surface and subsurface geometry is required. Based on laboratory testing and local experience, the following soil parameters were used for the silty clay and clay till soils encountered on site, as shown on Table D-1.

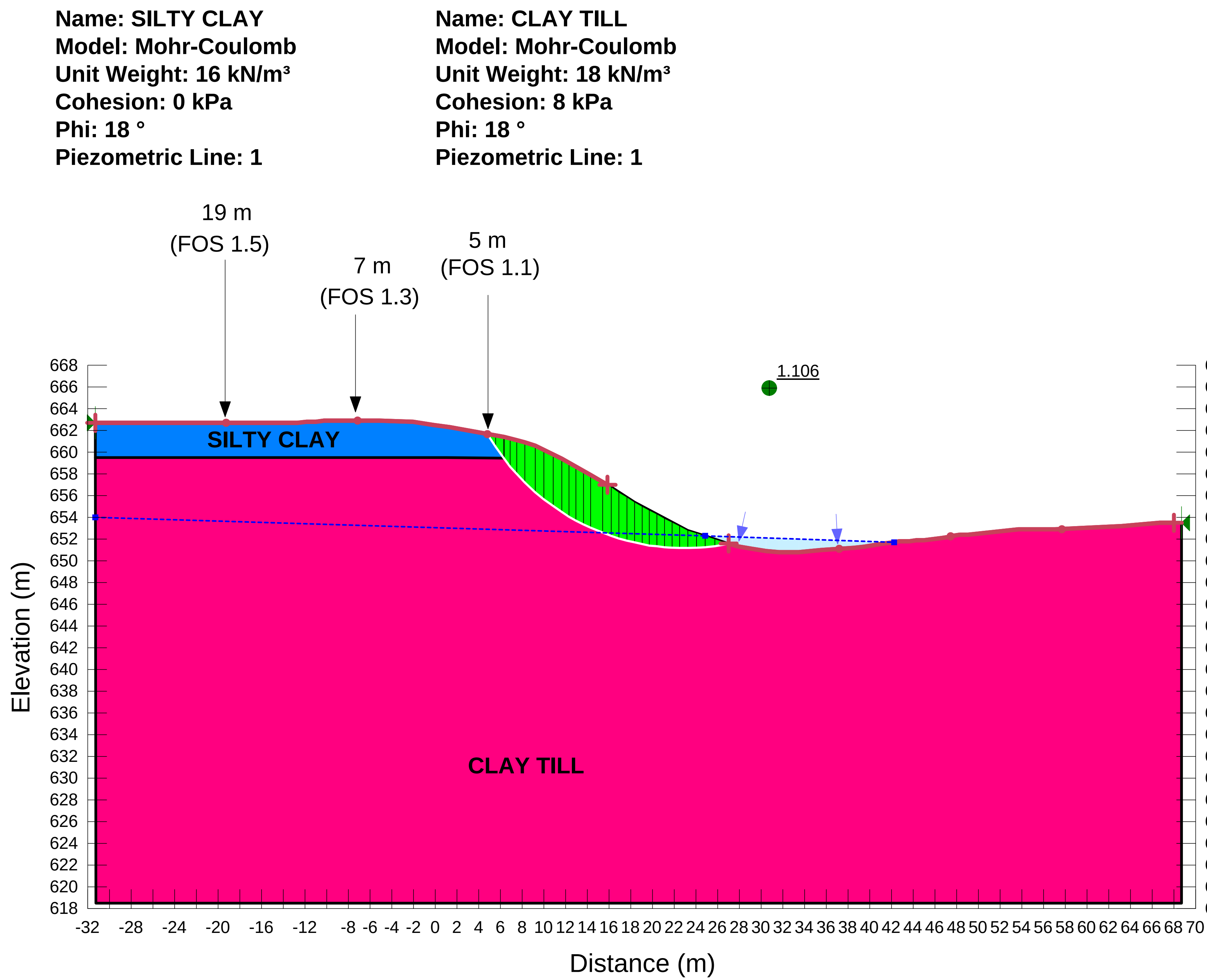
TABLE D-1: SOIL PARAMETER RANGES FOR STABILITY ANALYSES

Soil	Unit Weight (kN/m^3)	Cohesion (c') (kPa)	Friction Angle (φ')
Silty Clay	16	0 to 3	16
Clay Till	18.5	8 to 15	20
Clay Till at Residual	18.5	0	18

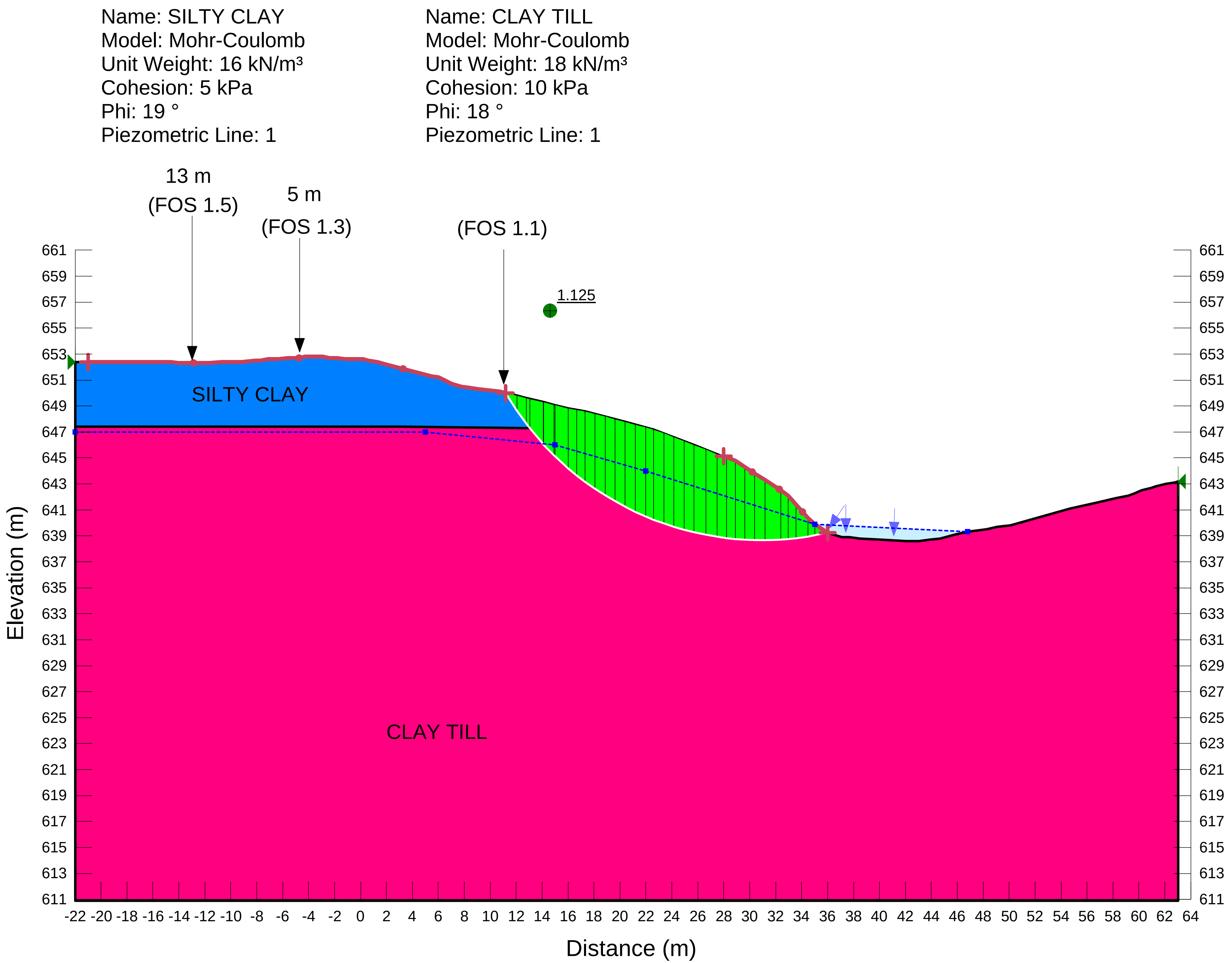

Name: SILTY CLAY
Model: Mohr-Coulomb
Unit Weight: 16 kN/m³
Cohesion: 0 kPa
Phi: 20 °
Piezometric Line: 1
Name: CLAY TILL
Model: Mohr-Coulomb
Unit Weight: 18.5 kN/m³
Cohesion: 15 kPa
Phi: 20 °
Piezometric Line: 1
15 m
(FOS 1.5)
(FOS 1.1)
(FOS 1.3)
1.484
SILTY CLAY
CLAY TILL
Elevation (m)
Distance (m)



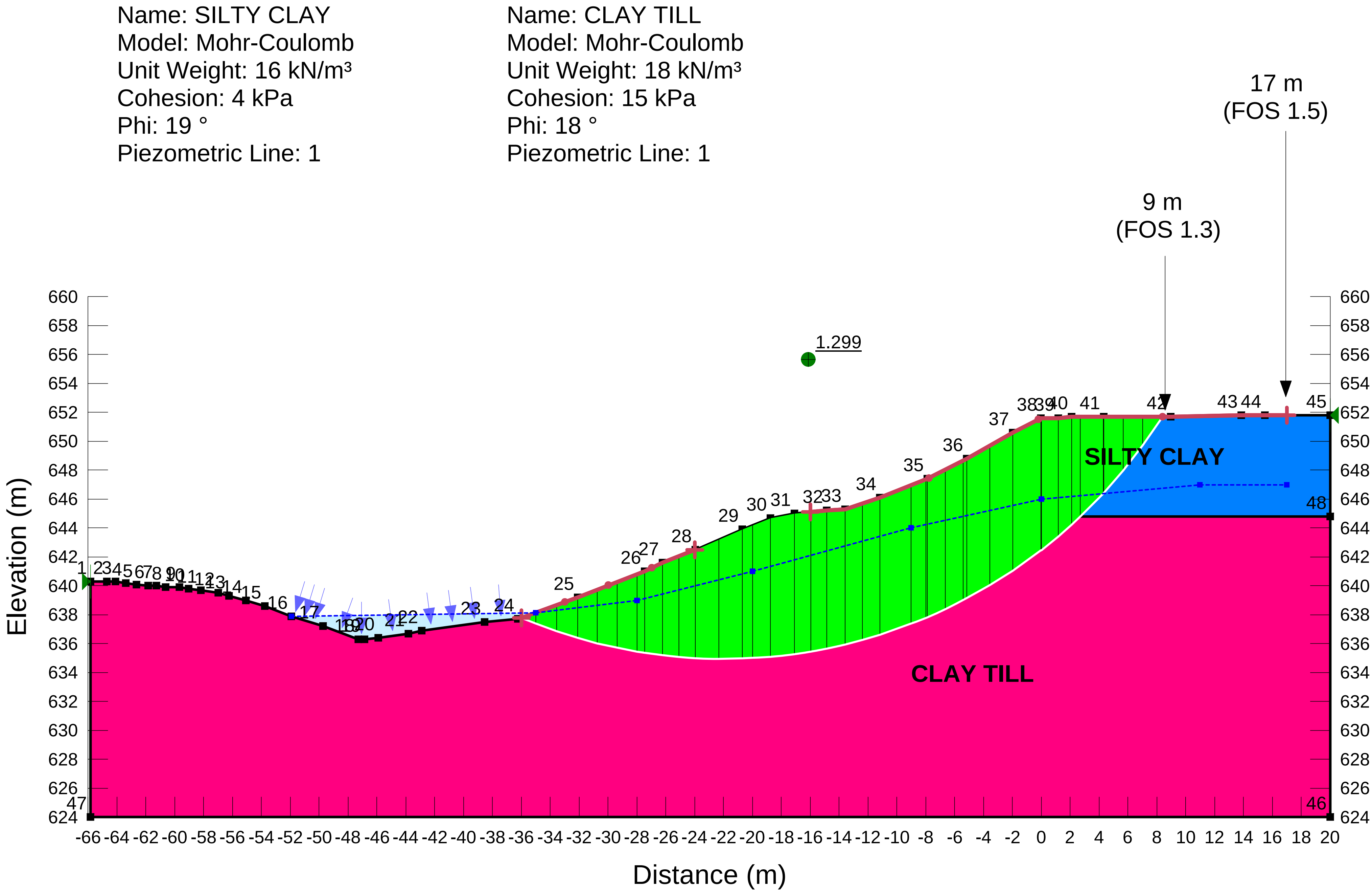
Name: SILTY CLAY
Model: Mohr-Coulomb
Unit Weight: 16 kN/m³
Cohesion: 0 kPa
Phi: 18 °
Piezometric Line: 1
Name: CLAY TILL
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 8 kPa
Phi: 15 °
Piezometric Line: 1
10 m
(FOS 1.5)
2 m
(FOS 1.3)
1.323
SILTY CLAY
CLAY TILL
Elevation (m)
Distance (m)



Name: SILTY CLAY
Model: Mohr-Coulomb
Unit Weight: 16 kN/m³
Cohesion: 0 kPa
Phi: 18 °
Piezometric Line: 1
Name: CLAY TILL
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 8 kPa
Phi: 18 °
Piezometric Line: 1
19 m
(FOS 1.5)
7 m
(FOS 1.3)
5 m
(FOS 1.1)
1.106
SILTY CLAY
CLAY TILL
Elevation (m)
Distance (m)

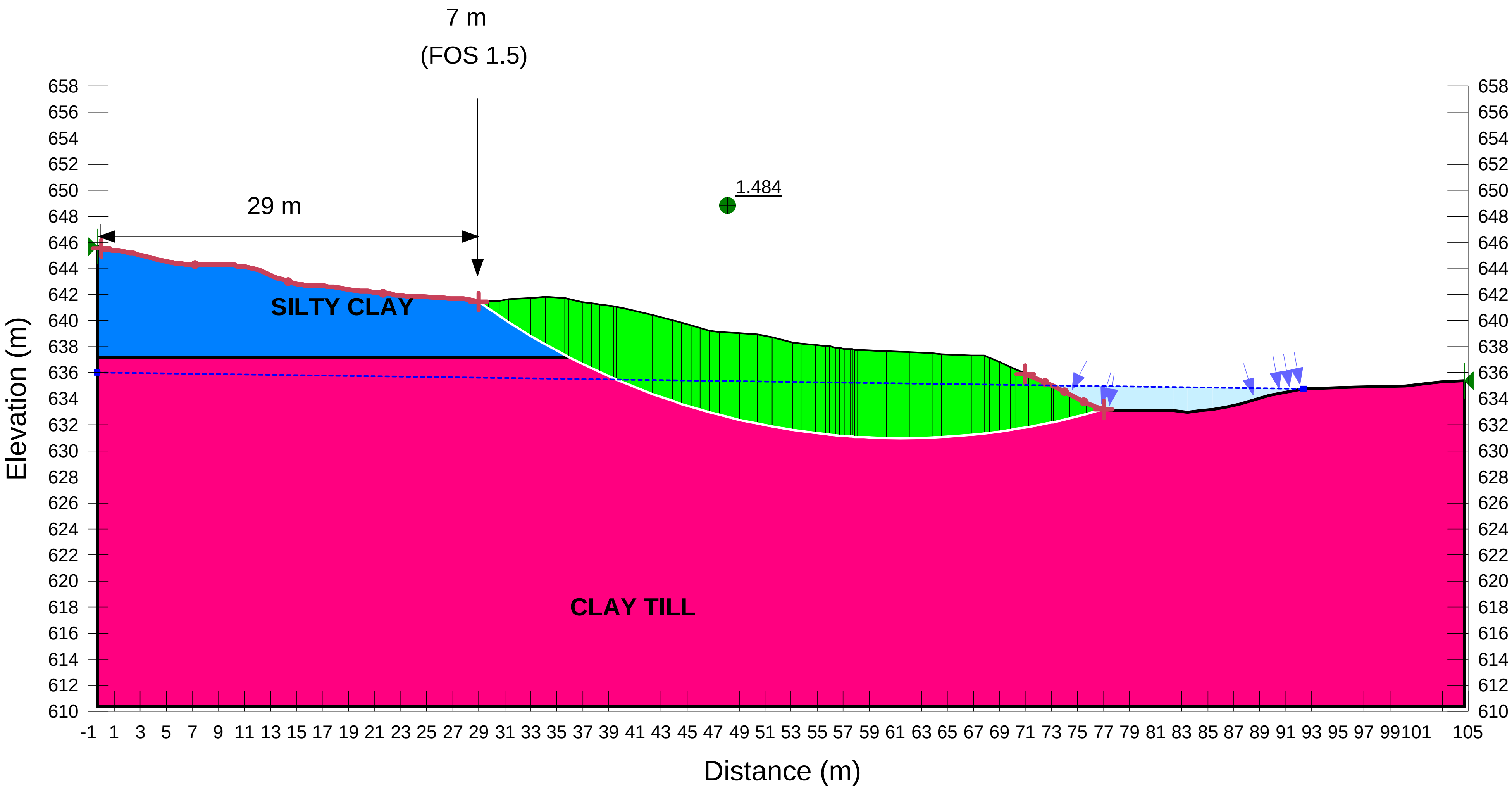


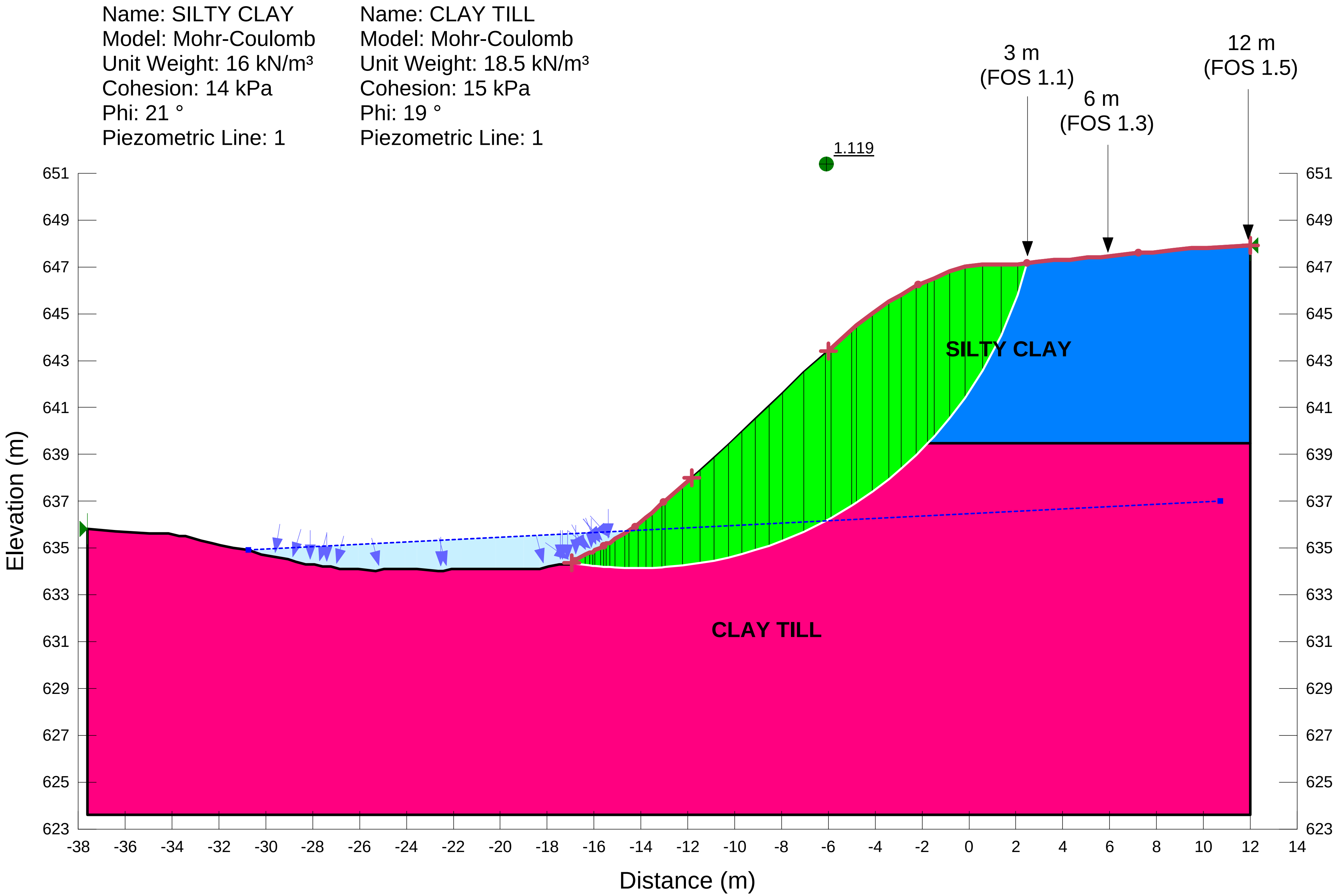
Name: SILTY CLAY
Model: Mohr-Coulomb
Unit Weight: 16 kN/m³
Cohesion: 5 kPa
Phi: 19 °
Piezometric Line: 1
Name: CLAY TILL
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 10 kPa
Phi: 18 °
Piezometric Line: 1
13 m
(FOS 1.5)
5 m
(FOS 1.3)
(FOS 1.1)
1.125
SILTY CLAY
CLAY TILL
Elevation (m)
Distance (m)


Name: SILTY CLAY
Model: Mohr-Coulomb
Unit Weight: 16 kN/m³
Cohesion: 4 kPa
Phi: 19 °
Piezometric Line: 1
Name: CLAY TILL
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 15 kPa
Phi: 18 °
Piezometric Line: 1
17 m
(FOS 1.5)
9 m
(FOS 1.3)
1.299
SILTY CLAY
CLAY TILL
Elevation (m)
Distance (m)

Name: SILTY CLAY
Model: Mohr-Coulomb
Unit Weight: 16 kN/m³
Cohesion: 0 kPa
Phi: 15 °
Piezometric Line: 1

Name: CLAY TILL
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 15 °
Piezometric Line: 1

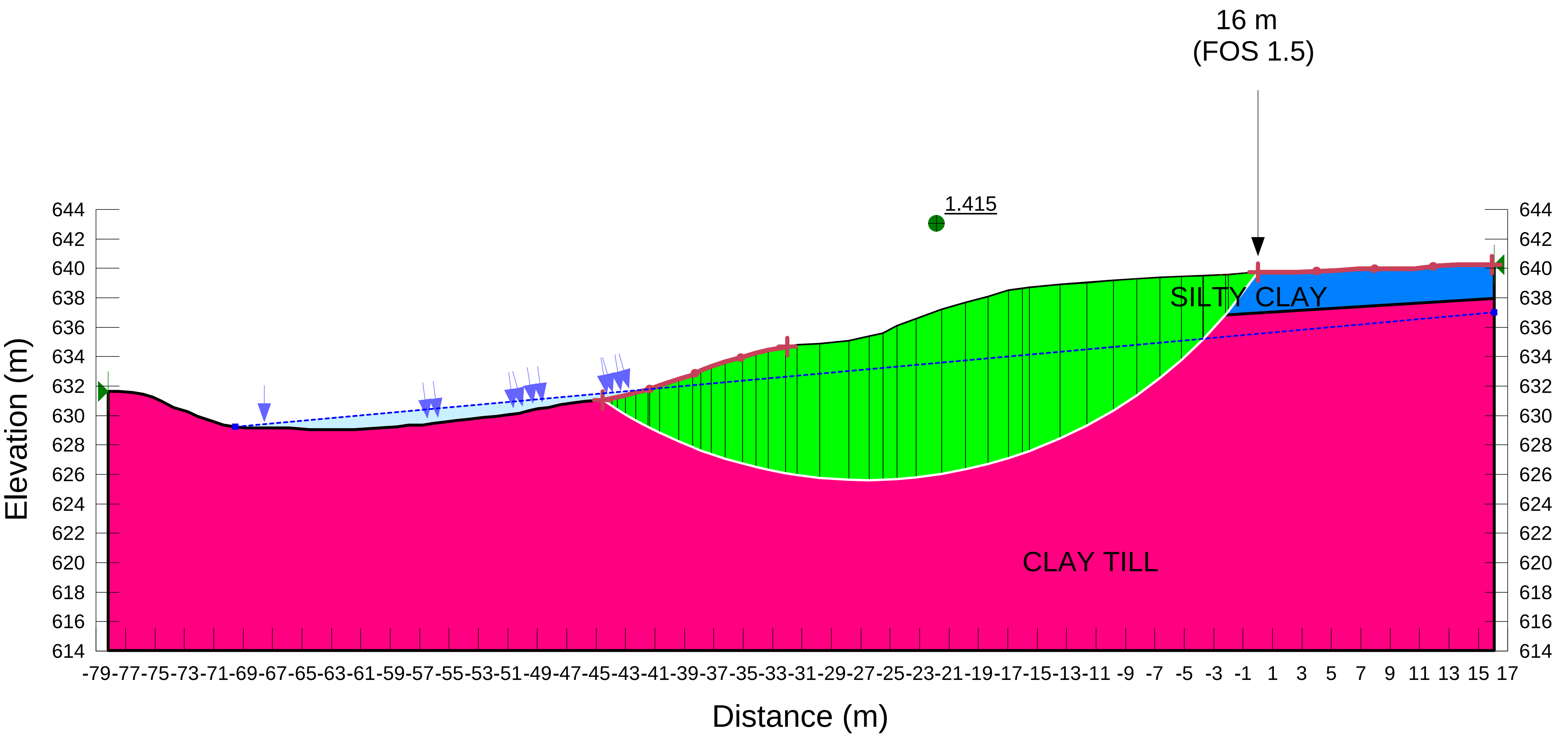




Name: SILTY CLAY
Model: Mohr-Coulomb
Unit Weight: 16 kN/m³
Cohesion: 14 kPa
Phi: 21 °
Piezometric Line: 1
Name: CLAY TILL
Model: Mohr-Coulomb
Unit Weight: 18.5 kN/m³
Cohesion: 15 kPa
Phi: 19 °
Piezometric Line: 1
3 m
(FOS 1.1)
6 m
(FOS 1.3)
12 m
(FOS 1.5)
1.119
SILTY CLAY
CLAY TILL
Elevation (m)
Distance (m)
651
649
647
645
643
641
639
637
635
633
631
629
627
625
623
-38
-36
-34
-32
-30
-28
-26
-24
-22
-20
-18
-16
-14
-12
-10
-8
-6
-4
-2
0
2
4
6
8
10
12
14

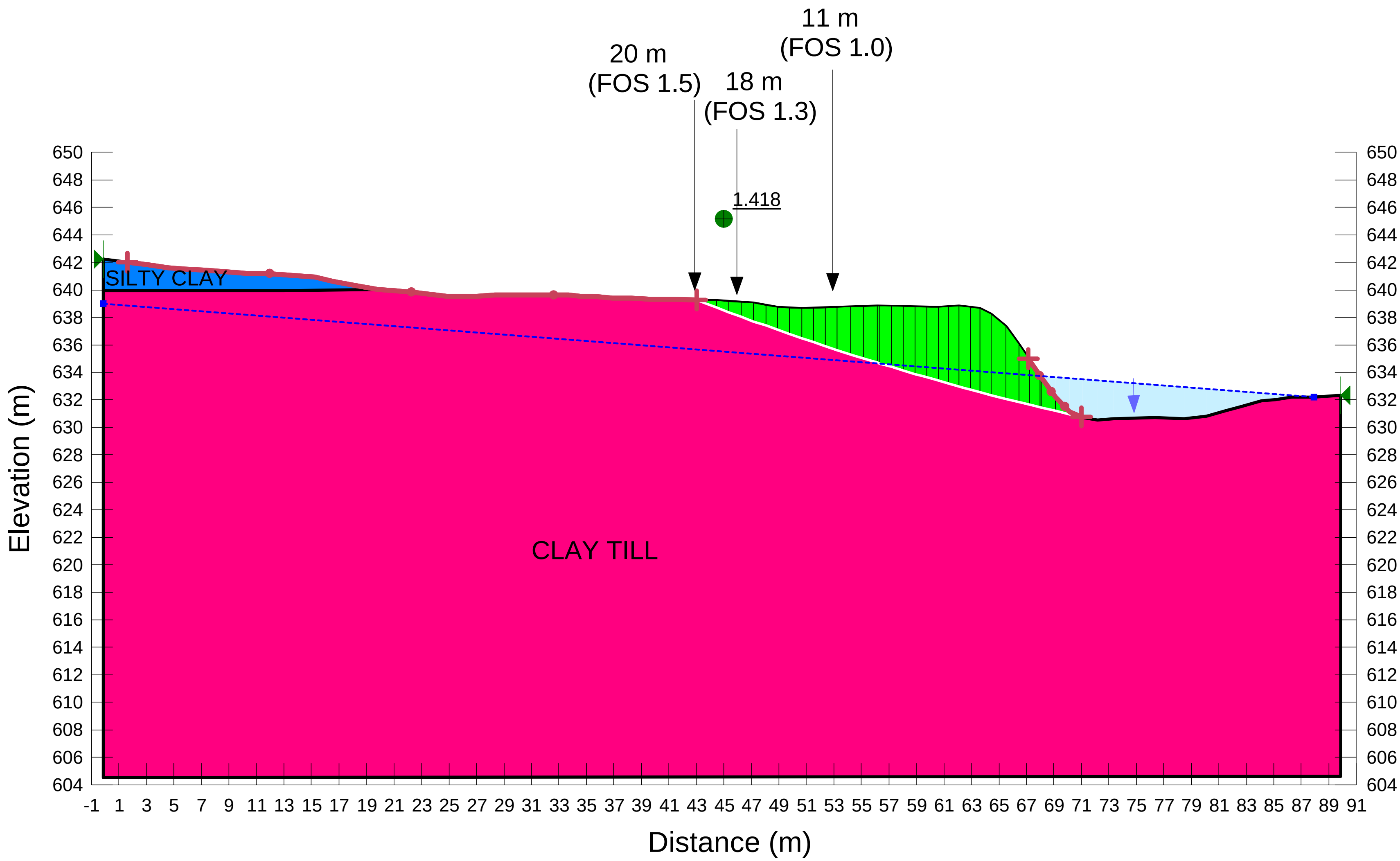
Name: SILTY CLAY
Model: Mohr-Coulomb
Unit Weight: 16 kN/m³
Cohesion: 0 kPa
Phi: 20 °
Piezometric Line: 1

Name: CLAY TILL
Model: Mohr-Coulomb
Unit Weight: 16 kN/m³
Cohesion: 0 kPa
Phi: 20 °
Piezometric Line: 1



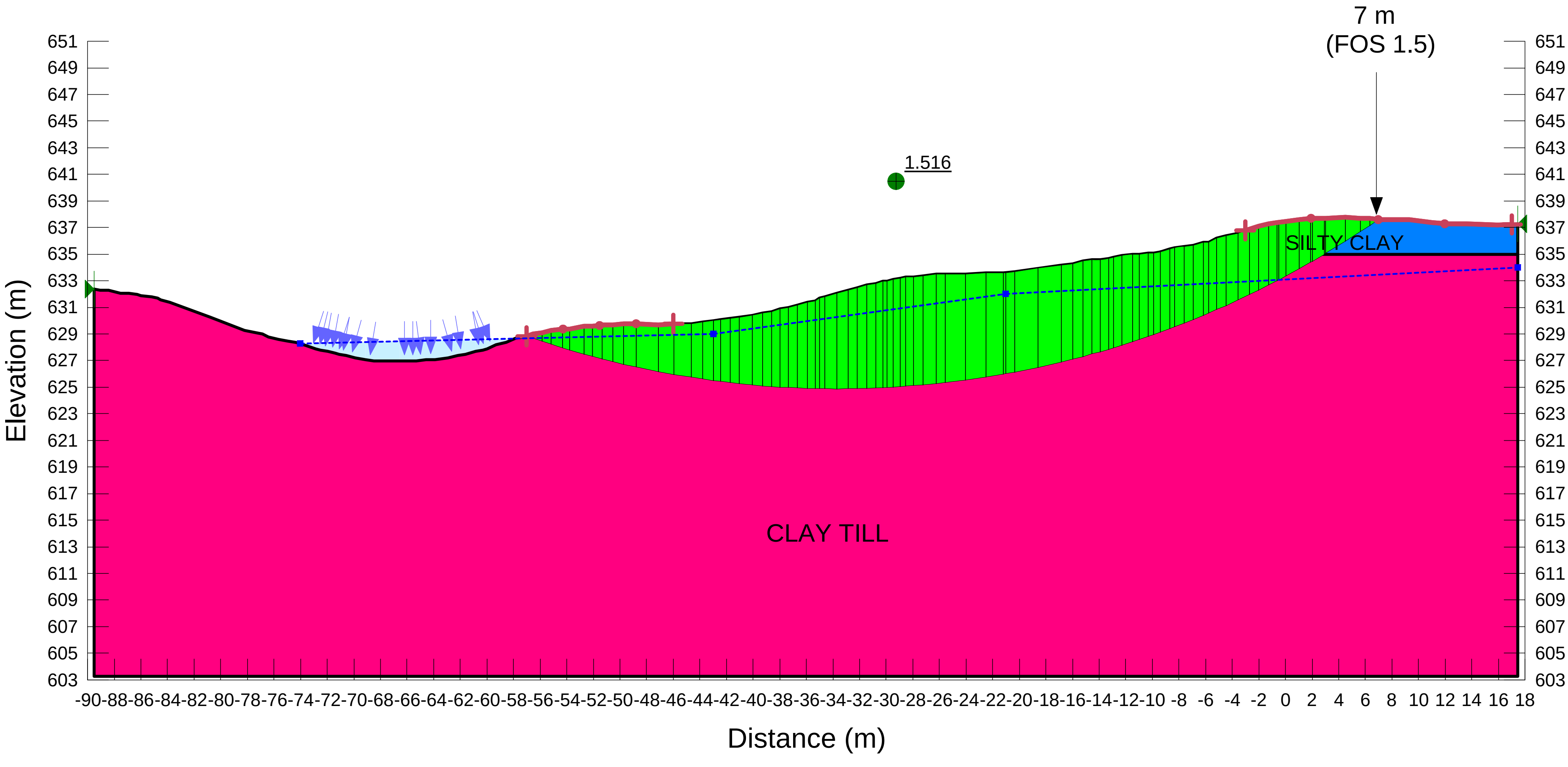
Name: SILTY CLAY
Model: Mohr-Coulomb
Unit Weight: 16 kN/m³
Cohesion: 3 kPa
Phi: 18 °
Piezometric Line: 1

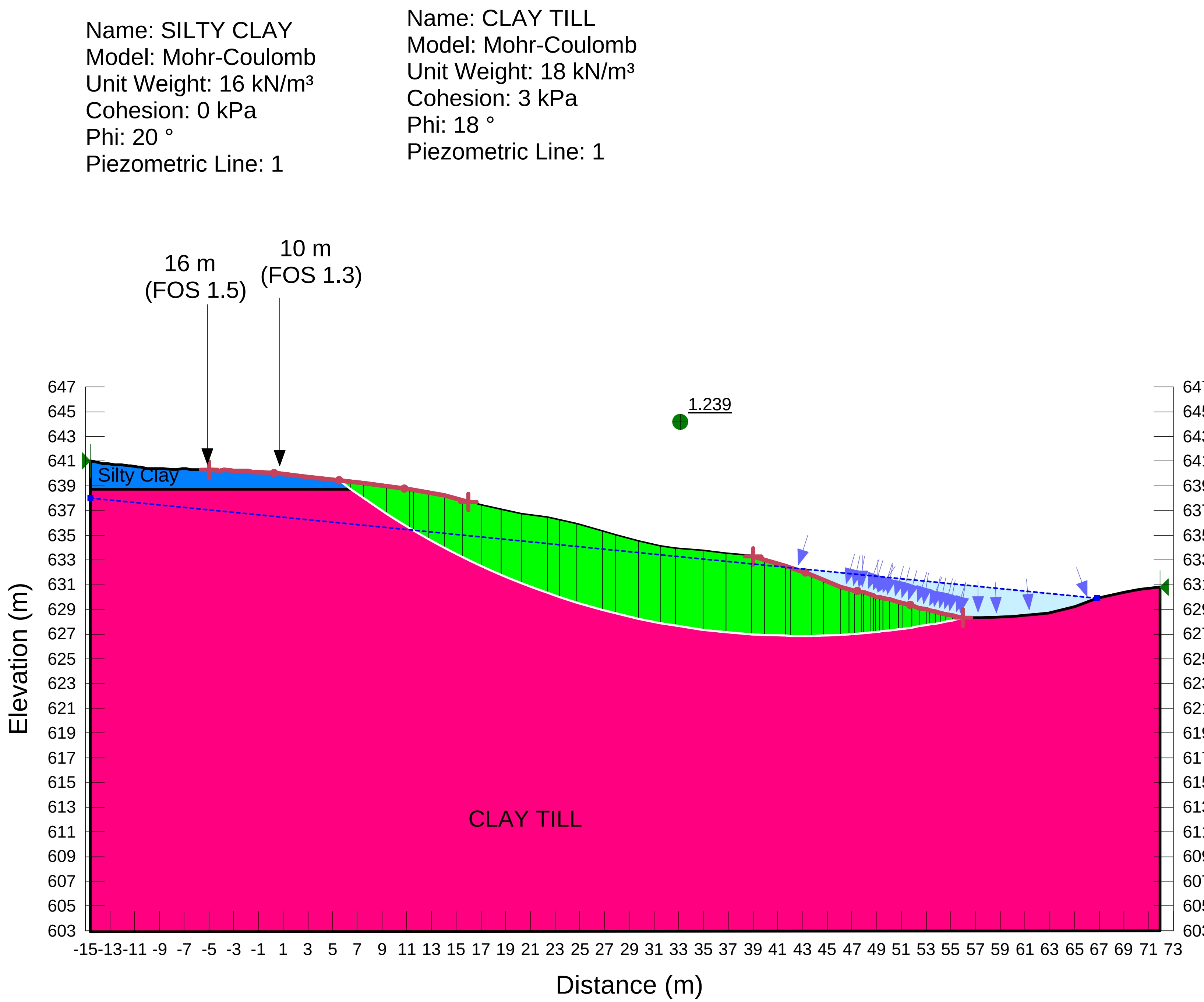
Name: CLAY TILL
Model: Mohr-Coulomb
Unit Weight: 18.5 kN/m³
Cohesion: 5 kPa
Phi: 18 °
Piezometric Line: 1



Name: SILTY CLAY
Model: Mohr-Coulomb
Unit Weight: 16 kN/m³
Cohesion: 0 kPa
Phi: 18 °
Piezometric Line: 1

Name: CLAY TILL
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 17.5 °
Piezometric Line: 1

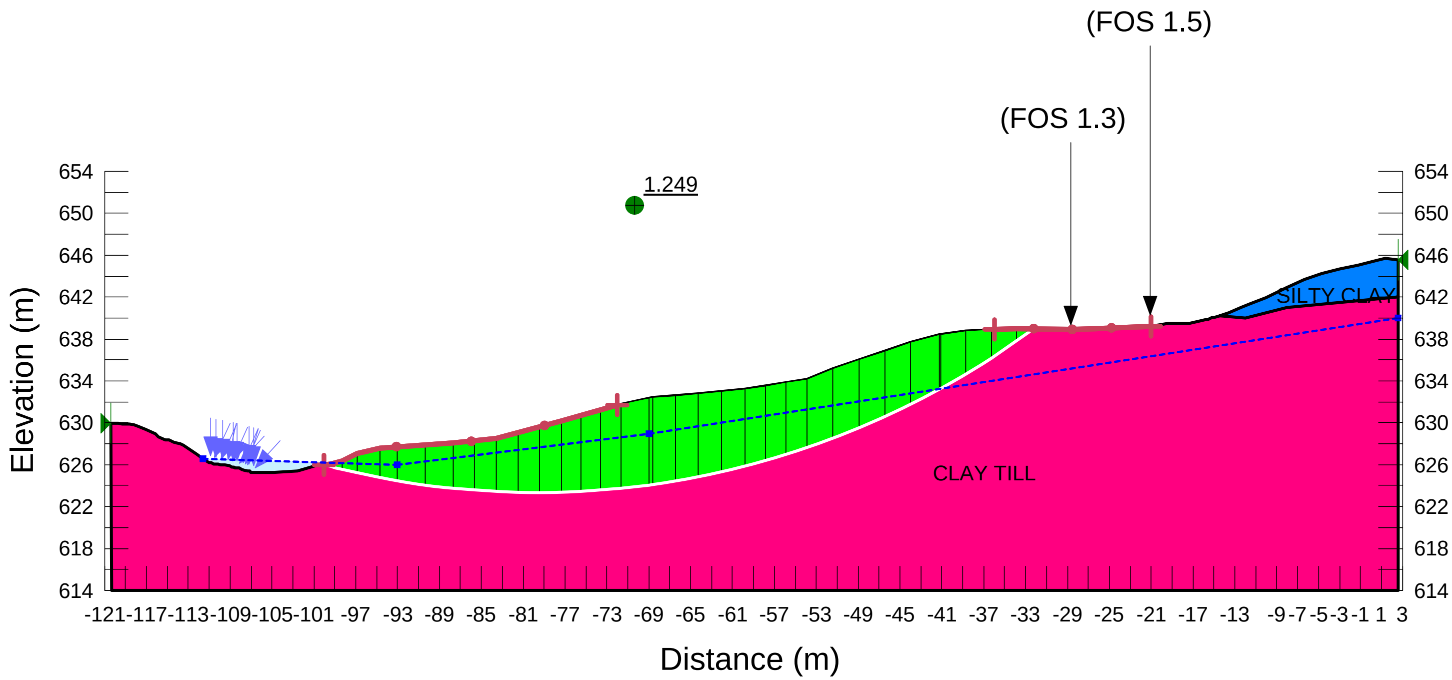


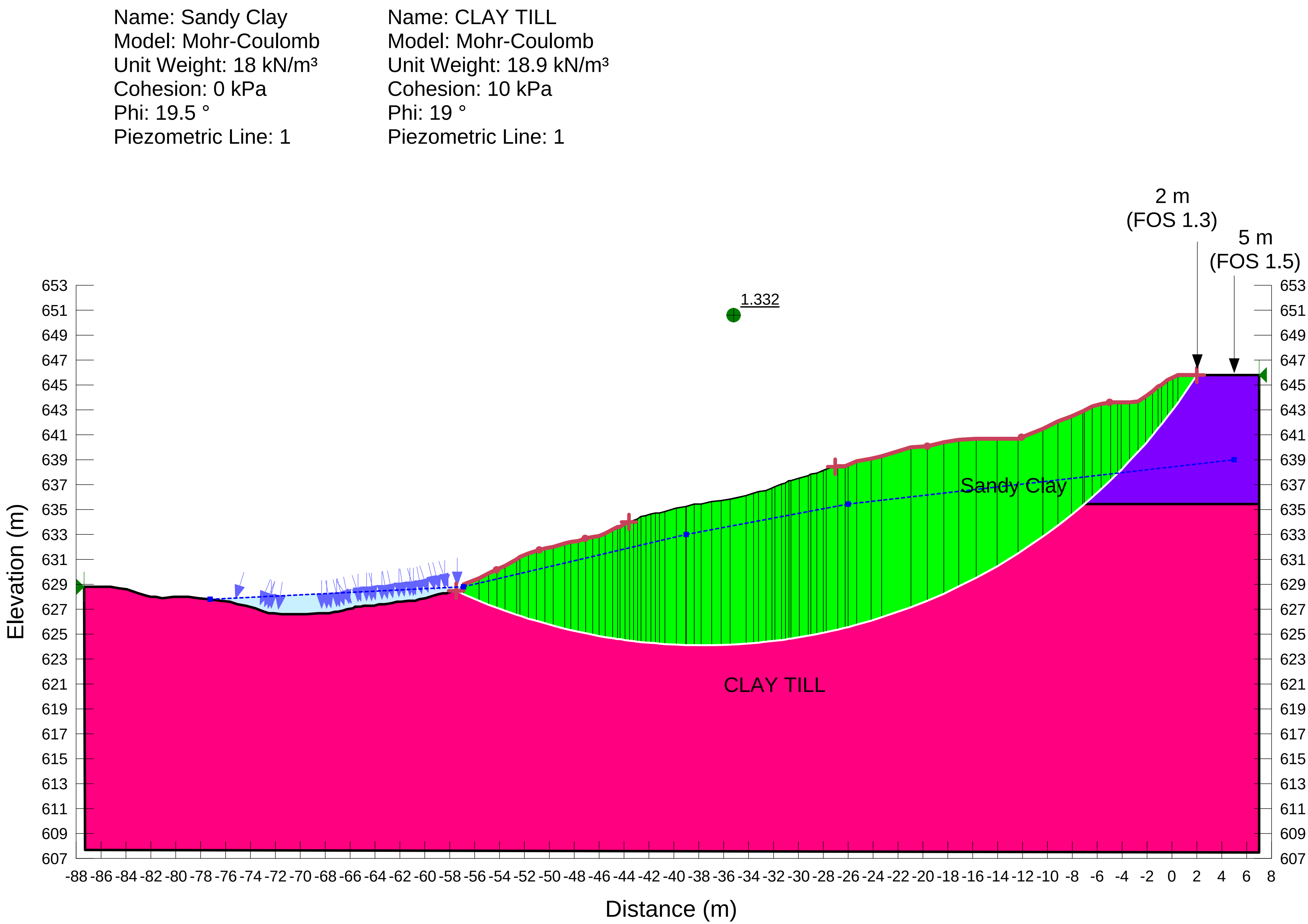


Name: SILTY CLAY
Model: Mohr-Coulomb
Unit Weight: 16 kN/m³
Cohesion: 0 kPa
Phi: 20 °
Piezometric Line: 1
Name: CLAY TILL
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 3 kPa
Phi: 18 °
Piezometric Line: 1
16 m
(FOS 1.5)
10 m
(FOS 1.3)
1.239
Silty Clay
CLAY TILL
Elevation (m)
Distance (m)
647 645 643 641 639 637 635 633 631 629 627 625 623 621 619 617 615 613 611 609 607 605 603
-15 -13 -11 -9 -7 -5 -3 -1 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71 73

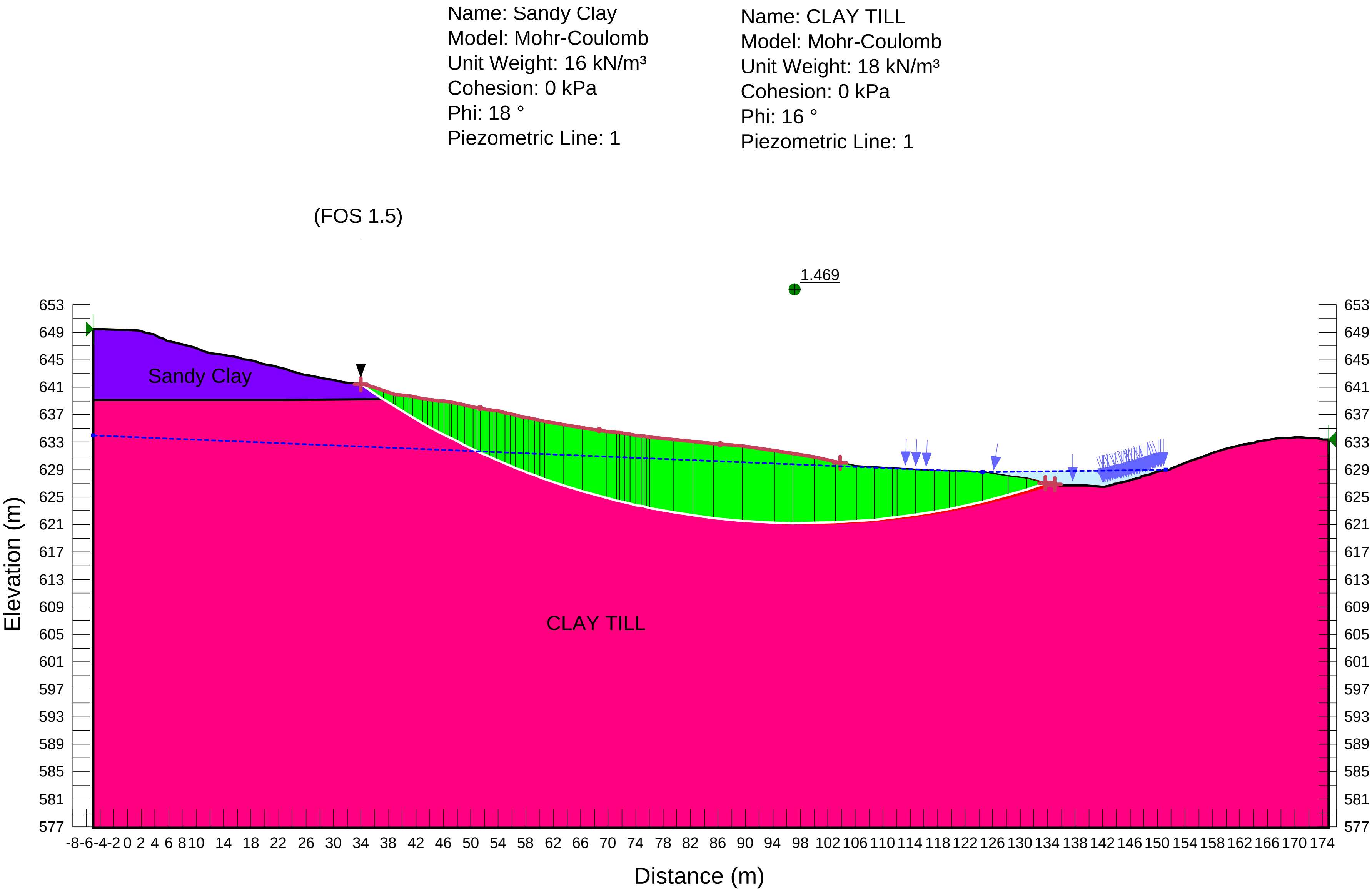
Name: SILTY CLAY
Model: Mohr-Coulomb
Unit Weight: 16 kN/m³
Cohesion: 0 kPa
Phi: 20 °
Piezometric Line: 1

Name: CLAY TILL
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 18 °
Piezometric Line: 1





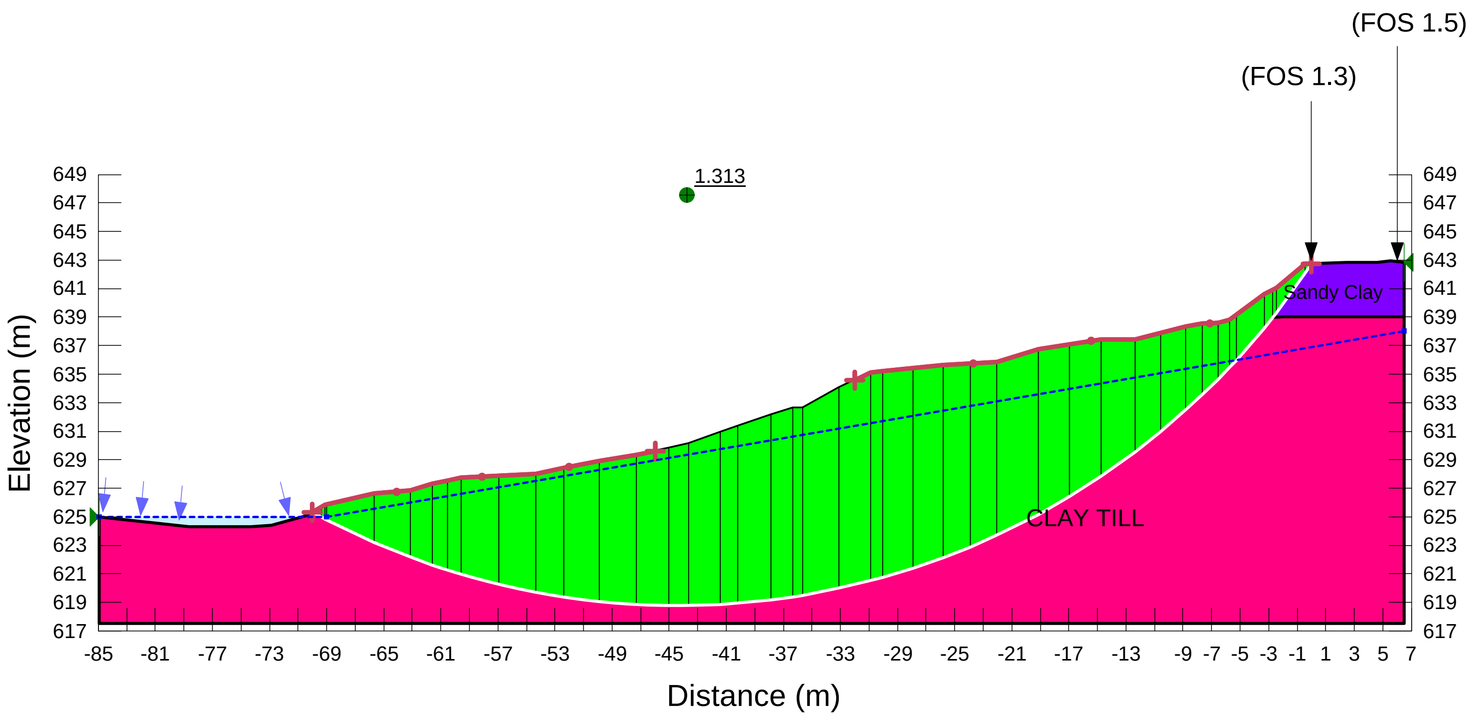
Name: Sandy Clay
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 19.5 °
Piezometric Line: 1
Name: CLAY TILL
Model: Mohr-Coulomb
Unit Weight: 18.9 kN/m³
Cohesion: 10 kPa
Phi: 19 °
Piezometric Line: 1
2 m
(FOS 1.3)
5 m
(FOS 1.5)
1.332
Sandy Clay
CLAY TILL
Elevation (m)
Distance (m)



Name: Sandy Clay
Model: Mohr-Coulomb
Unit Weight: 16 kN/m³
Cohesion: 0 kPa
Phi: 18 °
Piezometric Line: 1
Name: CLAY TILL
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 16 °
Piezometric Line: 1
(FOS 1.5)
1.469
Sandy Clay
CLAY TILL
Elevation (m)
Distance (m)

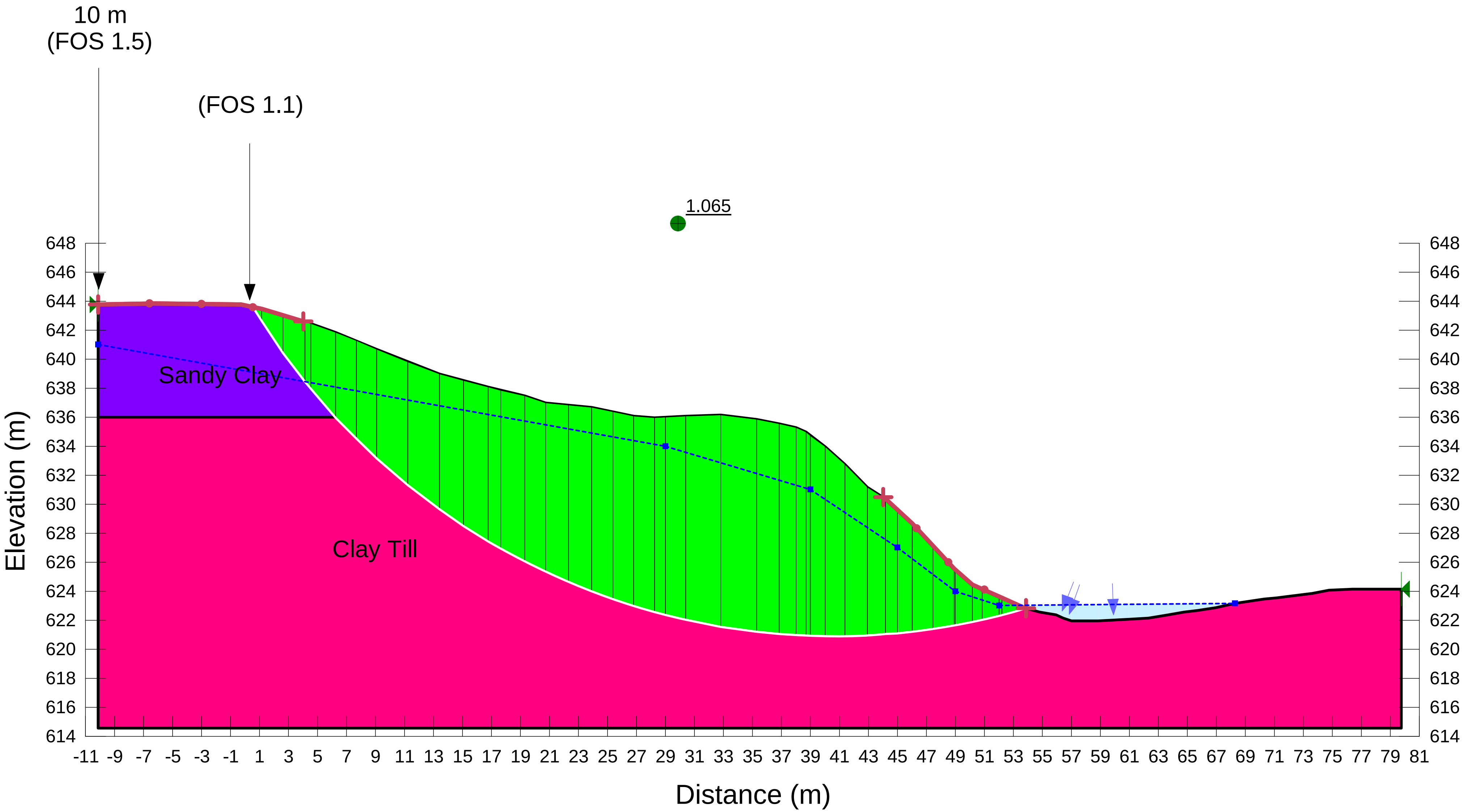
Name: Sandy Clay
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 2 kPa
Phi: 19 °
Piezometric Line: 1

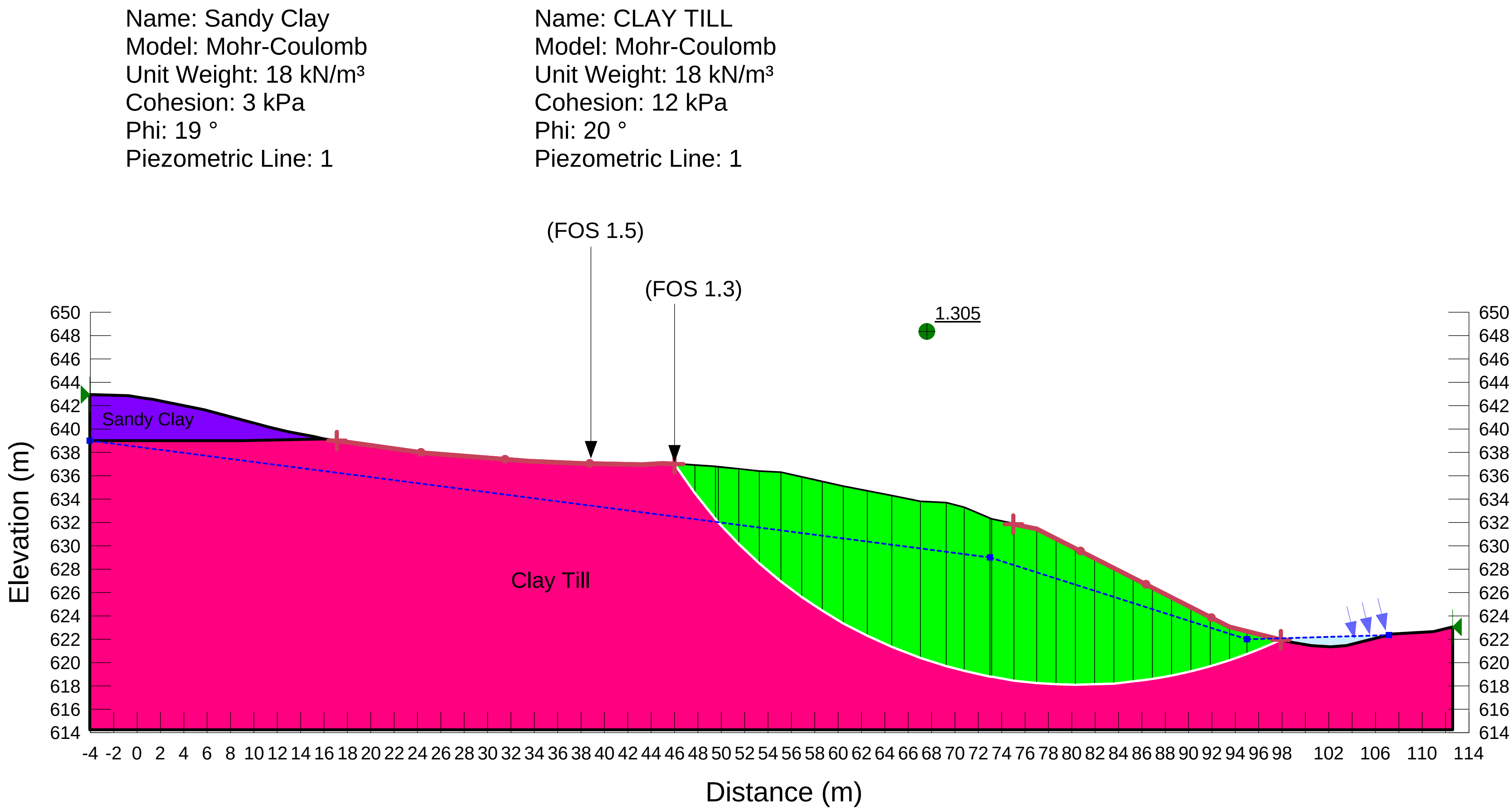
Name: CLAY TILL
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 12 kPa
Phi: 16 °
Piezometric Line: 1



Name: Sandy Clay
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 0 kPa
Phi: 20 °
Piezometric Line: 1

Name: Clay Till
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 15 kPa
Phi: 20 °
Piezometric Line: 1




Name: Sandy Clay
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 3 kPa
Phi: 19 °
Piezometric Line: 1
Name: CLAY TILL
Model: Mohr-Coulomb
Unit Weight: 18 kN/m³
Cohesion: 12 kPa
Phi: 20 °
Piezometric Line: 1
(FOS 1.5)
(FOS 1.3)
1.305
Sandy Clay
Clay Till
650
648
646
644
642
640
638
636
634
632
630
628
626
624
622
620
618
616
614
-4 -2 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90 92 94 96 98 102 106 110 114
Elevation (m)
Distance (m)

LIMITATIONS

REPORT LIMITATIONS AND USAGE

The use of this attached report is subject to acceptance of the following general terms and conditions.

1. STANDARD OF CARE - In the performance of professional services, ParklandGEO will use that degree of care and skill ordinarily exercised under similar circumstances by reputable members of its profession practicing in the same or similar localities. No other warranty expressed or implied is made or intended by this agreement or by furnishing oral or written reports of the findings made. ParklandGEO is to be liable only for damage directly caused by the negligence of ParklandGEO.

2. INTERPRETATION OF THE REPORT - The CLIENT recognizes that subsurface conditions will vary from those encountered at the location where borings, surveys, or explorations are made and that the data, interpretations and recommendation of ParklandGEO are based solely on the information available to him. Classification and identification of soils, rocks, geological units, contaminated materials and contaminant quantities will be based on commonly accepted practices in geotechnical or environmental consulting practice in this area. ParklandGEO will not be responsible for the interpretation by others of the information developed.

3. SITE INFORMATION - The CLIENT agrees to fully cooperate with ParklandGEO and provide all information with respect to the past, present and proposed conditions and use of the Site whether specifically requested or not. The CLIENT acknowledges that in order for ParklandGEO to properly advise and assist the CLIENT in respect of the investigation of the Site, ParklandGEO is relying upon full disclosure by the CLIENT of all matters pertinent to an investigation of the Site.

   Where specifically stated in the scope of work, ParklandGEO will perform a review of the historical information obtained or provided by the Client to assist in the investigation of the Site unless and except to the extent that such a review is limited or excluded from the scope of work.

4. COMPLETE REPORT - The Report is of a summary nature and is not intended to stand alone without reference to the instructions given to ParklandGEO by the CLIENT, communications between ParklandGEO and the CLIENT, and to any other reports, writings or documents prepared by ParklandGEO for the CLIENT relative to the specific Site, all of which constitute the Report. The word "Report" shall refer to any and all of the documents referred to herein. In order to properly understand the suggestions, recommendations and opinions expressed by ParklandGEO, reference must be made to the whole of the Report. ParklandGEO cannot be responsible for use of any part or portions of the report without reference to the whole report. The CLIENT agrees to the following statement:

   > "This report has been prepared for the exclusive use of the named CLIENT. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. ParklandGEO accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report."

   The CLIENT agrees that in the event that any such report is released to a third party, such disclaimer shall not be obliterated or altered in any manner. The CLIENT further agrees that all such reports shall be used solely for the purposes of the CLIENT and shall not be released or used by others without the prior written permission of ParklandGEO.

5. LIMITATIONS ON SCOPE OF INVESTIGATION AND WARRANTY DISCLAIMER
   There is no warranty, expressed or implied, by ParklandGEO that:
   a) the investigation shall uncover all potential geo-hazards, contaminants or environmental liabilities on the Site; or
   b) the Site will be entirely free of all geo-hazards or contaminants as a result of any investigation or cleanup work undertaken on the Site, since it is not possible, even with exhaustive sampling, testing and analysis, to document all potential geo-hazards or contaminants on the Site.

   The CLIENT acknowledges that:
   a) the investigation findings are based solely on the information generated as a result of the specific scope of the investigation authorized by the CLIENT;

b) unless specifically stated in the agreed Scope of Work, the investigation will not, nor is it intended to assess or detect potential contaminants or environmental liabilities on the Site;

c) any assessment regarding geological conditions on the Site is based on the interpretation of conditions determined at specific sampling locations and depths and that conditions may vary between sampling locations, hence there can be no assurance that undetected geological conditions, including soils or groundwater are not located on the Site;

d) any assessment is also dependent on and limited by the accuracy of the analytical data generated by the sample analyses;

e) any assessment is also limited by the scientific possibility of determining the presence of unsuitable geological conditions for which scientific analyses have been conducted; and

f) the laboratory testing program and analytical parameters selected are limited to those outlined in the CLIENT's authorized scope of investigation; and

g) there are risks associated with the discovery of hazardous materials in and upon the lands and premises which may inadvertently discovered as part of the investigation. The CLIENT acknowledges that it may have a responsibility in law to inform the owner of any affected property of the existence or suspected existence of hazardous materials and in some cases the discovery of hazardous conditions and materials will require that certain regulatory bodies be informed. The CLIENT further acknowledges that any such discovery may result in the fair market value of the lands and premises and of any other lands and premises adjacent thereto to be adversely affected in a material respect.

6. CONTROL OF WORK SITE AND JOBSITE SAFETY - ParklandGEO is only responsible for the activities of its employees on the jobsite. The presence of ParklandGEO personnel on the Site shall not be construed in any way to relieve the CLIENT or any contractors on Site from their responsibilities for Site safety. The CLIENT undertakes to inform ParklandGEO of all hazardous conditions, or possible hazardous conditions which are known to him.

7. COST ESTIMATES - Estimates of remediation or construction costs can only be based on the specific information generated and the technical limitations of the investigation authorized by the CLIENT. Accordingly, estimated costs for construction or remediation are based on the known site conditions, which can vary as new information is discovered during construction. As some construction activities are an iterative exercise, ParklandGEO shall therefore not be liable for the accuracy of any estimates of remediation or construction costs provided.

8. LIMITATION OF LIABILITY - The CLIENT hereby agrees that to the fullest extent permitted by the law ParklandGEO’s total liability to CLIENT for any and all injuries, claims, losses, expenses or damages whatsoever arising out of or in anyway relating to the Project, the Site, or this agreement from any cause or causes including but not limited to ParklandGEO ‘s negligence, errors, omissions, strict liability, breach of contract, or breach of warranty shall not exceed the total amount paid by the CLIENT for the services to ParklandGEO under this contract or $50,000, whichever is lessor, or as otherwise agreed to in writing.

9. NO SPECIAL OR CONSEQUENTIAL DAMAGES - The CLIENT and ParklandGEO agree that to the fullest extent permitted by law ParklandGEO shall not be liable to the CLIENT for any special, indirect or consequential damages whatsoever, whether caused by ParklandGEO's negligence, errors, omissions, strict liability, breach of contract, breach of warranty or other cause of causes whatsoever.

10. INDEMNIFICATION - To the fullest extent permitted by law, the CLIENT agrees to defend, indemnify and hold ParklandGEO, its directors, officers, employees, agents and subcontractors, harmless from and against any and all claims, defence costs, including legal fees on a full indemnity basis, damages, and other liabilities arising out of or in any way related to ParklandGEO 's reports or recommendations concerning this Agreement, ParklandGEO's work and presence on the project property, or the presence, release, or threatened release of hazardous substances or pollutants on or from the Site; provided that the CLIENT shall not indemnify ParklandGEO against liability for damages to the extent caused by the negligence or intentional misconduct of ParklandGEO, its agents or subcontractors.