August 2015

FEASIBILITY STUDY

Bow River Regional Pathway Douglasdale/McKenzie Lake Calgary, Alberta

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REPORT

Golder Associates

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Executive Summary

The Bow River Regional Pathway is a system of pathways, bikeways, and trails developed within the City of Calgary. In southeast Calgary, the pathway system passes through the communities of Douglasdale and McKenzie Lake along the top of the eastern side of the Bow River Valley. In this area, the pathway is heavily used by Calgarians and local residents and is known for its scenic views of the Bow River, Fish Creek Provincial Park, and the Rocky Mountains.

Over the years, the pathway has sustained damage from active slope movement. This has resulted in several path closures. The City of Calgary (the City) has engaged consultants and contractors to carry out repair work, maintenance, and minor pathway relocations/closures. Where larger failures have occurred, slope stabilization efforts have been implemented to maintain the pathway system.

In an effort to assess the feasibility of restoring and preserving City infrastructure and City-owned land, the City engaged Golder Associates Ltd. (Golder) to conduct this study. The main objective of the study is to assess the geotechnical and hydrological risks to be used to support decision making, planning and budgeting purposes.

Along the study area, a line (with station numbers) that generally follows the property line has been assigned so that the reader can identify and locate places referenced in the text. Nine zones were also defined as part of the assessment based on similar hydrological and geotechnical conditions.

Based on Golder's assessment, over 2.1 km of the pathway is "at risk" for damage caused by slope failure and excessive ground movement. The majority of these at risk areas are in areas close to relict slope failures, where the pathway follows the headscarp of the failure plane. Conceptual design options and recommendations are presented to mitigate and/or manage problematic areas taking into consideration the current hydrological, surface erosion, and geotechnical assessments.

Where design options are presented the anticipated service life of the proposed engineered structures has generally been taken as 75 years, with the exception of timber components, which are anticipated to require maintenance within 15 to 20 years. The proposed pathway alignment with relocated sections generally meets or exceeds a calculated minimum factor of safety of 1.3.

A summary of the recommended options and anticipated order of magnitude capital costs are provided below.

Zone	Concept Description	Priority	Estimated Cost ($ Canadian 2015)		
			Low (-20%)	50/50 Point	High (+30%)
1	Site Monitoring	Low	-	-	-
2	Cantilevered Caisson Wall and Slope Regrading	High	$906,000	$1,087,000	$1,413,000
3 & 4	Pathway Relocation	High	$321,000	$385,000	$501,000
	River Training	Moderate	$2,396,000	$2,875,000	$3,738,000
5	Pathway Relocation	Low	$188,000	$225,000	$293,000
6	Pathway Relocation	Moderate	$200,000	$240,000	$312,000
7	Anchored Caisson Wall	High	$11,916,000	$14,299,000	$18,589,000
8&9	Site Monitoring	Low	-	-	-
Total Estimate			**$15,927,000**	**$19,111,000**	**$24,846,000**

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1.0 INTRODUCTION

The Bow River Regional Pathway is a system of pathways, bikeways, and trails developed within the City of Calgary. In southeast Calgary, the pathway system passes through the communities of Douglasdale and McKenzie Lake along the top of the eastern side of the Bow River Valley. In this area, the pathway is heavily used by Calgarians and local residents and is known for its scenic views of the Bow River, Fish Creek Provincial Park, and the Rocky Mountains.

Over the years, the pathway has sustained damage from active slope movement. This has resulted in several path closures. The City of Calgary (the City) has engaged consultants and contractors to carry out repair work, maintenance, and relocations/closures. Where larger failures have occurred, slope stabilization efforts have been implemented to maintain the pathway system.

In an effort to assess the feasibility of restoring and preserving City infrastructure and City-owned land, the City engaged Golder Associates Ltd. (Golder) to conduct this study. The main objective of the study is to assess the geotechnical and hydrological aspects and risks to be used to support decision making, planning and budgeting purposes associated with maintaining the pathway system.

This report is prepared for the exclusive use of The City of Calgary, who is the only approved user of this information. Use of this report is subject to conditions outlined in the “*Important Information and Limitations of this Report*” that follow the main text of this report and form an integral part of the report.

1.1 Scope of Work

The scope of work for the feasibility study is outlined in Golder’s proposal (Proposal No. P1411598), dated November 14, 2014. The scope of work generally includes geotechnical, erosional and hydrological assessments, a conceptual design study, and order of magnitude cost estimates for the construction of potential remedial measures and slope (pathway) stabilization methods.

Specific tasks carried out by Golder include:

- collection and review of existing and available information;
- a site reconnaissance visit to supplement existing data, where necessary;
- a geotechnical drilling program to supplement existing data and to install slope inclinometers;
- geotechnical slope stability analysis;
- erosional and hydrological assessment studies;
- preparation of this report documenting the findings from the data review, site reconnaissance, drilling and laboratory testing program, and geotechnical and hydrological analyses; and
- preparation of recommended remediation and design options along with an order of magnitude construction capital cost estimates.

Written authorization to proceed with this scope was received from Ms. Brenda Rincon, P.Eng, Slope Stability Coordinator for The City of Calgary via email on December 22, 2014.

2.0 STUDY AREA

2.1 Location

The study area is located along the western edge of the communities of Douglasdale Estates and McKenzie Lake in southeast Calgary, Alberta as shown in Figure 1 and herein described as “the Site”.

The Site includes a 3.5 km segment of the pathway located along the top of the eastern slope of the Bow River Valley. The Site boundaries include City-owned land from:

- East of the Bow River and west of the western edge of the private residential property lines.
- South of the pedestrian bridge downslope of 57 Douglas Park Manor SE.
- North of 220 Mt. Victoria Place SE.

The Site boundaries are delineated in Figure 1.

2.2 Description

The major roadway that provides access to the Site is 130 Avenue SE near the northern part of the area. Residential roadways include Mt. Douglas Circle SE and Mt. Alberta View SE, which provide access to the middle and south of the area. Private residential homes border the majority of the eastern edge of the Site boundary and the Bow River borders the western edge.

- At the north end of the Site, two baseball diamonds exist with public parking and washroom facilities. The pathway connects to this area and follows the Bow River southward within the floodplain.
- South of the baseball diamonds, a pedestrian bridge crosses a small drainage channel that flows along the toe of the eastern Bow River Valley slope. South of the bridge, the pathway traverses the slope to the top of the slope where it meets the access point to 130 Avenue SE. One sitting area with three park benches is located near this intersection.
- Between the 130 Avenue access and Mt. Douglas Circle access, the pathway closely follows the crest of the slope. Three sitting areas are located in this stretch of pathway, two of which that have been constructed as lookouts branching from the main pathway.
- Between Mt. Douglas Circle and Mt. Alberta View one sitting area exists. Just north of the Mt. Alberta View access, an anchored caisson retaining wall has been constructed to protect the pathway and City-owned land.
- South of Mt. Alberta View, the Patterson Homestead Memorial Park exists. The park is surrounded by large trees and a monument in the centre. South of the park, undeveloped park space approximately 2.6 hectares in area exists.
- South of the Site, the pathway crosses the Bow River over the McKenzie Pedestrian Bridge to Fish Creek Provincial Park.

A study conducted by the City in 2014 indicates that the pathway is used by up to 55 users per hour (City of Calgary, 2014).

3.0 REGIONAL SETTING

3.1 Topography

The terrain within the Site has been previously characterized by two main topographic features: relatively flat prairie upland and the Bow River Valley slope. Currently, the prairie upland gently slopes towards the Bow River and is mostly developed with private residential properties.

Based on topographic data provided by the City, the elevation at the top of the slope ranges from approximately 1,015 to 1,035 metres above sea level (masl) and the bottom of the slope at normal river level ranges from approximately 1,000 to 1,005 masl within the Site.

The average slope varies from 15 to 40 degrees from horizontal; however, past slope failures and erosional processes have caused localized steepened areas and some areas to become near vertical. These steeper portions are prevalent in the lower portions of the slope near the river at the southern part of the Site.

Two historic erosion gullies intersect the slope. One is located just south of the 130 Avenue SE and one at the south end of the Site.

3.2 Surficial Geology

As described by Tharin (1960), glaciers twice invaded the Calgary area from the prairies and from the mountains. Ice covered the entire area in the first advance, and the second advance dammed the Bow River Valley to form a large lake referred to as Lake Calgary.

The present Bow River Valley follows the alignment of a wide pre-glacial valley which was in-filled with glacial drift (till) and glaciolacustrine deposits overlying pre-glacial gravel over Tertiary bedrock (Moran 1986). The upper slopes are anticipated to have a recent thin colluvium veneer (till debris that has been moved downslope by gravity) and in some areas, the lower slopes may be covered with thick deposits of landslide debris.

The pre-glacial gravel is found immediately above bedrock but not continuous over the region. The deposit consists of well-rounded gravel and cobbles of quartzite, dark gray limestone, and minor amounts of local sedimentary rock. In some outcrops, the gravel has been partly or completed cemented or filled with silt. In the valley, the gravel deposits have been observed up to about 10 m in thickness.

The till deposits that overlie the gravel have been identified to consist of ground moraine, ablation moraine and hummocky disintegration moraine. Depending on the mode of deposition, the till ranges from silt to clay with occasional pebbles to a very coarse textured with cobbles and boulders. Some till sheets have been over-consolidated by the weight of the glacial ice (i.e. basal till). Ablation tills typically exhibit relatively large variation in lithology, index and engineering properties. Some of the till has been modified to a depth usually not exceeding 3 m but locally up to 15 m by previous slope activities, surface drainage, frost and desiccation.

Recent post-glacial fluvial channel gravel is present within the valley consisting of poorly-sorted to moderately well-sorted gravels, sandy gravels and gravelly sands, with little silt or clay.

3.3 Bedrock Geology

According to Hamblin (2004), the surficial deposits are underlain by bedrock of the Paskapoo Formation of the middle-to-late Paleocene age consisting of a non-marine sequence of sandstones, mudstone and siltstone. The sediments were derived from the Canadian Cordillera during tectonic uplift and erosion, and were transported eastward by river systems and deposited in fluvial and floodplain environments. Bedrock strata are generally sub-horizontal and variably weathered. A higher degree of weathering tends to exist within the upper portion of the bedrock and these layers are significantly weaker than the adjacent more competent bedrock.

The sandstones were deposited in fluvial channels and are generally cross-bedded, medium- to coarse-grained and laterally extensive. The sandstone outcrops observed have basal, sharp erosional surfaces which cut down into and are separated by thick units of mudstone dominated overbank strata. The sandstone beds range up to 15 m in thickness but are typically 5 m to 10 m thick.

The sandstones are interbedded with light grey to greenish or brownish, soft, calcareous, sandy siltstone and mudstone with thin fine-grained sandstone beds. The siltstones and mudstones represent fluvial dispersal systems. They commonly include plant fossils, rooted horizons, and may include slickensides. Carbonaceous mudstones and coaly beds that represent oxygen-poor, swampy settings may also exist. The bedrock may also contain minor claystone strata, bentonite and coal partings.

As described by Hardy (1980), with the exception of some indurated siltstone and sandstone strata, the bedrock is relatively weak because compression was the main diagenetic (rock forming) process for the shale and mudstone. These sediments have a complex stress history. It is considered that extensive erosion of the pre-glacial surface and subsequent rebound has produced horizontal stresses which are commonly greater than the vertical stresses. Jointing in the competent sandstone in valley slopes and also the characteristic bedrock cliff recession both indicate that lateral stresses are being relieved as the valley is down-cut.

In general, the bedrock-overburden contact is anticipated to rise slightly from west to east. Based on the published data, the Bow River is expected to be entrenched into the bedrock at the Site.

3.4 Surface Hydrology

The Bow River is the dominant hydrological feature within the Site. The Bow River flows south along the western boundary of the Site with a mean annual discharge of approximately 100 m^3/s. The Bow River has other smaller side channels within this reach, including the Mallard Point Side Channel. Several gravel bars and mid-channel islands also exist within the Site area.

Within the Site, the natural surface drainage system is poorly developed consisting only of a small watercourse that flows along the toe of the slope in the north portion of the Site. The surface drainage along the steep slopes generally consists of several rills and large gullies. On top of the slope, a series of catch basins and grass-lined swales are located between the pathway system and the private properties. These catch basins are connected to three outfalls within the project site which direct outlet to the Bow River (Outfalls B124, B135, and B136).

3.5 Hydrogeology

Based on measured groundwater levels, observations of seepage during drilling and site visits, and our understanding of the geology of the general area, it would appear that there are two main regional groundwater regimes within the slope. One is relatively shallow and located primarily within the upper till layer and another deeper regime located within the underlying bedrock.

Shallow, localized flow is anticipated within the granular lenses in the till. In the absence of granular lenses, low permeability till units can retard groundwater discharge into the valley, thus producing high groundwater tables and possible artesian conditions. This shallow groundwater regime would be expected to be relatively sensitive to groundwater infiltration due to precipitation, changes in surface drainage, and leaking/damaged underground facilities (water, sanitary, stormwater). In general, the groundwater level would be expected to vary seasonally and with changes in precipitation and runoff conditions.

At depth above bedrock, groundwater movement is anticipated to be mainly within the sands and gravels towards the river valley. Meyboom (1961) found that the Paskapoo sandstones have relatively high permeability and deep regional flow is anticipated to occur towards the valley within the bedrock formation and overlying sands and gravels. Where lower permeability mudstones and claystone units form the upper bedrock strata, groundwater discharge into the valley is anticipated to occur along the overburden-bedrock contact.

4.0 INFORMATION REVIEW

4.1 Historical Aerial Photographs

Golder completed a review of selected aerial photographs obtained from 1950 to 2014 at the Site. The scale of the photographs reviewed ranged from 1:3,000 to 1:40,000. The review noted evidence of historic deep-seated retrogressive landslides at several locations within the Site, which have left landslide scars and benches extending the full height of the slope in some places.

Around the Douglasdale Point area (Stations 0+800 to 0+900), a comparison between an aerial photograph taken in 1989 and current conditions shows that approximately 5 m of localized bank erosion at river level has taken place in the last 25 years. Prior to development of the pathway, relict failures are observed with headscarps upslope of the current pathway alignment approximately from Stations 0+350 to 1+025. The relict slide debris is observed to be deposited into the Bow River.

A relict slope failure is also observed in a 1989 aerial photograph set from about Stations 1+900 to 2+475. In comparison to the current imagery it can be observed that the pathway was constructed over the relict failure approximately from Station 1+850 to 1+950. Further, vegetation and slide debris that existed along the toe of the slope has since been eroded within this area.

Shallow surficial slope movements and surface erosion were observed in the aerial photographs from 1998 throughout the Site (typically more pronounced in the steeper portions of the slopes).

Changes in river morphology based on aerial images are documented in Section 6.1.

4.2 Literature Review

For development to take place, the City of Calgary requires that a slope stability setback study be conducted and requires the calculated post-development slope stability factor of safety to be at least 1.5 for unrestricted residential development. The term “factor of safety” (FoS) refers to the ratio of forces available to resist slope failure to those tending to cause this event. A FoS of 1.0 or less implies that the slope has failed or is at the point of failure.

The Provincial Planning Act requires that current unstable lands be classified as environmental reserve lands. Unstable land is considered to be those where the calculated minimum FoS is less than 1.5.

In 1980, Hardy Associates (1978) Ltd. (Hardy) conducted a slope stability study on a portion of the Site as part of a larger investigation in connection with proposed residential development of the Canadian Industries Ltd. property for Douglasdale Estates Ltd. The Hardy report studied an area extending along the Bow River Valley and a portion of prairie upland area east of the river, approximately from Deerfoot Trail SE to Mt. Douglas Close SE. Hardy’s study area extends from Station 0+450 to Station 2+200 of the current study.

The Hardy report included site observations of the riverbank and slope areas, delineation of overburden-bedrock contact where possible and slope stability analysis. Four boreholes were drilled as part of the slope stability investigation. An approximate residential development setback line was drawn and additional setback considerations were discussed in the report (Hardy 1980).

EBA Engineering Consultants Ltd. (EBA) were retained in 1994 by Douglasdale Estates Inc. to perform a slope stability evaluation for the proposed South Douglasdale residential development and to recommend slope stability setback lines for the development. EBA’s 1994 study area extends from Station 0+450 to Station 2+200 of the current study as shown in Figure 2. Five boreholes were drilled as part of the slope stability investigation. The setback line that was developed was likely used as the basis for the current private property lines parallel to the slope crest in the area studied. The EBA report makes reference to several reports that were not made available to Golder for review prior to the submission of this report, including the 1980 Hardy report titled “Report on Geotechnical Investigation Douglasdale Estates, McKenzie Lands” (EBA 1994).

The EBA 1994 report states that, “If the bicycle path is placed along the bottom of the Bow River Valley slope, earth works and disturbance of the slope surface should be minimized”, indicating that the pathway was constructed after 1994.

After the pathway development, the pathway sustained damage from slope movement. Agra Earth and Environmental (Agra) was engaged by Kellam Berg Engineering Inc. in 1999 to conduct a limited geotechnical evaluation of surface erosion and slope movement on the slopes within Douglasdale Estates and Mountain Park subdivisions. Agra’s study area extends from Stations 0+700 to 2+200. Detailed site observations of erosion, seepage and slope movements were recorded. Agra’s report noted that slope movements appeared to be causing cracking on the existing pathway and it was expected that over time other sections of the path would also experience cracking due to slope movement. However, it was concluded that it would be more economical to relocate short sections of the pathway over time, rather than attempt to prevent periodic episode of slope movement along the valley wall.

Further, Agra noted that the loss of ground caused by soil erosion was observed to be an active process, with potential to affect a significant amount of the slope over a short period of time. Agra recommended the reconfiguration of roof drainage to the front of the private lots and re-seeding areas within City property where grass cover had not established. Detailed recommendations for erosion mitigation due to over-slope drainage were also made, including installation of catch basins and drainage pipes, minor re-grading and use of erosion control blankets to re-vegetate eroded areas.

In 2003, Golder was retained by the City to carry out a geotechnical and slope stability assessment in the area of 130 Avenue SE and Mount Douglas Point SE, from Stations 0+900 to 1+725 of the current study. Slope observations were noted during a site visit and at the time, the extent of slope instabilities did not appear to be negatively impacting the residential properties located east of the slope crest; however, some instability features (cracks) were approaching the pathway. The results from stability analysis indicate that the slopes were stable under conditions at that time, but were highly sensitive to changes in the groundwater table. It was noted that should the groundwater table becomes higher than 2 mbgs the slope would tend to become unstable, based on the calculated factor of safety (Golder 2003).

Following unusually heavy rainfalls in the summer of 2005, Golder was retained by the City to carry out slope stability evaluations in three study areas, including Mt. Douglas Point (Stations 0+975 to 1+925), Mt. Alberta View (Stations 2+125 to 2+325) and Mt. Victoria Place (Stations 3+325 to 3+525). Slope observations were noted during site visits and five slope inclinometers and nested piezometers were installed as part of these studies. Slope stability analysis was carried out and setback distances from the slope crest for factors of safety of 1.3 and 1.5 were calculated.

The Golder report noted that there was potential for retrogression of historical deep-seated landslides in the future based on signs of instability (cracking) and triggering factors such as toe erosion. Reducing surface water runoff on the slope face was recommended, and several other slope stabilization options were discussed. Regular monitoring of the slopes was also recommended and since 2006, Golder has conducted annual site visits from Stations 0+000 to 3+525 of the current study to read slope inclinometers and piezometers and record visual observations of the slope such as headscarps, tension cracks, seepage points, ponded water, erosional zones, bedrock outcrops, pathway condition and any other signs of recent movements (Golder, May 2006).

In 2006, the City made several efforts to improve sections for the pathway system affected by ongoing slope instability. These included re-routing the pathway near 130 Avenue SE, re-grading and rebuilding a portion of the severely damaged pathway in the Mt. Alberta View area, and several small scale re-grading and re-paving projects in other areas (Golder, March 2007).

In 2007, Golder proposed several design options to protect the pathway in the Mt. Alberta View area. An anchored caisson wall was the chosen option. Construction of the wall began in 2008 and was completed in 2009. It consists of 70 steel-reinforced concrete piles (0.9 m in diameter) and 35 pressure grouted anchors to stabilize the slope uphill of the caisson wall. The caisson wall is approximately 20 m deep, and the anchors are approximately 26 m long. Two slope inclinometers were installed at the wall to monitor further slope movements. Golder was on-site for construction monitoring for the duration of the project (Golder, October 2009).

Golder conducted a slope stability study of the area immediately north of the Mt. Alberta View caisson wall in 2008 as a consequence of further slope movement. Slope observations were noted during a site visit, setback distances from the crest were calculated, and ongoing monitoring was recommended (Golder, March 2008).

An additional slope stability evaluation was conducted by Golder in 2008 in the Douglas Park area, from Stations 0+200 to 0+625 as a result of observed retrogressive slope movements. Slope observations were noted and a slope inclinometer and nested piezometers were installed. Setback distances from the crest were calculated and further monitoring was recommended. Reduction of surface water runoff on the slope face and other slope stabilization measures were also recommended by Golder (Golder, July 2008).

A slope stability study was carried out by Golder in 2009 in the Douglasdale Point area, from Stations 0+675 to 1+025 of the current study, where the pathway had been damaged by slope movements. Slope observations were noted during a site visit and three boreholes were drilled as part of the study. Design options to stabilize the slope were recommended. The presence of a high plastic clay layer is thought to be the primary contributor to slope instability in this area, as opposed to weak bedrock controlled failure as exhibited in other areas (Golder, May 2009).

In 2014, EBA was engaged to conduct a slope stability study in the area south of the Mt. Alberta View caisson wall from Stations 2+300 to 2+475 of the current study where there is significant pathway damage. Two slope inclinometers and two piezometers were installed and a geophysical survey was conducted. Slope stability analysis included short-term remediation and long-term remediation options. Advantages, disadvantages and risk were assigned to each option. It was noted that short-term solutions would only restore the pathway temporarily and would not stabilize the slope. The long-term design option involved the installation of a deep pile wall. At the time of this report, slope inclinometer data were not available from these new installations (EBA 2014).

The list of available existing reports and information from each of these reports is summarized in Appendix A.

5.0 SUPPLEMENTARY INVESTIGATION

5.1 Site Reconnaissance

Erosion processes and sliding have exposed the geological profile within the valley wall in many areas. These exposures have been documented in various reports as described in Section 4.2. The existing site observations by Golder and by others were compiled and shown on Figures 3 to 7 following the text of this report.

A supplementary site visit was made by Golder on January 19, 2015 to obtain additional seepage data from frozen groundwater discharge points to supplement the existing data. Photographs were taken across the river in Fish Creek Park along the majority of the southern portion of the Site. Seepage point elevations were approximated and are included in the field observations shown on Figure 6. Example photographs are provided in Figure 8.

Figure 8: Frozen groundwater seepage observation located at interpreted overburden-bedrock contact (Left: approximately located at Station 2+650, Right: approximately located at Station 2+400).

Additional bedrock observations were recorded near the slope toe at approximate elevations ranging between 1,006 to 1,012 masl (or up to 7 m above the toe of the slope) at the southern portion of the Site. Example photographs of the exposed bedrock are shown in Figure 9.

Figure 9: Exposed bedrock observations at slope toe (approximately located at Station 2+550).

The bedrock observed consists of brown, weathered sandy siltstone and mudstone with thin, fine-grained sandstone bedding.

5.2 Geotechnical Drilling Program

In addition to the site reconnaissance observations, a geotechnical drilling investigation was carried out by Golder from March 2 to March 6, 2015. Boreholes BH15-01, BH15-01A and BH15-02 were drilled and slope inclinometers were installed in Boreholes BH15-01 and BH15-02. Baseline readings and one additional set of inclinometer readings were taken on March 7, 2015 and April 27, 2014, respectively.

Details of the methodology, subsurface conditions encountered in the boreholes, and the slope inclinometer readings are provided in Appendix B.

6.0 TECHNICAL ASSESSMENT

6.1 River Morphology Assessment

A river morphological assessment of the Bow River was conducted over the Site. The assessment was used to assess potential impacts on the geotechnical stability of the slope along the eastern Bow River Valley from changes within the river. The assessment also identified potential locations of progressive changes in the river that may in the future cause potential damage to existing slopes.

6.1.1 Methodology

The river morphological study included a comparison of post-flood and historical information, based on available historical air photos and bathymetry. The following is a summary of the methods:

- comparison of historical aerial images from 1924 to 2014 as provided by the City of Calgary. The images were geo-referenced and delineated to show changes in banks, gravel bars, and islands;
- comparison of bathymetry information collected before and after the June 2013 flood. This provides an estimate of the amount of scour or bed aggradation that occurred;
- flood levels and velocities were estimated from available hydraulic models developed for the City of Calgary by Golder (2012). Draft results from an updated 2015 hydraulic model were also considered;
- interpretation of river geomorphology and the potential for additional erosion near Douglasdale during a 100-year flood based on historical images, bathymetry, surficial geology, and water velocity estimates;
- identification of high erosion hazard areas along the river that also correspond with potential slope instability;
- consideration of potential intervention measures to stabilize the stream bank, based on professional judgement;
- recommendation of bank stabilization measures for consideration by the City of Calgary; and
- estimated cost of the recommended bank stabilization measures.

6.1.2 Existing Conditions

The river within the study area is characterized as meandering with several relict channels, one large side change that was re-activated during the 2013 flood (Mallard Point Side Channel), and several large gravel bars. There is also a large mid-channel island located within the hydrological study area. The study area extents for the river morphological assessment are shown on Figure 10.

The study area is broken into three distinct areas along the river bank for the purposes of the hydrological study. Upstream Area 1 has low lying banks and is largely vegetated with large mature trees. The river bank along Area 2 is largely vegetated with some bedrock outcrops, and the downstream river bank in Area 3 is steep with exposed bedrock (see Figures 10 and 11).

Figure 10: Area Delineation for River Morphology Assessment (Stn. 0+000 to 3+525)

Figure 11: River Bank Sections along the Site (Left - Area 1 (~ Stn. 1+150), Right - Area 3 (~ Stn.2+100))

Historical aerial images indicate that the Bow River alignment has been stable from 1966 to 2011 with only small changes to gravel bars and mid-channel islands (see Figure 12).

A major flood, estimated as a 100-year flood event, recently occurred In June 2013. The 2013 flood caused morphological changes along the Bow River near Douglasdale. An upstream channel avulsion occurred during the flood near the Ivor Strong Bridge (Deerfoot Trail crossing), resulting in up to 150 m of bank erosion and realignment of the river. This change resulted in subsequent downstream changes whereby the river thalweg alignment now migrates across the channel at different locations.

The meander wavelength is similar to the historical trend of approximately 1 km, but the locations where the thalweg approaches the riverbank have changed. The effects can be seen by comparing the 2011 and 2013 aerial imagery and bathymetry as illustrated on Figure 13.

This comparison shows the corresponding bed scour (colour-coded in red), bank erosion and re-activation of several side channels, despite the river alignment (i.e. the wetted width) remaining largely unchanged. The bathymetry interpretation highlights areas of deposition and scour, whereby the scour that has formed new thalweg locations is sometimes located along the inside meander bend.

The thalweg is normally situated along the outside meander bend. Downstream of the channel avulsion is some excessive bank erosion (up to 40 m in some locations). The estimated amount of bed scour within the main stem ranges from 0.5 to 1.5 m where the thalweg has shifted to new locations along the river.

These changes result in a significant alteration of the Bow River erosion hazards downstream of Ivor Strong Bridge. The Bow River continues to be located within the original channel alignment, but is now starting to erode meander bends at new locations. The changes will likely continue to evolve in the coming years until a new equilibrium has developed. This will impact the locations where bank stabilization may be required to protect infrastructure, which may be threatened at locations that were previously stable, shallow water areas.

The following is a summary of the major changes to river morphology that occurred from the June 2013 flood:

- The main stem river bed scour ranges from 0.5 m to 1.5 m along the current channel thalweg.
- The new thalweg alignment impacts the bank at 8 different locations between the Ivor Strong Bridge and the downstream extent of the Douglasdale study area (i.e. 4 wavelengths).
- Severe erosion downstream of the Sue Higgins Pedestrian Bridge along the right bank has caused the Mallard Point Side Channel to be reactivated.
- At the most northern extent of the study area, the left bank experienced up to 10 m of bank erosion.
- On the north portion of the project site, the flood eroded the right bank by up to 40 m. This scalloping of the bank occurs along the inside meander bend of the previous channel thalweg.
- The northern portion of a mid-channel island (in Area 2) was heavily eroded with large gravel bars forming on the west side of the island. With the erosion of the northern portion of the island, the mouth of the side channel between the island and the left bank was enlarged.
- Downstream of the island, the right bank was eroded by up to 50 m.

Within the study area, the lateral bank erosion rate is about 2 m over a 100-year time period with some small localized areas of up to 6 m. Generally the left bank within the study reach has not seen excessive erosion over the past 50 to 60 years, including the June 2013 flood. Bank erosion is limited by bedrock outcrops along the shoreline as seen on Figures 14 and 15. Erosion rates were measured from historical imagery plus consideration of large flood event frequency.

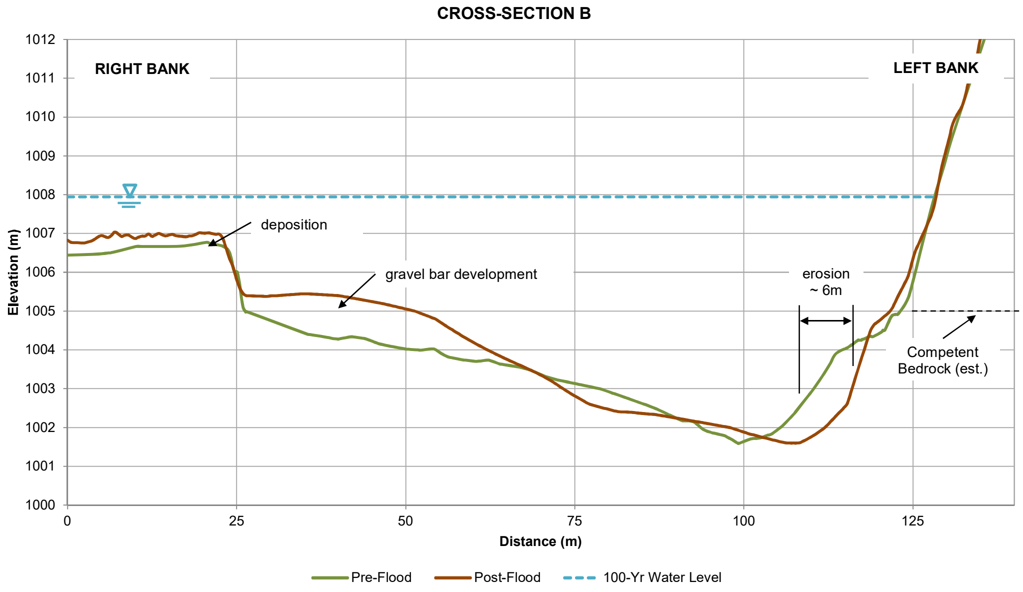

Figure 14: Cross Section Showing Pre and Post-Flood Conditions in Area 1(~ Stn. 0+950)

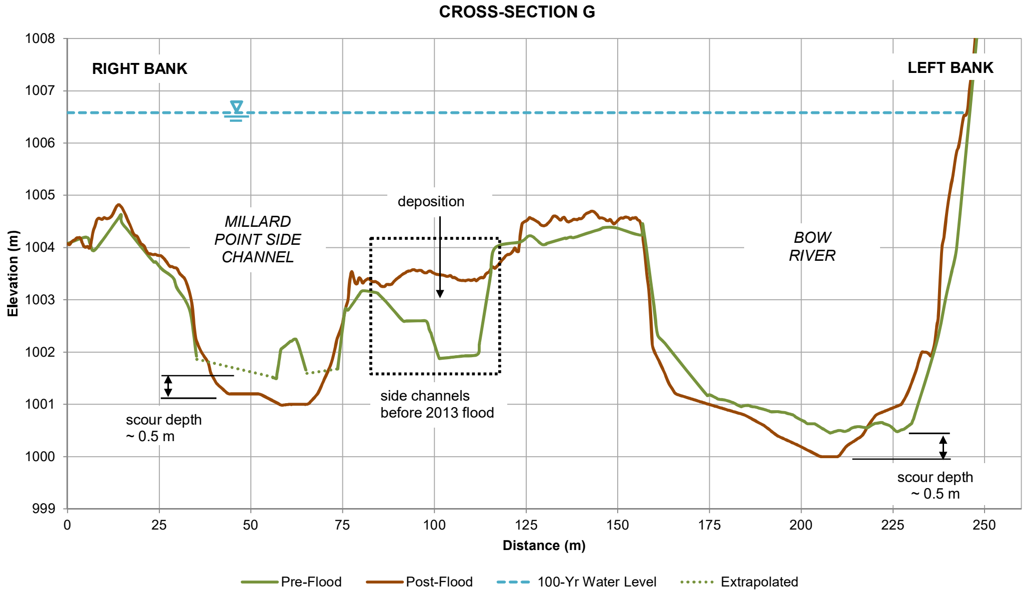

Figure 15: Cross-section Showing Pre and Post-Flood Conditions in Area 2 (~ Stn. 2+200)

6.2 Erosion Hazard Areas

The existing river banks are bedrock-controlled along most of the study area, and are not currently susceptible to large-scale erosion. We expect that the erosion rate will be similar to the past 60 years, about 2 m over a span of about 100 years. This assumes a normal number of large floods may occur in the foreseeable future, based on existing information. An erosion rate of 2 m per 100 years is less than the level of precision for this assessment.

There is some future susceptibility to erosion based on river changes that have not yet occurred. We expect that the river will continue to migrate laterally according to the new thalweg meander pattern that was created by the Douglasdale avulsion (Figure 13). This avulsion led to bed scour (Figure 16) which enlarged the side channel around the mid-channel island. This new pattern may continue eroding the mouth of the side channel (as indicated on Figure 16) until the side channel forms the main river channel.

The continued side channel expansion depends on the thalweg within this reach. Currently, the thalweg is not well-defined due to the formation of a new gravel bar between the island and the right bank (facing downstream). The gravel deposits and the poorly defined thalweg correspond to a location where the thalweg wavelength has been reduced locally by about 50% as a result of the island and overall river alignment. This reduction is a direct result of the upstream avulsion and subsequent re-alignment of the thalweg. The reduced wavelength is likely not stable and additional river alignment changes are anticipated within this reach.

If the thalweg continues to be poorly defined and erosion of the mouth of the side channel continues, the side channel may eventually become the new main channel. As the new main river channel, the existing side channel would likely result in significant initial erosion along the bank. The potential amount of bank erosion along the side channel is uncertain, but is likely to be in excess of 5 m.

The river bank is also eroding at the upstream end of the study area, near the baseball diamonds. This erosion, however, was not addressed as part of this study because it does not impact the slope stability along the valley wall. In other words, this morphological assessment was focused on supporting the slope remediation scope of work.

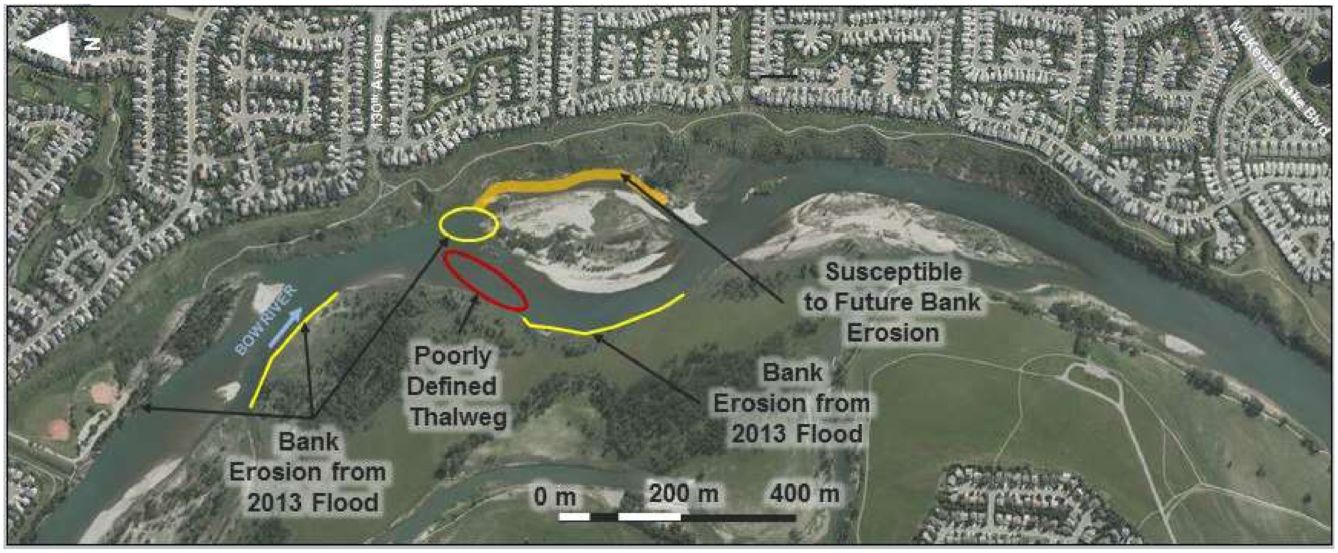

Figure 16: Identified Areas for Future Bank Erosion (~Stn. 1+150 to 1+550)

6.3 Surface Drainage Assessment

A drainage assessment was used to confirm that the existing surface drainage features are adequate to avoid unnecessarily excessive soil moisture along the slope that might otherwise trigger slope instability.

6.3.1 Methodology

The drainage assessment interpreted the local drainage network using available LiDAR topography, available City of Calgary stormwater infrastructure data, and GIS drainage identification methods. The predicted drainage flow paths were developed using ArcGIS tools that estimate flow direction and flow accumulation by analyzing the ground surface topography.

6.3.2 Results

The existing drainage features include a system of swales and catch basins between the pathway and the residential properties, plus pipe drains to the toe of the slope, as shown on Figures 17 to 20. The drainage works are extensive, although potential drainage changes may result in improved soil moisture along the slope. The following is a summary of our drainage observations:

- The swales in the upland areas appear to be collecting the majority of runoff from back yards and from the top of the slope. There are a few locations where the drainage swales do not appear to be intercepting drainage (see Figure 17, 18 and 19).
- The drainage area along the slope includes several large gullies, but the majority of water appears to be conveyed down the slope by small rills (see Figures 17 to 20).

Where the existing drainage is deficient, some drainage options may be available to improve the down-slope soil moisture. Options were not assessed as part of this preliminary desktop investigation.

6.4 Geotechnical Assessment

6.4.1 Methodology

Previous site information indicates that portions of the slope in this area are marginally stable during periods of dry weather and have the potential to become unstable, particularly during periods of wet weather. Review of historical data shows that some of these stability issues are potentially related to a history of ongoing, retrogressive instability. These slope movements have damaged existing City infrastructures (pathways) at the Site. The current study evaluates the long-term stability of the slopes at the Site in order to evaluate short- and long-term remedial options.

Despite similarity in site conditions within the Site, differences in geology, river hydrology, surface water drainage, groundwater conditions, past slope movement and the location of City infrastructure in relation to the slope crest influence slope stability issues. Therefore, the Site has been divided into nine smaller study zones with similar site conditions. In each zone, one or two representative cross-sections were selected for evaluation of slope stability. In total, thirteen cross-sections were selected for slope stability assessments. At each representative cross-section, available information was used to model subsurface and groundwater conditions. The slope stability analysis was performed under current slope geometry conditions assuming that the current slope geometry will be preserved (i.e. no allowance for potential future toe erosion was included). Mitigation measures such as the installation of toe erosion protection, surface erosion protection, and/or retaining walls may be required to preserve the current slope geometry.

Calculated FoS of 1.3 and 1.5 were used to quantify the extent of potential slope stability hazards at each cross-section location. The delineation of “lines” associated with computed FoS of 1.3 and 1.5 provide an indication of potential extent and corresponding probability of slope stability issues on the slope and its crest. The accuracy of the computed FoS of 1.3 and 1.5 lines is dependent on the accuracy of the information on geometry (survey data), geology, groundwater conditions and of the numerical model.

6.4.2 Subsurface Conditions

The following is a summary of subsurface conditions encountered during geotechnical investigations by Golder and by others, and Golder’s experience with similar soil conditions.

The soil and bedrock descriptions provided are based on accepted standard methods of classification and identification routinely used in current geotechnical state-of-practice. The stratigraphic boundaries described were inferred from non-continuous sampling, observations of drilling progress, results of SPT N-values, observations of ground exposures within slope failure areas and geotechnical laboratory testing. These boundaries typically represent transitions between soil and bedrock types rather than exact planes of geological change. Subsurface conditions vary both with depth and laterally across the site.

A generalized subsurface stratigraphy encountered consists of:

- Topsoil or Fill;
- Modified Morainal or Ablation Till;
- Basal Till;
- Weathered Sedimentary Bedrock; and
- Competent Sedimentary Bedrock.

From Stations 0+000 to 0+900 of the current study, additional stratigraphic units encountered were:

- High Plastic Clay Till; and
- Fluvial Gravel.

The soil types observed are described below.

Topsoil or Fill

A thin layer of topsoil or fill was encountered in all boreholes. Topsoil thickness generally ranged from 0.1 to 0.3 m, and was described as silty, brown, with trace organics.

For boreholes advanced on the asphalt pavement structure, encountered fill materials consists of sand and gravel, 0.3 m thick. Some boreholes encountered a silty clay fill, 0.3 to 2 m thick.

Geotextile fabric was observed in BH15-01 at 50 mm below ground surface.

Ablation or Morainal (Modified) Till

Underlying the topsoil or fill, morainal till ranging in thickness from 1.8 to 7.6 m and consisting of firm becoming stiff silty clay was encountered. These layers were normally modified by geological processes. Plastic limits ranged from 13% to 23%, with an average of 15%. Liquid limits ranged from 24% to 48%, with an average of 33%. The till was generally described as low to intermediate plastic, trace sand to sandy, trace gravel and brown to grey.

High Plastic Clay Till

A thin layer of stiff to very stiff high plastic clay till ranging in thickness from 0.5 m to 0.8 m was encountered in boreholes between Stations 0+000 and 0+900 of the current study. It was found between Elevations 1012.4 to 1020.8 masl, interbedded by silty clay or silt till. Plastic limits ranged from 18% to 21%. Liquid limits ranged from to 50% to 57%.

Basal Till

Underlying the modified morainal till, basal till consisting of very stiff to hard silty clay till and/or dense silt till was encountered. It generally had increased silt content with depth. Thickness ranged from 1.2 to 21.9 m, with an average thickness of 8.9 m. Plastic limits ranged from 14% to 20%, with an average of 16%. Liquid limits ranged from 18% to 41%, with an average of 25%.The very stiff to hard silty clay till was generally described as low to intermediate plastic, trace sand to sandy, trace gravel and brown to grey. Cobbles were also encountered. The dense silt till was described as non-plastic to low plastic, some sand to sandy, trace gravel and grey.

Fluvial Gravel

A layer of fluvial sandy gravel to sand and gravel ranging in thickness from 0.5 to 3.4 m was encountered in boreholes between Stations 0+000 and 0+900 of the current study. The cobble content (by volume) was estimated to be up to 50%. The fluvial gravel layer was found between Elevations 1009.2 and 1015.6 masl, overlying weathered bedrock.

Weathered Bedrock

Weathered sedimentary bedrock ranging in thickness from 1.1 to 14.2 m was encountered in all boreholes that progressed beyond overburden materials. It was generally described as residual soil becoming slightly weathered, extremely weak to weak, interbedded claystone, siltstone and sandstone, of the Paskapoo Formation. The elevation of weathered bedrock generally increases from north to south between Stations 0+000 and 3+025 of the current study, from Elevations 1008.2 to 1023.4 masl. The weathered bedrock elevation decreases between Stations 3+025 and 3+525 of the current study, from Elevations 1023.4 to 1015.8 masl, as the height of the slope decreases.

Competent Bedrock

Underlying the weathered bedrock was competent sedimentary bedrock. It was generally described as slightly weathered to fresh, weak to medium strong, interbedded claystone, siltstone and sandstone, of the Paskapoo Formation. Where encountered, the elevation of competent bedrock ranged from Elevations 1001.3 to 1020.8 masl across the Site.

Groundwater Conditions

Since 1980, eighteen standpipes have been installed in boreholes on site. Golder has read four of these standpipes on an annual basis since 2006. Based on the annual readings of these four standpipes and other reported readings, two anticipated groundwater regimes were identified on Site.

One is a shallow local groundwater regime, sensitive to precipitation and overland drainage. Measured elevations of the shallow groundwater table show a range from 1014.4 to 1034.5 masl. The other is a deep regional groundwater table, located within the bedrock.

Similar to the elevation trend within the weathered bedrock, the measured elevations of the deep groundwater table generally increase from north to south between Stations 0+000 and 3+025 of the current study, from Elevations 1007.4 to 1019.8 masl. The deep groundwater table elevation decreases between Stations 3+025 to 3+525 of the current study, from Elevations 1019.8 to 1013.6 masl.

Hydrophytic vegetation (thrives in wet, poorly-drained areas) are observed on terraced areas on the slope, which indicate that groundwater seepage and/or local ponding of water may exist within the site. Localized perched groundwater conditions are anticipated to exist.

6.4.3 Material Properties

Soil and rock properties used in slope stability analysis were estimated based on geological information, findings of previous site investigations, laboratory test data, previous back-analysis of material properties and information in the literature. For the purpose of slope stability analysis, the soil layers in the study area are divided into modified morainal till, basal till, weathered bedrock and competent bedrock. Relatively thin fill and topsoil layers in the sections were not separated to simplify the geological sections. At some areas, previous slide activities may have deposited colluvium on the slope but the extent and depths is not known and was not modeled in the stability analysis. The soil parameters used in the slope stability analysis are summarized in Table 1.

Table 1: Parameters for Slope Stability Analysis

Predominant Soil Type	Unit Weight, γ (kN/m^3)	Effective Cohesion, c' (kPa)	Effective Friction Angle, ϕ' (degrees)
Stiff to very stiff silty clay or clayey silt (Modified Morainal Till)	19	2	28
Hard silty clay or clayey silt (Basal Till)	20	5	30
Stiff to very stiff clay till (High Plastic Till)	19	0	26
Dense to very dense silt/silty sand/sandy silt (Basal Till)	20	0	33
Dense to very dense sand and gravel (Fluvial)	21	0	38
Weathered claystone or mudstone (Weathered Bedrock)	20	0	22
Weathered siltstone or sandstone (Weathered Bedrock)	20	0	38
Competent bedrock	Impenetrable		

6.4.4 Failure Mechanisms

Signs of ground movement and slope instability at the Site vary from near-vertical scarps at the crest and bulges at the toe of the slope, to cracks, leaning trees and surface erosion. A variety of failure mechanisms may result for the observed conditions of the slope. The most relevant causes of the ground movement in the study area may include:

- movement of the slope on existing slide surfaces within soil layers or weathered bedrock;
- surface erosion of sandy or silty soil at steeper slope locations, normally accompanied by groundwater daylighting (egressing) on the slope face;
- local stability problems due to steep pathway fill side slopes, deficiency in fill compaction, or inadequate retention structures, and/or weak foundation soil beneath the pathway fill; and
- local sloughing of the material at river level from river erosion.

Although local instabilities are an important consideration for long-term performance of the pathway, these repairs can be done locally and in smaller scale in comparison to overall larger ground movements. The movement of ground due to existing or potential large slide surfaces or failure modes can produce high risk to City infrastructure at Site.

The main focus of this study is to review slope movement resulting in large existing or potential failure surfaces within the overall slope. These slope stability issues may be caused by a variety of failure modes and are divided into three categories depending on their location and size as follows:

- Toe failures: movement of the slope at the toe area adjacent to the river bank normally on a failure surface through soil and the top portion of the weaker weathered bedrock in steeper portions of the slope adjacent to the river.
- Mid-slope failures: movement within the slope with a backscarp at the mid-slope area. The start of the failure surface is contained within the slope and is downslope of the slope crest.
- General slope failure: failures with a main headscarp at the slope crest or beyond the slope crest. The failure surface for these slope failure modes may exit at the mid-slope area or at the toe area on top of competent bedrock (for example, passing through the weaker bedrock).

All three of these categories of possible slope failure modes were considered in this study. The hazard and risk to City infrastructure at the slope crest is directly related to the general slope failure modes. However, the toe and mid-slope failure modes can affect the area beyond the slope crest due to slope retrogression in time. The toe and mid-slope failure modes were analysed to confirm material, stratigraphy and groundwater conditions that were used in the stability models. The largest general slope failure surface for a given calculated FoS was then used to estimate the extent of the potential slope instability beyond the current slope crest.

6.4.5 Geological Cross-Sections

In total, 13 cross-sections were selected to representative the Site for the slope stability analysis. The ground surface of the representative cross-sections were adopted from LiDAR survey data captured between September 9, 2013 and October 7, 2013, provided by the City. Table 2 presents a summary of selected geological cross-section locations and a summary of topographical information at each section location.

Table 2: Geological Cross-Section Location and Summary of Slope Geometry

Section	Station	Representative Area	Crest Elevation (masl)	Normal River Level (masl)	Slope Length (1) (m)	Average Slope Angle (2) (°)
1	0+375	Stn. 0+000 to Stn. 0+480	1027	1007	45	24
2	0+785	Stn. 0+480 to Stn.0+785	1033	1006	70	21
3	0+865	Stn. 0+785 to Stn. 1+105	1033	1006	90	17
4	1+135	Stn. 1+105 to Stn. 1+375	1034	1005	55	28
5	1+475	Stn. 1+375 to Stn. 1+525	1033	1005	77	20
6	1+565	Stn. 1+525 to Stn. 1+675	1030	1005	70	20
7	1+975	Stn. 1+675 to Stn. 2+025	1033	1004	55	28
8	2+075	Stn. 2+025 to Stn. 2+105	1034	1004	40	37
9	2+275	Stn. 2+105 to Stn. 2+295	1036	1003	90	20
10	2+375	Stn. 2+295 to Stn. 2+475	1035	1003	90	20
11	2+595	Stn. 2+475 to Stn. 2+625	1035	1003	45	35
12	2+705	Stn. 2+625 to Stn. 3+125	1035	1002	45	36
13	3+405	Stn. 3+125 to Stn. 3+525	1019	1002	20	40

Notes: 1. The slope length is calculated from the crest to the toe at normal river level
2. The average slope angle is calculated from the crest to the toe at the normal river level

The geological and groundwater conditions at each cross-section were based on borehole records, site observations, instrumentation data, and in some cases modeling the apparent historical slope failure surface. Detailed information on the analysis sections are presented in Appendix C.

6.4.6 Results

Stability analyses were performed with the most probable strength and groundwater conditions for each representative cross-section along the Site. Different potential failure surfaces were considered to match the observed slope movements at the Site and to confirm or calibrate the material strength and groundwater assumptions. The effect of adverse strength conditions on the calculated FoS lines were assessed in Section 6.4.8.

The controlling general slope failure surfaces initiating from the slope crest and the potential failure surfaces corresponding to the FoS 1.3 and 1.5 lines for this general failure mechanism were calculated for each cross-section.

Table 3 presents the results of the slope stability analysis for each representative cross-section. Stability analysis figures are presented in Appendix D.

As previously mentioned, the slope stability analysis is based on slope geometry as of Fall 2013. Should river bank erosion and surface erosion continue to occur, a change in the geometry of the slope may consequently change the location of factor of safety lines with time. The purpose of the surface erosion and hydrology study that was conducted as part of this feasibility study was to identify areas of high concern and to address these problematic areas to generally maintain the current slope geometry.

Table 3: Summary of Stability Analysis Results

Cross-Section	Failure Surface	Calculated Factor of Safety	Stability Analysis Figure Number	Figure Number/ Zone Number	Controlling Failure Surface Exit Point From Model Results
1	Crest Failure	1.1	D-1	21/1	Toe above competent bedrock
	FoS 1.3	1.3	D-2		Toe above competent bedrock
	FoS 1.5	1.5	D-3		Toe above competent bedrock
2	Toe Failure	0.9	D-4	22/2	Toe above weathered siltstone/sandstone
	Mid-slope Failure	1.1	D-5		Toe above high plastic clay layer
	Crest Failure	0.9	D-6		Toe above high plastic clay layer
	FoS 1.3	1.3	D-7		Toe above weathered siltstone/sandstone
	FoS 1.5	1.5	D-8		Toe above weathered siltstone/sandstone
3	Crest Failure	1.1	D-9	22/2	Mid-slope bench within basal till
	FoS 1.3	1.3	D-10		Mid-slope above gravel and sand layer
	FoS 1.5	1.5	D-11		Mid-slope above gravel and sand layer
4	Controlling Crest Failure	1.1	D-12	22/3	Toe within weathered claystone/mudstone
	FoS 1.3	1.3	D-13		Toe within weathered claystone/mudstone
	FoS 1.5	1.5	D-14		Toe within weathered claystone/mudstone
5	Crest Failure	1.0	D-15	23/4	Toe within weathered claystone/mudstone
	FoS 1.3	1.3	D-16		Toe within weathered claystone/mudstone
	FoS 1.5	1.5	D-17		Toe within weathered claystone/mudstone
6	Crest Failure	1.1	D-18	23/5	Toe within weathered claystone/mudstone
	FoS 1.3	1.3	D-19		Toe within weathered claystone/mudstone
	FoS 1.5	1.5	D-20		Toe within weathered claystone/mudstone

Table 3: Summary of Stability Analysis Results

Cross-Section	Failure Surface	Calculated Factor of Safety	Stability Analysis Figure Number	Figure Number/ Zone Number	Controlling Failure Surface Exit Point From Model Results
7	Crest Failure	1.1	D-21	23/6	Toe within weathered claystone/mudstone
	FoS 1.3	1.3	D-22		Toe within weathered claystone/mudstone
	FoS 1.5	1.5	D-23		Toe within weathered claystone/mudstone
8	Crest Failure	0.8	D-24	23/6	Toe within weathered claystone/mudstone
	FoS 1.3	1.3	D-25		Toe within weathered claystone/mudstone
	FoS 1.5	1.5	D-26		Toe within weathered claystone/mudstone
9	Crest Failure	1.2	D-27	24/7	Toe above competent bedrock
	FoS 1.3	1.3	D-28		Toe above competent bedrock
	FoS 1.5	1.5	D-29		Toe above competent bedrock
10	Crest Failure	1.1	D-30	24/7	Toe above competent bedrock
	FoS 1.3	1.3	D-31		Toe above competent bedrock
	FoS 1.5	1.5	D-32		Toe above competent bedrock
11	Crest Failure	0.9	D-33	24/7	Toe within weathered claystone/mudstone
	FoS 1.3	1.3	D-34		Toe above competent bedrock
	FoS 1.5	1.5	D-35		Toe above competent bedrock
12	Crest Failure	0.9	D-36	24/8	Toe above competent bedrock
	FoS 1.3	1.3	D-37		Toe above competent bedrock
	FoS 1.5	1.5	D-38		Toe above competent bedrock
13	Crest Failure	0.9	D-39	25/9	Mid-slope within weathered claystone/mudstone
	FoS 1.3	1.3	D-40		Mid-slope above competent bedrock
	FoS 1.5	1.5	D-41		Mid-slope above competent bedrock

6.4.7 Factor of Safety "Line" Delineation

The location of the potential failure surfaces for calculated FoS of 1.3 and 1.5 are presented in plan view at each cross-section location in Figures 21 to 25. Based on the location of the potential failure surface corresponding to calculated FoS of 1.3 and 1.5 at each cross-section location, factor of safety "lines" were drawn.

6.4.8 Uncertainties in Delineation

Similar to any other geotechnical engineering problem, there are sources of uncertainty in the estimation of the calculated factor of safety “lines” location. Sources of uncertainty in the factor of safety line locations include:

- Modelling uncertainty:
  - Simplification and idealization in modeling is required. In this study, simplifications in the geological layers and their contact, groundwater elevation estimation and the factor of safety calculation are sources of uncertainty. Practically, in a two-dimensional stability analysis, a limited number of cross-sections can be analyzed within a study area.
- Site condition uncertainty:
  - Variation in material properties: spatial variation (change in strength from location to location within the same layer), temporal variation (change in strength with time due to different time dependent processes) and accuracy of testing methods result in uncertainty in calculated factor of safety and therefore to location of factor of safety “lines”.
  - Change in slope geometry: The analysis is based on slope geometry as of Fall 2013. River bank erosion and surface erosion may change the geometry of the slope and change the location of factor of safety lines with time.
  - Change in groundwater conditions: The analysis relies on piezometric measurements and estimated peak groundwater fluctuations. Further urban development in this area may change the surface and groundwater regime which can affect the stability analysis results.
  - Variability in soil properties: Primary sources of uncertainty in the material properties are inherent soil variability, measurement error, and transformation uncertainty. The degree of uncertainty arising from these sources generally depends on factors such as the variability of the soil profile at the site, the degree of equipment and procedural control maintained during testing, and the precision of the correlation model used to transform laboratory test results into the desired soil property.

To estimate the effect of uncertainty in the material properties on the factor of safety line locations, sensitivity of the location of the factor of safety “lines” of 1.3 and 1.5 were assessed by varying strength parameters.

Cross-section 2 was selected as the representative section. The most uncertain parameters were selected as variables and a sensitivity analysis was performed to estimate the possible range in location of the factor of safety “lines” when these parameters were varied.

Table 4 presents the strength parameters used in the sensitivity analysis. The relevant stability analysis results are presented in Figures D-42 to D-45 (Appendix D).

Table 4: Strength Parameters for Slope Stability Sensitivity Analysis

Soil Type	Lower Strength Limit		Upper Strength Limit	
	c' (kPa)	ϕ' (degrees)	c' (kPa)	ϕ' (degrees)
Stiff to very stiff silty clay or clayey silt (Modified Morainal Till)	0	28	5	28
Hard silty clay or clayey silt (Basal Till)	0	30	10	30
Stiff to very stiff clay (High Plastic Till)	0	24	0	28
Dense to very dense silt/silty sand/sandy silt (Basal Till)	0	30	0	35
Dense to very dense sand and gravel (Fluvial)	0	38	0	38
Weathered Claystone or mudstone (Weathered Bedrock)	0	20	0	24
Weathered Siltstone or sandstone (Weathered Bedrock)	0	35	0	40

Table 5 presents sensitivity of the factor of safety line locations to the changes in the material strength within the upper and lower limit ranges listed in Table 4.

Table 5: Sensitivity Analysis - Change in FOS "Lines"

Factor of Safety "Line"	With Lower Limit Strength Parameters	With Upper Limit Strength Parameters
Calculated FoS = 1.3	-4.5 m	+5.7 m
Calculated FoS = 1.5	-8.2 m	+7.0 m

Note: A negative (-) number means a change of factor of safety line location in the upslope direction and (+) represents change of factor of safety line location toward the downslope direction.

The results in Table 5 show a variation of approximately +/- 5.0 m and +/- 7.5 m in the locations of the calculated FoS of 1.3 and 1.5 "lines" due to changes in selected strength parameters, respectively.

7.0 CONCEPTUAL DESIGN OPTIONS

Conceptual remediation options and recommendations were prepared to mitigate and/or manage problematic zones within the Site taking into consideration the hydrological, surface erosion, and geotechnical assessments.

Nine zones were defined based on similar site conditions and erosional risk at the toe of the slope. The nine zones are delineated on the key plan (Figure 2).

Where design options are presented, the anticipated service life of engineered structures has generally been taken as 75 years, with the exception of timber components, which are anticipated to require maintenance within 15 to 20 years.

Where applicable, the proposed pathway alignment with relocated sections generally meets or exceeds a minimum FoS of 1.3.

7.1 Pathway/Property Protection Measures

7.2 Zone 1

The pathway is located within the floodplain in Zone 1 and, therefore, the pathway is at low risk for slope failure. City land between the slope crest and private property lines varies from approximately 2 m to 40 m. Recent deep-seated retrogressive slope movement has generally not been observed in this zone; however, one area near Borehole BH08-DP-1 has been observed to be recently active. This area was studied by Golder in 2008, and it was postulated that this could have been caused by unusually high piezometric levels. Possible remedial measures discussed in 2008 included a reduction of surface water infiltration, slope drainage, structural support and slope re-profiling.

Since the study in 2008, little movement has been observed in this area. It is recommended that this area be inspected by City Parks' personnel on a bi-annual basis. No further action in this zone is recommended at this time.

7.3 Zone 2

In Zone 2, the pathway is constructed over a large historical failure that deposited soil and weathered bedrock into the Bow River in the past. The rotation of the slide mass is anticipated to have displaced bedrock upwards at the slope toe, causing discontinuous natural erosion protection at the river bank.

Comparing the pre-development aerial photograph (1989) to current conditions, the following observations are made regarding the pathway construction:

- localized bank erosion in the order of 5 m has occurred in the last 25 years;
- minor grading was performed at the crest of the slope to reduce the headscarp height and flatten the upper slopes; and
- timber and sandstone block retaining walls were constructed on the slope to retain the soil above the pathway and retain fill that was used to construct a level surface for the pathway, respectively.

For the most part, the displaced bedrock at the toe of the slope is anticipated to have prevented large scale erosion of the colluvium mass; however, slow and localized erosion (mass wasting) continues to occur. As mass wasting occurs at the slope toe, small failures have occurred within the lower portion of the slope. These small failures deposit soil at the toe of the slope which is eroded by the river. This causes slow movement of the larger slide mass, which consequently causes the relict headscarp and tension cracks to increase in size. This process is anticipated to occur relatively slowly; however, larger-scale single events are possible.

Movement of the timber retaining walls became evident in 2006. Since that time, the existing timber retaining walls have been observed to move and are currently considered to have failed. Further, the sandstone block wall is anticipated to be either rotating or shifting downslope, resulting in the increased cross-slope currently observed on the pathway surface in the vicinity of this wall.

Based on the above observations and results of the geotechnical and hydrological considerations, three options were considered to maintain the pathway in its current alignment. Relocation of the pathway was also considered as described below.

7.3.1 Pathway Relocation

The following re-routing options for the pathway were evaluated:

- traverse the slope in an alternate location to the north; or
- continue along the crest of the slope from the intersection near 130 Avenue.

The results of the evaluation are summarized below:

- If the re-routed pathway would connect to the existing pathway that is currently located downslope within the floodplain, the re-routed alignment would need to traverse the slope within Zone 1. Steep and potentially marginally stable slopes are located to the north and considering the slope gradients, steps/stairs or switchbacks over a large area would be required. These steep slopes will likely experience on-going movement and present significant construction challenges, safety issues, and long-term maintenance. For these reasons, relocation of the pathway to traverse the slope in Zone 1 is not recommended.
- If the pathway remains at the top of the slope, retention structures would likely be required in a number of areas due to the limited availability of City land between the slope crest and private property lines (less than 2 m in some areas). Further, the marginal stability of the slope between the private property line and top of slope may create serviceability issues for the relocated pathway. Should future failures occur, space limitations will restrict maintenance or further opportunities to protect the pathway. For these reasons, continuing along the crest of the slope is not recommended.

7.3.2 Pathway Abandonment

The option to abandon and re-route the pathway at the intersection near 130 Avenue SE exists along Douglas Park Boulevard SE. This option includes removal of the existing pathway, infrastructure (bridge, sandstone/timber retaining walls) and re-vegetation, and is anticipated to cost approximately $50,000 to $75,000.

The re-routed pathway would pass through residential areas and parks. Considering the current number of pathway users this would significantly increase pedestrian and cycling traffic on the residential streets. New signage, dedicated bike lanes, and cross-walks may be required.

With the above considerations, pathway abandonment would be a cost effective option. However, relocation to the residential area would likely affect a large number of private property owners and have an impact on the safety of the pathway users. Further, this option would not address the slope movement. For these reasons, pathway abandonment is not considered a preferred option at this time.

7.3.3 Engineered Stabilization

Engineered stabilization efforts are required if the pathway is to remain in its current alignment and a long-term solution is desired. The recommended option for stabilization efforts is to construct a shear key by using a cantilevered caisson wall installed below the existing pathway and through the high plastic clay layer into bedrock. The approximate location and configuration is shown in Figure 26.

The existing grasses, bushes and trees within the footprint of the proposed options will be required to be removed to facilitate construction. Temporary construction access is considered feasible from the pathway and accessing the site from the south near the intersection by 130 Avenue SE; however, the selection of the temporary construction access should be determined in future design stages, in consultation with contractors, the Residents and the City. Temporary stockpiling and general lay-down areas would also be needed at that time.

The slope surface gradient near the crest of the slope would need to be flattened by cutting down to 3H (horizontal):1V (vertical) to unload the slope and reduce potential future retrogressive soil movements at the crest of the slope. The cutting depth is approximately 3.5 m in the clayey silt till unit. The extent of slope regrading beyond the crest of the slope remains within City property. This option would not cause significant impact to the private properties at the crest of the slope.

To facilitate installation of the caisson wall, the pathway and approximately 1.5 m of fill would need to be temporarily excavated to 1.5H (horizontal):1V (vertical) slope to accommodate an approximate 8 m wide proposed temporary access or working platform. The platform would be intended for construction equipment to operate and installation of caissons, and may be widen as required. The excavated slope along the pathway would be backfilled, to re-establish current profile, with fill from native soils after the caisson wall is installed. Upon completion of caisson wall construction, the pathway would be re-established.

At and beyond (downslope) of the existing pathway, potential surficial soil erosion in the lower part of the overall slope (above river) is not anticipated to affect the overall slope stability performance. This option has an anticipated service life of 75 years.

7.4 Zones 3 and 4

Zones 3 and 4 are located between the mid-channel island and the eastern valley slopes. A large deep-seated relict slope failure is observed within Zones 3 and 4 with headscarps that closely follow the current pathway alignment.

The large relict failure that can be observed in Zone 3 and 4 is anticipated to have rotated along a plane within weak bedrock. This movement is anticipated to have deposited soil and bedrock at the toe of the slope causing marginal stability. Over time, mass wasting (river and surface erosion) at the slope toe is anticipated to have occurred, leading to small failures within the colluvium in the lower portion of the slope. As the small failures occur, they deposit soil at the river bank which is consequently eroded by the river. The removal of soil from the lower portion of the slope is causing slow movement of the larger slide mass.

As the height of the headscarp increases and the un-vegetated, exposed soils erode, localized failures are anticipated to occur near the crest of the slope. With its proximity to the slope crest, the pathway would likely be damaged in multiple locations by these retrogressive-type slope failures.

If the river shifts towards the bank, an increased erosion rate is anticipated. This may lead to larger movements in the slope and may cause retrogressive-type slope failures that would impact the FoS for the private properties. For these reasons, proactive protection of the bank is recommended.

Proactive protection of the bank (in the form of river training) may be sufficient to avoid large-scale river realignment along Zone 4 but it is anticipated that smaller localized failures will continue to occur in the short-term. For this reason, it is recommended that river bank protection be carried out, as well as pathway realignment to meet a minimum FoS of 1.3 as described in Section 7.4.1 and Section 7.4.2, respectively.

7.4.1 River Bank Protection

Several design options were considered to manage the potential for future erosion along the side channel. These options included monitoring of the bank, river training structures, river diversion structures (e.g. rock mattresses), the development of an additional side channel along the right bank, and the reclamation of the mid-channel island. A summary of the considered options with environmental and high level cost estimates are listed in Table 6.

Table 6: River Bank Protection Measures Considered for Zone 3

Option	Description	Erosion Risk	Environmental Considerations	Social Considerations	Cost Comparison
A	Monitoring of the river bank	Continued erosion of the mouth of the side channel that would eventually enlarge the side channel and possibly put additional slope areas at risk of erosion and subsequent failure during large flood events.		Risk of high traffic pathway loss due to potential for sudden erosion of the bank and subsequent slope instability near the pathway and homes.	-
B	River Training Groynes	Deflect the thalweg away from the left bank. Groynes would be designed for the 100-year flood event and constructed of riprap. Groynes have been proven as effective erosion control measures within the City of Calgary.	Potential habitat improvements along the bank resulting from local flow and depth diversity, despite temporary in-stream works	Residual potential risk to re-activate the side channel.	$2 million
C	River Training Groynes with Rock Mattress	Deflect the thalweg from the left bank and control the amount of flow entering the side channel. Side channel flow would be controlled by constructing a raised inlet with large rock to allow continuous flow into the channel during base flow conditions.	Potential habitat improvements along the bank plus stabilization of flow along the side channel.	Manage risk of bank erosion along the pathway.	$2.5 million

Table 6: River Bank Protection Measures Considered for Zone 3

Option	Description	Erosion Risk	Environmental Considerations	Social Considerations	Cost Comparison
D	Side Channel	Divert some flow to a side channel along the right bank to reduce the erosion potential along the left bank.	Additional side channel habitat and may offset habitat losses at other locations.	Flow diversion may result in additional sediment deposition that further diffuses the thalweg and increases the potential to reactivate the mid-channel island side channel.	$1 million
E	Vegetate Mid-Channel Island	Stabilize the island and allow future sediment capture to occur.	Additional terrestrial habitat	Uncertain short term performance until the vegetation becomes established to be effective.	$0.5 million

The preferred option consists of river training structures and a rock mattress (Option C) because it provides a long-term solution to reduce the potential risk of bank erosion along the left bank. A series of small groynes spaced 100 m would deflect the high velocity water away from the bank. A river cobble embankment would be constructed between the groynes for local access. A rock mattress would further prevent local scour of the side channel. Reclamation measures might include willow staking above the toe apron and other fish habitat structures such as root wads. The general proposed location and configuration of this conceptual design option is shown in Figure 26.

The anticipated construction access would be from 130 Avenue SE, or from the north. This would need to be confirmed during preliminary and/or the detailed design phases.

7.4.2 Pathway Relocation

Near the crest of the slope, the pathway is generally offset around 1.5 m to 4.0 m from the headscarp of the large and complex, retrogressive failure area. The pathway's proximity to the headscarp puts it at risk for tension crack development and small scale failures within Zones 3 and 4.

On-going damage is anticipated to continue to occur within this zone if the pathway remains in its current alignment, regardless of whether toe protection is installed. The pathway is recommended to be re-routed upslope, towards the private properties as shown in Figures 26 and 27. This would allow a buffer distance so that natural erosional process and small scale failures could occur without affecting the pathway. The calculated minimum FoS for the relocated pathway is 1.3. The re-routed length would be approximately 450 m.

The new pathway is proposed to have a minimum width of 3 m and paved with asphaltic concrete. The proposed pathway will be designed to meet the applicable City of Calgary guidelines and standard specifications (City of Calgary 2013).

The existing pathway is recommended to be removed and the area restored. Where possible, consideration may be given to keeping existing sections by replacing the asphalt with a gravelled surface to maintain secondary routes to existing benched sitting areas and/or lookouts.

7.5 Zone 5

Zone 5 has been largely protected by a vegetated soil mass that diverts the side channel from Zone 4 west, away from the slope toe. Within Zone 5, a small seasonally active channel exists at the slope toe but the flow is anticipated to be slow and likely only significant during large flood events.

Within the area, a portion of the slope is relatively steep and evidence suggest that it has not been affected by past large-scale slope failure. This is postulated to be caused from a combination of the lack of toe erosion and more competent sandstone bedrock layer closer to the ground surface.

Although the area is relatively protected from mass wasting at the slope toe and larger scale failures has not been observed, active erosion from groundwater discharge on the slope and surface water erosion is occurring. This erosion is postulated to be causing small slope failures in the lower portion of the slope. These failures are anticipated to retrogress upslope, which will likely affect the pathway.

For these reasons, the pathway is recommended to be re-routed upslope, towards the private properties as shown in Figure 27. This would allow a buffer distance so that natural erosional process and small scale failures could occur without affecting the pathway. The calculated minimum FoS for the relocated pathway is 1.3. The re-routed length would be approximately 150 m.

The new pathway is proposed to have a minimum width of 3 m and paved with asphaltic concrete. The proposed pathway will be designed to meet the applicable City of Calgary guidelines and standard specifications (City of Calgary 2013).

The existing pathway is recommended to be removed and the area restored. Where possible, consideration may be given to keeping existing sections by replacing the asphalt with a gravelled surface to maintain secondary routes to existing benched sitting areas and/or lookouts.

7.6 Zone 6

Within Zone 6, a relict slope failure is observed in the 1989 aerial photography, from about Stations 1+900 to 2+650. Based on an assessment of the surface features and subsurface data, it appears that slope failures have occurred near the toe of the slope leading to a larger retrogressive failure mode. The associated failure surfaces appear to have occurred within the weathered bedrock, at or just above river level.

The current alignment of the pathway crosses the failure and based on recent imagery, it can be seen that grading and fill placement has been carried out to accommodate the current pathway. Within the relict failure area, recent slope movement has occurred that has damaged the pathway. This movement is anticipated to continue to occur as colluvium and weathered bedrock erode at the slope toe. Further, there is potential that the fill that was placed at the top of the slope could also fail leading to a large failure. On-going damage is anticipated to continue to occur within this zone if the pathway remains in its current alignment, regardless of whether toe protection is installed. The existing pathway is recommended to be re-routed upslope by approximately 10 m to 20 m, towards the private properties as shown in Figure 27. This would move the pathway out of the existing relict failure area. The calculated minimum FoS for the relocated pathway is 1.3 and the re-routed length would be approximately 275 m.

The new pathway is proposed to have a minimum width of 3 m and paved with asphaltic concrete. The proposed pathway will be designed to meet the applicable City of Calgary guidelines and standard specifications (City of Calgary 2013).

The existing pathway is recommended to be removed and the area restored. Where possible, consideration may be given to keeping existing sections by replacing the asphalt with a gravelled surface to maintain secondary routes to existing benched sitting areas and/or lookouts.

7.7 Zone 7

A large historical failure is present in Zone 7. Generally, the pathway is located adjacent to or across the headscarp of this failure area. The historical failure appears to have occurred within the zone of weathered bedrock. The majority of the relict colluvium (slide debris) at the toe of the slope has mostly been eroded. Sliding and removal of the colluvium over the bedrock has been observed in recent years.

The majority of the upper slope is heavily vegetated and steep. Therefore, access to the toe of the slope would likely be difficult and require removal of vegetation and either large in-stream work or cutting into the slope, neither of which are recommended. A potential option considered to reduce erosion at the toe of the slope is to use soil-nailing techniques but this would not increase the stability upslope and generally be unaesthetically pleasing. No options for pathway relocation currently exist. For these reasons, slope stabilization efforts along the crest of the slope are recommended.

Extension of the existing anchored concrete caisson retaining structure along the crest of the existing slope is recommended in Zone 7 (Figure 28). Based on the observed relict failure area, the recommended extension length would be approximately 100 m to the north and 300 m to the south. The wall would be installed vertically into competent bedrock. The length of the extensions is recommended to increase the stability of the slope to meet a minimum FoS of 1.5 at the private property line and to provide a stable area for the pathway.

An external support force would likely be needed using a waler system and a row of ground anchors to provide lateral resistance to the retained soil behind the caisson wall. To facilitate the installation of the row of anchors near the top of the wall, the top of the existing slope would need to be cut-down to approximately 1 m below the existing ground to accommodate a 10 m wide temporary access or working platform. A treated timber facing wall would be installed to match the existing wall.

The caissons would extend beneath the potential slope slip surface and, therefore, be anticipated to provide long-term solution to protect the pathway within Zone 7 from potential future retrogressive slope movement. This option has an anticipated service life of 75 years.

7.8 Zones 8 and 9

Recent deep-seated retrogressive slope failures have generally not been observed in Zones 8 and 9; however, one area near Borehole BH05-MV-1 has been observed to be recently active. An area in Zone 9 was studied by Golder in 2005, and it was postulated that this could have been caused by unusually high piezometric levels. Possible remedial measures discussed at that time include reduction of surface water infiltration, slope drainage, structural support and slope re-profiling.

Since the study in 2005, little movement has been observed in this area. It is recommended that this area be inspected by City Parks' personnel on a bi-annual basis. No further action in this area is recommended at this time.

7.9 Additional Controls and Measures

As a precautionary measure, the integrity of the stormwater management system located along the top of the slope along the Site should be verified using a remote pipe inspection camera. If damages are observed, the pipe should be removed and replaced. Damaged pipes could introduce surface water causing an increase in groundwater leading to reduced stability and slope failure.

Where pathway realignment is proposed it is recommended to grade the areas around the pathway in such a way to divert as much water as possible away from the slope. This may involve the addition of swales or gutters along the pathway to divert flow to a concentrated location and convey the water down the slope in a controlled, engineered manner. This would potentially reduce the amount of water conveyed over the entire slope and bring the surface water to a few locations.

8.0 COST ESTIMATION

As part of this feasibility study, an order of magnitude cost estimate is required. The level of project definition at a feasibility stage generally does not exceed 15%. The general purpose of this cost estimate is for confirmation of economic feasibility and preliminary budget approval to proceed to the next stage of the project and cost estimation.

The following estimate has been classified as per the Association for the Advancement of Cost Engineering International (AACEI) Class "4" in general accordance with AACEI Recommended Practice No. 56-R08 Cost Estimate Classification System – as applied for the building and general construction industries. Typical accuracy ranges are -10% to -20% on the low side, and +20% to +30% on the high side, depending on the construction complexity of the project, appropriate reference information and other risks.

This estimate has been developed as a top-down cost model in a unit cost analysis format based upon historical data and previous experience from similar projects and/or activities. Scheduling and a work breakdown structure have not been established at this point.

A contingency of 15% has been included to account for items, conditions, or events for which the state, occurrence, and/or effect are uncertain and that experience shows will likely result in additional costs. The contingency does not include:

- major scope changes such as changes in end product specification, capacities, increase to the length of pathway relocation/retention structures/erosion protection, structure location, and the like;
- extraordinary events such as major strikes and natural disasters;
- management reserves; and
- escalation and currency effects.

Further, a risk model was not created to evaluate the risks. It is recommended that a Risk Analysis workshop for all stakeholders be conducted with the right mix of people with sufficient knowledge of the project.

8.1 Scope of Estimate

A general summary of the conceptual design options recommended in Section 7.0 is provided in Table 7.

Table 7: Recommended Design Concepts

Zone	Representative Area	Recommended Concept(s)
1	Stn. 0+000 to 0+480	Site Monitoring
2	Stn. 0+480 to 0+950	Slope Regrading and Cantilevered Caisson Wall
3 & 4	Stn. 0+950 to 1+525	River Training and Pathway Relocation
5	Stn. 1+525 to 1+675	Pathway Relocation
6	Stn. 1+675 to 2+085	Pathway Relocation
7	Stn. 2+085 to 2+610	Anchored Caisson Wall
8&9	Stn. 2+610 to 3+525	Site Monitoring

The general proposed location and dimensions of these conceptual design options are shown in Figure 26 to Figure 28.

8.2 Assumptions

In developing the Class “4” estimate, a number of assumptions have been made, including:

- mobilization and demobilization of local contractor equipment and site facilities to the proposed site;
- full unhindered access to the site location for the duration of the project operations;
- no other contractors will be operating within the site limits of the project site during the construction works;
- construction staff and/or the contractor selected are non-union;
- grading allowances assume an average of 150 mm of topsoil to be stripped and for pathway relocation, will be used to reclaim the existing pathway such that there is no additional waste to be disposed;
- new pathway construction is 3 m in width, surfacing is asphaltic concrete, and can be designed to meet the minimum requirements as outlined in the City of Calgary guidelines for pathway construction;
- asphalt allowance assumed a 75 mm asphalt thickness;
- an allowance for additional engineering survey has been provided prior to and after construction;
- design of engineered structures are generally as described in Section 7.0 of this report;
- restoration works will consist of broadcast seeding, erosion protection (where required), and replacement of existing trees/shrubs (these items will need to be confirmed in future stages); and
- reasonable market availability of suitable and competent general contractors to provide a competitive bidding environment.

8.3 Exclusions

The following exclusions have been made at this stage

- obtaining any permits or permissions to undertake the work. It is been assumed that all required permits will be obtained by others;
- removal or disposal of any hazardous, contaminated, or toxic materials encountered;
- an allowance for potential habitat compensation, as this will need to be negotiated with the Department of Fisheries and Oceans (compensation costs may be zero to 50% of the overall cost for in-stream works, depending on the proposed design);
- escalation costs;
- allowances for any potential delays resulting from inclement or unseasonal weather;
- costs associated with event-driven risks; and
- taxes and duties.

8.4 Other Allowances

In the event that it is decided that one or any of the above options will be constructed, it is possible that additional site investigation is required to support additional analysis and detailed design phases to better define the soil and bedrock stratigraphy in the vicinity of the option.

Additional costs for engineering services (e.g., site investigation, analysis, detailed design, tender package preparation, construction quality assurance/quality control) will also be incurred. Typically 5% to 10% of the construction capital costs for civil structures can be used for preliminary budgeting purposes.

For the purposes of this cost estimate, 15% of the capital cost has been included for additional site investigation, pre- and post-construction monitoring, and engineering/administration services.

8.5 Cost Estimate

A Class “4” estimate with an accuracy range of low -20% to high of +30%, after the application of a 15% contingency was chosen based on the relative maturity level (i.e., feasibility study) of the project.

Table 8: Estimated Costs for Construction, Engineering, and Administration

Zone	Concept Description	Priority	Estimated Cost ($ Canadian 2015) (1)		
			Low (-20%)	50/50 Point	High (+30%)
1	Site Monitoring	Low	-	-	-
2	Cantilevered Caisson Wall and Regrading	High	$906,000	$1,087,000	$1,413,000
3 & 4	Pathway Relocation	High	$321,000	$385,000	$501,000
	River Training	Moderate	$2,396,000	$2,875,000	$3,738,000
5	Pathway Relocation	Low	$188,000	$225,000	$293,000
6	Pathway Relocation	Moderate	$200,000	$240,000	$312,000
7	Anchored Caisson Wall	High	$11,916,000	$14,299,000	$18,589,000
8&9	Site Monitoring	Low	-	-	-
Total Estimate			**$15,927,000**	**$19,111,000**	**$24,846,000**

1) Values have been rounded to the nearest thousand dollars. Excludes tax.

2) Includes a 15% contingency and an allowance for additional investigation, and engineering costs as described in Section 8.4.

9.0 CLOSURE

We trust the above information meets your present requirements. If you have any questions or require additional details, please do not hesitate to contact the undersigned.

Yours truly,

GOLDER ASSOCIATES LTD.

APEGA Permit to Practice #5122

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Soil, Rock and Groundwater Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. **The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report.** The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

Sample Disposal: Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

FIGURES

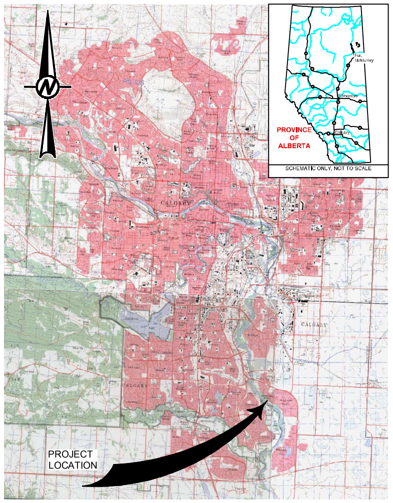
PFC2020-0510
ATTACHMENT 2

ISC: UNRESTRICTED

THE CITY OF
CALGARY

SLOPE STABILITY PROGRAM - DOUGLASDALE

SITE LOCATION
NOT TO SCALE



SITE VICINITY
NOT TO SCALE

LEGEND

▬ ▬ ▬ STUDY AREA

REFERENCE

1. SITE LOCATION IMAGERY PROVIDED BY CITY OF CALGARY, NOV 29, 2013.
2. TOPOGRAPHIC MAP SCANNED BY MAPTOWN, © 2000 HER MAJESTY THE QUEEN IN RIGHT OF CANADA. DEPARTMENT OF ENERGY, MINES AND RESOURCES. CANADIAN TOPOGRAPHIC MAP NUMBERS 82-I/13, 82-J/16, 82-0/1, 82-P/04.

CLIENT
CITY OF CALGARY

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-06-19
PREPARED	DW
DESIGN	AW
REVIEW	AE
APPROVED	DEB

PROJECT
BOW RIVER REGIONAL PATHWAY
DOUGLASDALE / MCKENZIE LAKE FEASIBILITY STUDY

TITLE
OVERALL SITE LOCATION PLAN AND STUDY AREA

PROJECT No.	CONTROL	Rev.	FIGURE
11-1321-0003.2200		0	1

Path: \\golder.gds\calgary\EDCAD\2011\11-1321-0003\PRODUCTION\FIGURES\ | File Name: 1113210003FG007.dwg

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B
25 mm
0

PFC2020-0510
ATTACHMENT 2

ISC: UNRESTRICTED

REFERENCE

1. PROPERTY LINES FROM CITY OF CALGARY DIGITAL DATA, 2009.
2. LIDAR DATA PROVIDED BY CITY OF CALGARY, SEPTEMBER 9 - OCTOBER 7, 2013.

CLIENT
CITY OF CALGARY

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-06-19
PREPARED	DW
DESIGN	AW
REVIEW	AE
APPROVED	DEB

PROJECT
BOW RIVER REGIONAL PATHWAY
DOUGLASDALE / MCKENZIE LAKE FEASIBILITY STUDY

TITLE
KEY PLAN

PROJECT No.	CONTROL	Rev.	FIGURE
11-1321-0003.2200		0	2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B
0
25 mm

Path: \\golder.gds\calgary\Active\EDCAD\2011\11-1321-0003\PRODUCTION\FIGURES\ | File Name: 1113210003FG004.dwg

ISC: UNRESTRICTED

BORE HOLE LEGEND

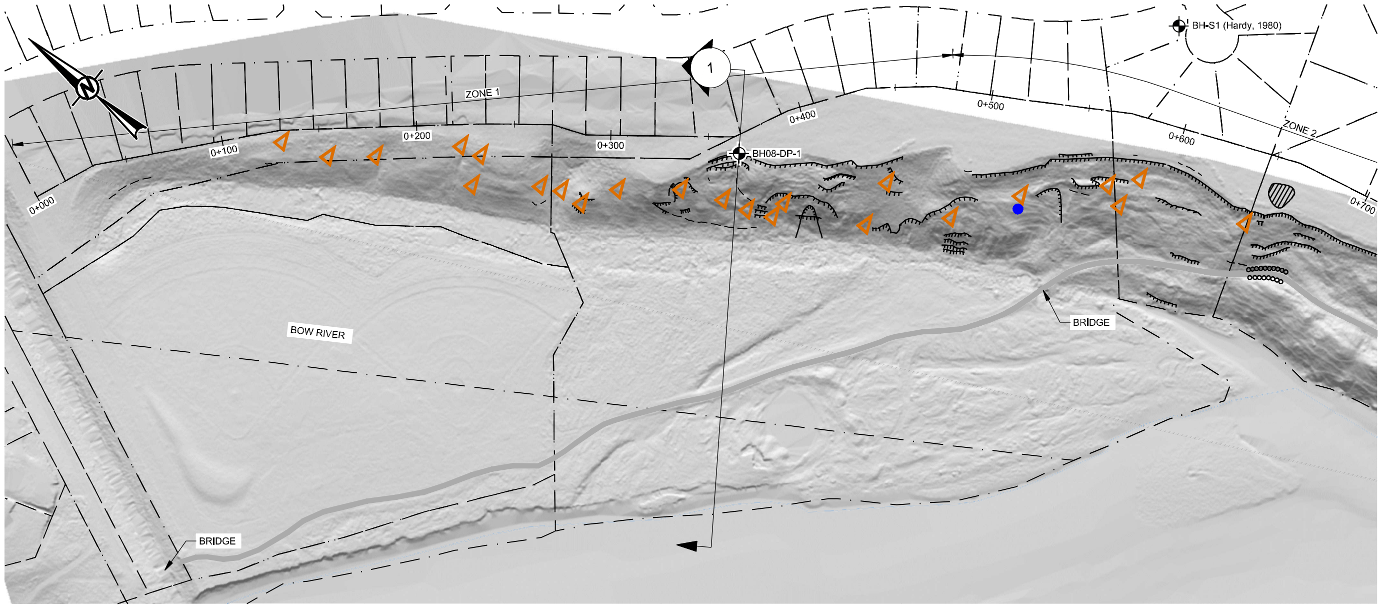
⬛	TOPSOIL OR FILL
🟥	TILL - CLAY
▨	TILL - SILTY CLAY OR CLAYEY SILT - STIFF
▨	TILL - SILTY CLAY OR CLAYEY SILT - HARD
🟩	TILL - SILT OR SANDY SILT
▨	SAND AND GRAVEL
▨	WEATHERED CLAYSTONE OR MUDSTONE
▨	WEATHERED SILTSTONE OR SANDSTONE
🟪	COMPETENT CLAYSTONE OR MUDSTONE
🟫	COMPETENT SILTSTONE OR SANDSTONE

LEGEND

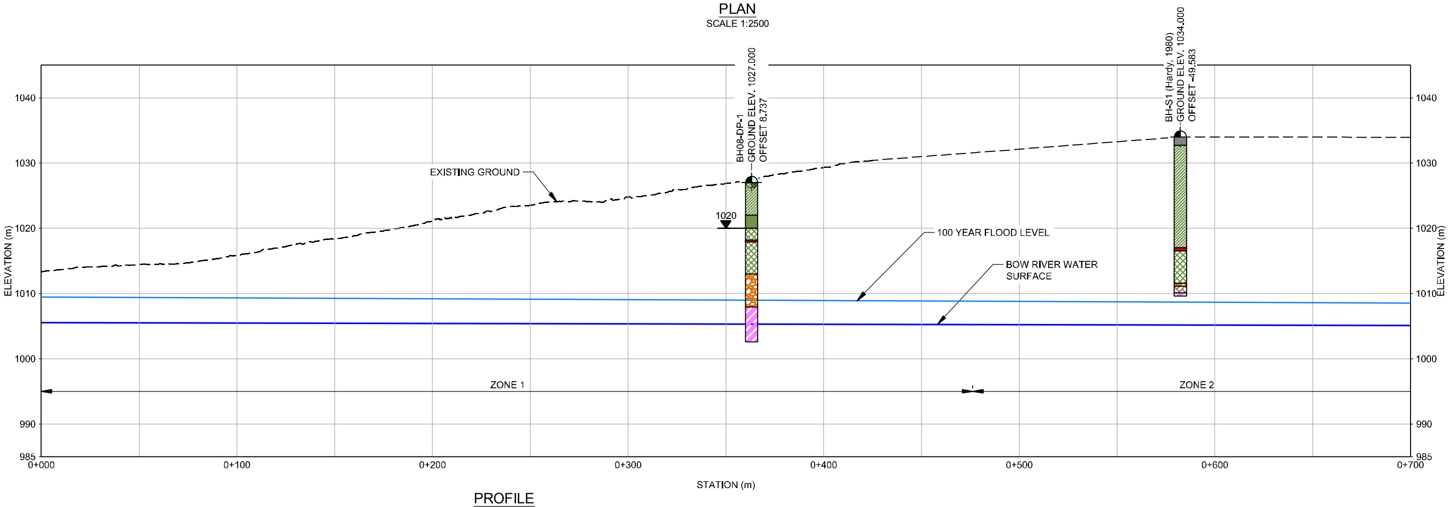
┬┬┬┬┬┬┬	SCARP
– – – – – –	TENSION CRACKS
oooooooooo	RIP RAP
▨	ANCHORED CAISSON WALL
▷	EROSION AND DRAINAGE ZONES
✱	PONDED WATER
●	SEEPAGE
▨	POSSIBLE ACTIVE SLIDE AREA
⋙	LEANING TREES
✗	PATHWAY DAMAGE OR REPAIR
▭	OBSERVED BEDROCK OUTCROP
⊕	BOREHOLE
▼	MEASURED WATER LEVEL - (S) SHALLOW, (D) DEEP

REFERENCE

1. PROPERTY LINES FROM CITY OF CALGARY DIGITAL DATA, 2009.
2. LIDAR DATA PROVIDED BY CITY OF CALGARY, SEPTEMBER 9 - OCTOBER 7, 2013.
3. FIELD OBSERVATION DATA BY GOLDER BETWEEN 2006 AND 2014.
4. 100 YEAR FLOOD LEVEL FROM BOW AND ELBOW RIVER HYDRAULIC MODELLING AND INUNDATION MAPPING PROJECT PREPARED FOR THE CITY OF CALGARY BY GOLDER 2012.
5. WATER SURFACE OBTAINED FROM LIDAR DATA, SEPTEMBER 9 - OCTOBER 7, 2013.



PLAN
SCALE 1:2500



PROFILE
HOR. SCALE 1:2500
VERT. SCALE 1:750

0 50 100
1:2,500 METRES

0 12.5 25
1:750 METRES

CLIENT
CITY OF CALGARY

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-06-19
PREPARED	DW
DESIGN	AW
REVIEW	AE
APPROVED	DEB

PROJECT
BOW RIVER REGIONAL PATHWAY
DOUGLASDALE / MCKENZIE LAKE FEASIBILITY STUDY

TITLE
SITE PLAN AND PROFILE *STA 0+000 TO 0+700*

PROJECT No.	CONTROL	Rev.	FIGURE
11-1321-0003.2200		0	3

PFC2020-0510
ATTACHMENT 2

25 mm
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

Path: \\golder.gds\calgary\Active\EDCAD\2011\11-1321-0003\PRODUCTION\FIGURES\ | File Name: 1113210003F G005.dwg

PFC2020-0510
ATTACHMENT 2

ISC: UNRESTRICTED

BORE HOLE LEGEND

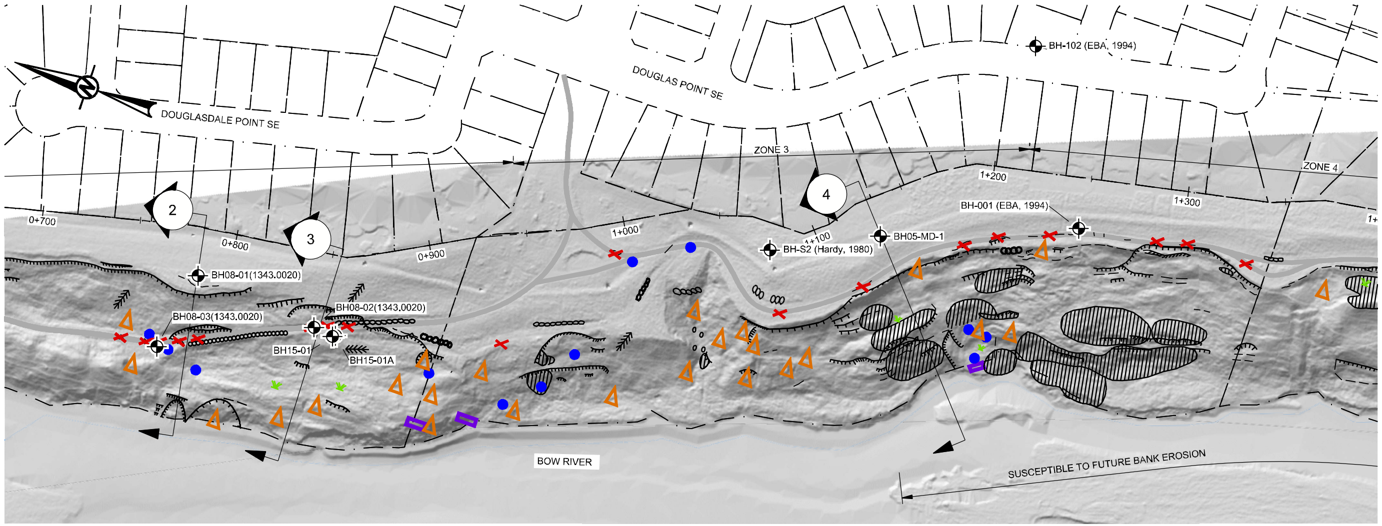
- ■ TOPSOIL OR FILL
- 🟥 TILL - CLAY
- ▨ TILL - SILTY CLAY OR CLAYEY SILT - STIFF
- ▨ TILL - SILTY CLAY OR CLAYEY SILT - HARD
- 🟩 TILL - SILT OR SANDY SILT
- 🟧 SAND AND GRAVEL
- ▨ WEATHERED CLAYSTONE OR MUDSTONE
- ▨ WEATHERED SILTSTONE OR SANDSTONE
- 🟪 COMPETENT CLAYSTONE OR MUDSTONE
- 🟫 COMPETENT SILTSTONE OR SANDSTONE

LEGEND

- SCARP
- TENSION CRACKS
- RIP RAP
- ANCHORED CAISSON WALL
- EROSION AND DRAINAGE ZONES
- PONDED WATER
- ● SEEPAGE
- POSSIBLE ACTIVE SLIDE AREA
- LEANING TREES
- ✗ PATHWAY DAMAGE OR REPAIR
- ▭ OBSERVED BEDROCK OUTCROP
- BOREHOLE
- ▼ MEASURED WATER LEVEL - (S) SHALLOW, (D) DEEP

REFERENCE

1. PROPERTY LINES FROM CITY OF CALGARY DIGITAL DATA, 2009.
2. LIDAR DATA PROVIDED BY CITY OF CALGARY, SEPTEMBER 9 - OCTOBER 7, 2013.
3. FIELD OBSERVATION DATA BY GOLDER BETWEEN 2006 AND 2014.
4. 100 YEAR FLOOD LEVEL FROM BOW AND ELBOW RIVER HYDRAULIC MODELLING AND INUNDATION MAPPING PROJECT PREPARED FOR THE CITY OF CALGARY BY GOLDER 2012.
5. WATER SURFACE OBTAINED FROM LIDAR DATA, SEPTEMBER 9 - OCTOBER 7, 2013.



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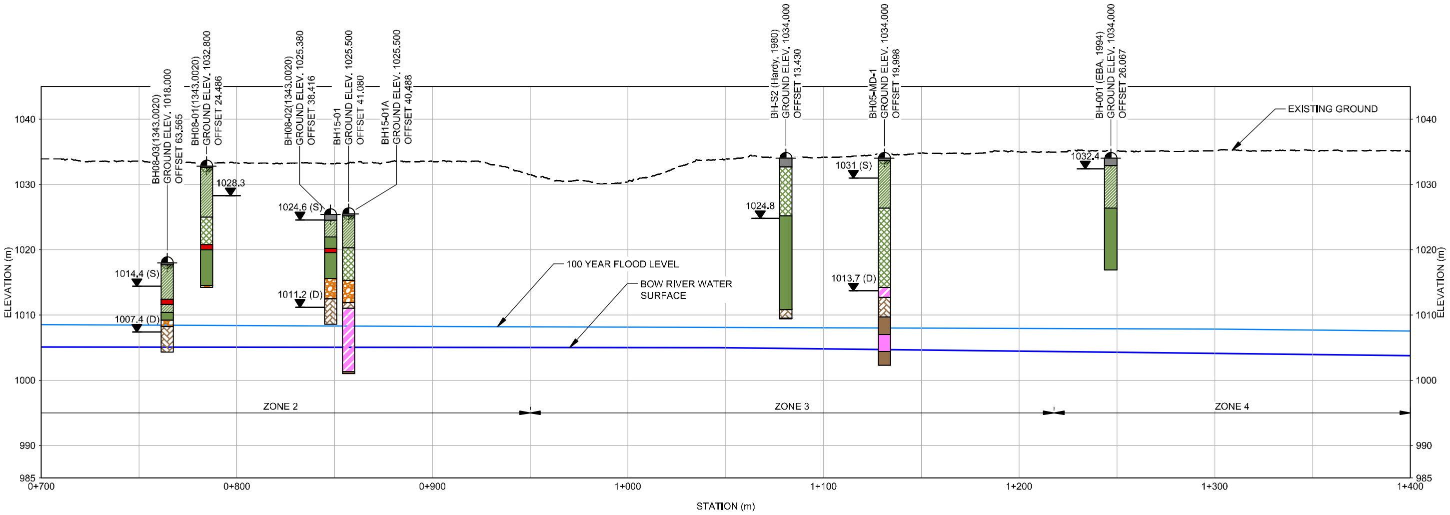
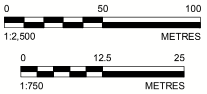


PROFILE
HOR. SCALE 1:2500
VERT. SCALE 1:750



CLIENT
CITY OF CALGARY

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-06-19
PREPARED	DW
DESIGN	AW
REVIEW	AE
APPROVED	DEB

PROJECT
BOW RIVER REGIONAL PATHWAY
DOUGLASDALE / MCKENZIE LAKE FEASIBILITY STUDY

TITLE
SITE PLAN AND PROFILE *STA 0+700 TO 1+400*

PROJECT No.	CONTROL	Rev.	FIGURE
11-1321-0003.2200		0	4

Path: \\golder.gds\calgary\Active\EDCAD\2011\11-1321-0003\PRODUCTION\FIGURES\ | File Name: 1113210003F005.dwg

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

0 25 mm

ISC: UNRESTRICTED

BORE HOLE LEGEND

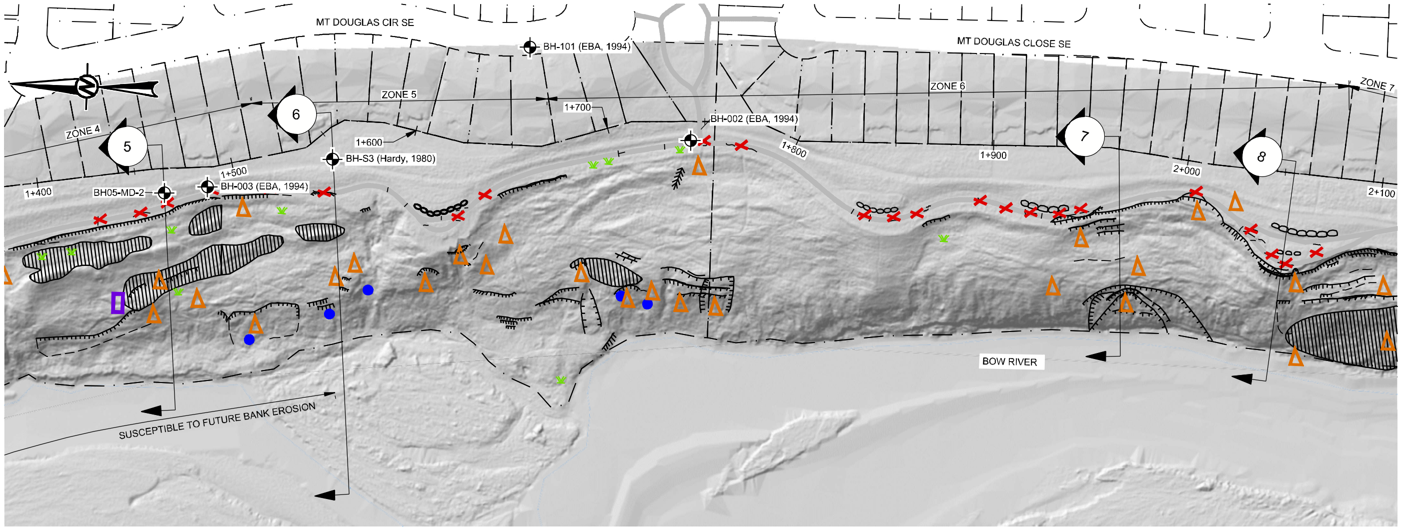
▨	TOPSOIL OR FILL
🟥	TILL - CLAY
▨	TILL - SILTY CLAY OR CLAYEY SILT - STIFF
▨	TILL - SILTY CLAY OR CLAYEY SILT - HARD
🟩	TILL - SILT OR SANDY SILT
▨	SAND AND GRAVEL
▨	WEATHERED CLAYSTONE OR MUDSTONE
▨	WEATHERED SILTSTONE OR SANDSTONE
▨	COMPETENT CLAYSTONE OR MUDSTONE
▨	COMPETENT SILTSTONE OR SANDSTONE

LEGEND

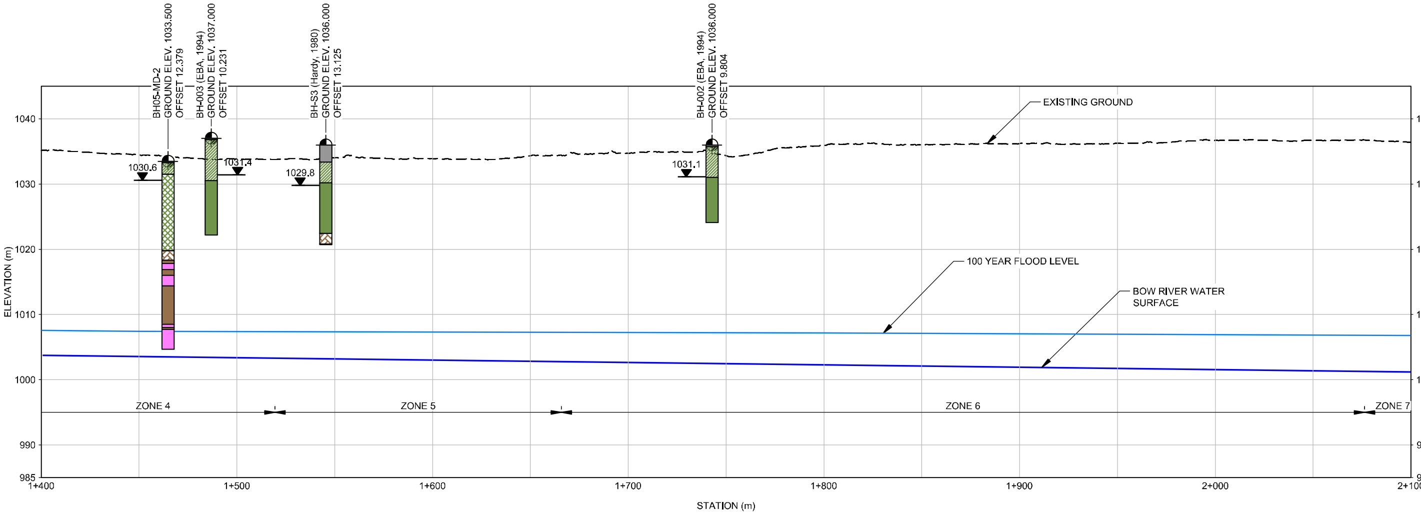
┬┬┬┬┬┬┬	SCARP
– – – – –	TENSION CRACKS
○○○○○○	RIP RAP
▨	ANCHORED CAISSON WALL
▷	EROSION AND DRAINAGE ZONES
✱	PONDED WATER
●	SEEPAGE
▨	POSSIBLE ACTIVE SLIDE AREA
⋙	LEANING TREES
✗	PATHWAY DAMAGE OR REPAIR
▭	OBSERVED BEDROCK OUTCROP
⊕	BOREHOLE
▼	MEASURED WATER LEVEL - (S) SHALLOW, (D) DEEP

REFERENCE

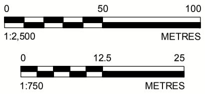
1. PROPERTY LINES FROM CITY OF CALGARY DIGITAL DATA, 2009.
2. LIDAR DATA PROVIDED BY CITY OF CALGARY, SEPTEMBER 9 - OCTOBER 7, 2013.
3. FIELD OBSERVATION DATA BY GOLDER BETWEEN 2006 AND 2014.
4. 100 YEAR FLOOD LEVEL FROM BOW AND ELBOW RIVER HYDRAULIC MODELLING AND INUNDATION MAPPING PROJECT PREPARED FOR THE CITY OF CALGARY BY GOLDER 2012.
5. WATER SURFACE OBTAINED FROM LIDAR DATA, SEPTEMBER 9 - OCTOBER 7, 2013.



PLAN
SCALE 1:2500



PROFILE
HOR. SCALE 1:2500
VERT. SCALE 1:750



CLIENT
CITY OF CALGARY

CONSULTANT

Golder Associates

YYYY-MM-DD	2015-06-19
PREPARED	DW
DESIGN	AW
REVIEW	AE
APPROVED	DEB

PROJECT
BOW RIVER REGIONAL PATHWAY
DOUGLASDALE / MCKENZIE LAKE FEASIBILITY STUDY

TITLE
SITE PLAN AND PROFILE *STA 1+400 TO 2+100*

PROJECT No.	CONTROL	Rev.	FIGURE
11-1321-0003.2200		0	5

PFC2020-0510
ATTACHMENT 2

25 mm

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

Path: \\golder.gds\calgary\Active\EDCAD\2011\11-1321-0003\PRODUCTION\FIGURES\ | File Name: 1113210003F G005.dwg

PFC2020-0510
ATTACHMENT 2

ISC: UNRESTRICTED

BORE HOLE LEGEND

⬛	TOPSOIL OR FILL
🟥	TILL - CLAY
▨	TILL - SILTY CLAY OR CLAYEY SILT - STIFF
▨	TILL - SILTY CLAY OR CLAYEY SILT - HARD
🟩	TILL - SILT OR SANDY SILT
🟧	SAND AND GRAVEL
▨	WEATHERED CLAYSTONE OR MUDSTONE
▨	WEATHERED SILTSTONE OR SANDSTONE
🟪	COMPETENT CLAYSTONE OR MUDSTONE
🟫	COMPETENT SILTSTONE OR SANDSTONE

LEGEND

┬┬┬┬┬┬	SCARP
– – – –	TENSION CRACKS
○○○○○○	RIP RAP
▨	ANCHORED CAISSON WALL
▷	EROSION AND DRAINAGE ZONES
✱	PONDED WATER
●	SEEPAGE
▨	POSSIBLE ACTIVE SLIDE AREA
⋙	LEANING TREES
✗	PATHWAY DAMAGE OR REPAIR
▭	OBSERVED BEDROCK OUTCROP
⊕	BOREHOLE
▼	MEASURED WATER LEVEL - (S) SHALLOW, (D) DEEP

REFERENCE

1. PROPERTY LINES FROM CITY OF CALGARY DIGITAL DATA, 2009.
2. LIDAR DATA PROVIDED BY CITY OF CALGARY, SEPTEMBER 9 - OCTOBER 7, 2013.
3. FIELD OBSERVATION DATA BY GOLDER BETWEEN 2006 AND 2014.
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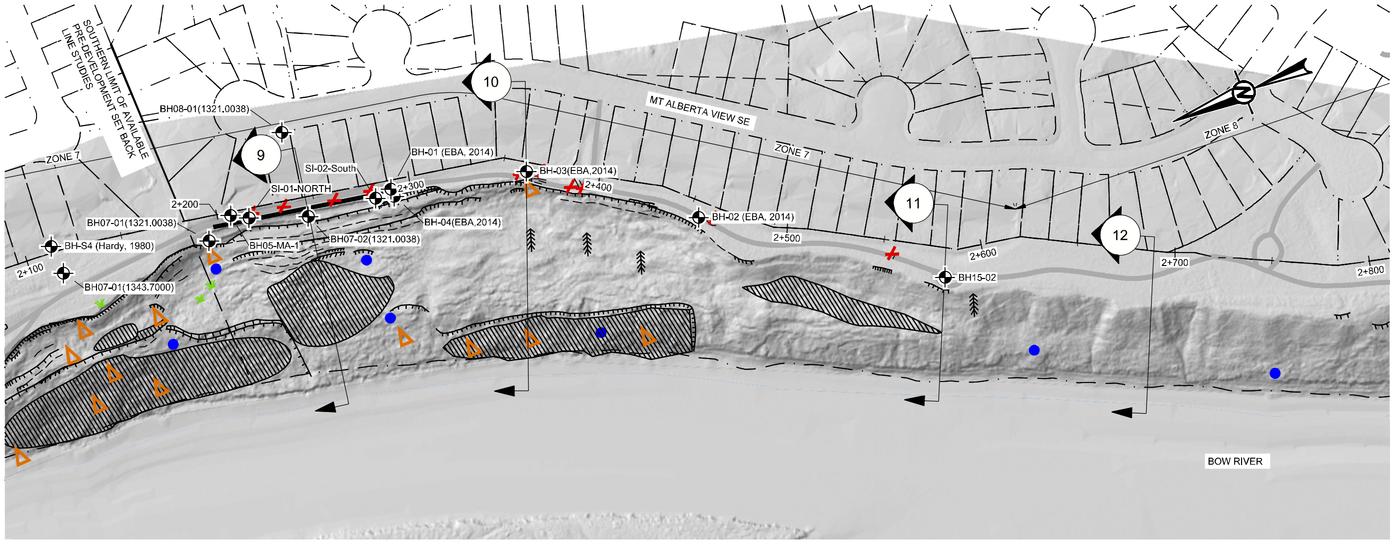
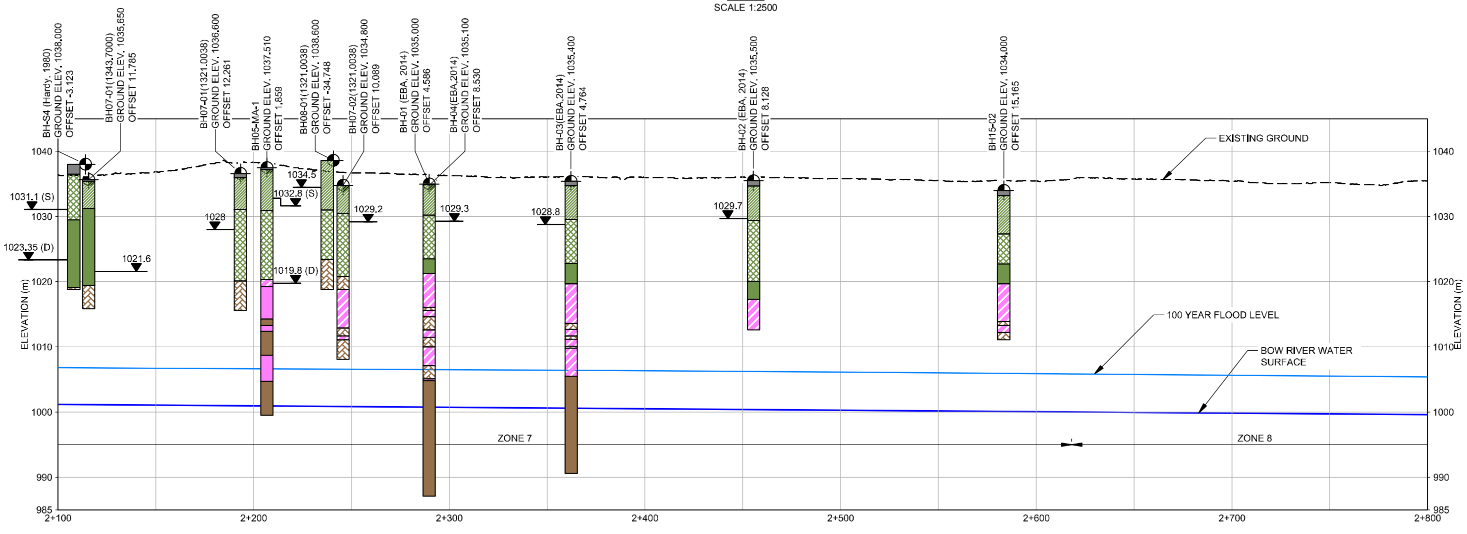
5. WATER SURFACE OBTAINED FROM LIDAR DATA, SEPTEMBER 9 - OCTOBER 7, 2013.



PLAN
SCALE 1:2500



PROFILE
HOR. SCALE 1:2500
VERT. SCALE 1:750

0 50 100
1:2,500 METRES

0 12.5 25
1:750 METRES

CLIENT	CITY OF CALGARY
CONSULTANT	Golder Associates
YYYY-MM-DD	2015-06-19
PREPARED	DW
DESIGN	AW
REVIEW	AE
APPROVED	DEB

PROJECT
BOW RIVER REGIONAL PATHWAY
DOUGLASDALE / MCKENZIE LAKE FEASIBILITY STUDY

TITLE
SITE PLAN AND PROFILE *STA 2+100 TO 2+800*

PROJECT No.	CONTROL	Rev.	FIGURE
11-1321-0003.2200		0	6

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B
0 25 mm

Path: \\golder.gds\calgary\Active\EDCAD\2011\11-1321-0003\PRODUCTION\FIGURES\ | File Name: 1113210003F G005.dwg

ISC: UNRESTRICTED

PFC2020-0510
ATTACHMENT 2

BORE HOLE LEGEND

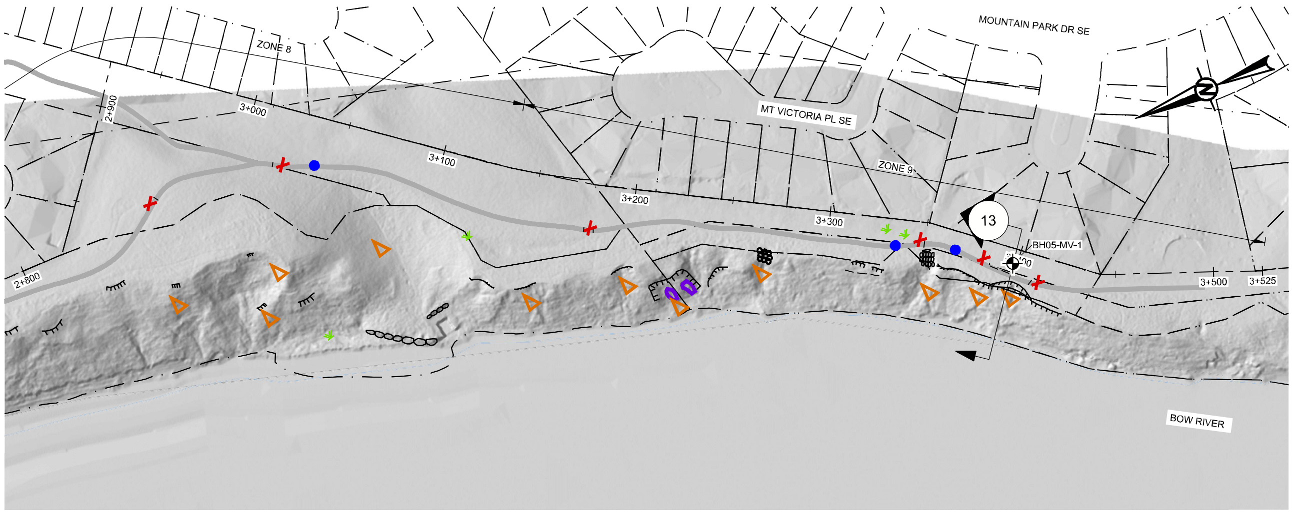
- ⬛ TOPSOIL OR FILL
- 🟥 TILL - CLAY
- ▨ TILL - SILTY CLAY OR CLAYEY SILT - STIFF
- ▩ TILL - SILTY CLAY OR CLAYEY SILT - HARD
- 🟩 TILL - SILT OR SANDY SILT
- 🟧 SAND AND GRAVEL
- ▨ WEATHERED CLAYSTONE OR MUDSTONE
- ▩ WEATHERED SILTSTONE OR SANDSTONE
- 🟪 COMPETENT CLAYSTONE OR MUDSTONE
- 🟫 COMPETENT SILTSTONE OR SANDSTONE

LEGEND

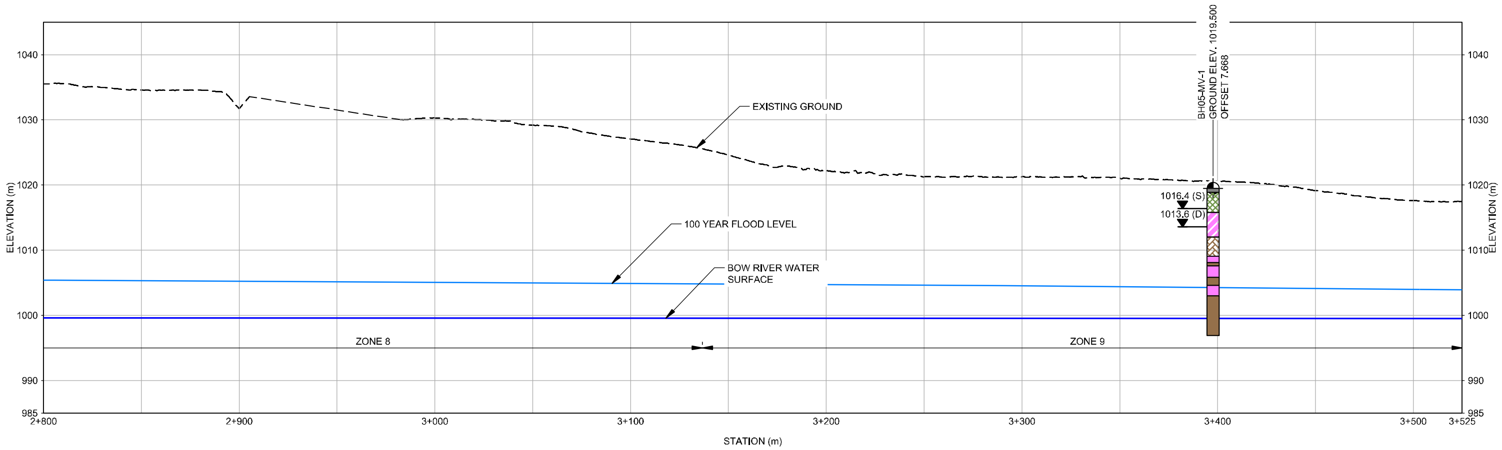
- ┬┬┬┬┬┬┬ SCARP
- – – – – – TENSION CRACKS
- ∞∞∞∞∞ RIP RAP
- ▨ ANCHORED CAISSON WALL
- ▷ EROSION AND DRAINAGE ZONES
- ✱ PONDED WATER
- ● SEEPAGE
- ▥ POSSIBLE ACTIVE SLIDE AREA
- ⋙ LEANING TREES
- ✗ PATHWAY DAMAGE OR REPAIR
- ▭ OBSERVED BEDROCK OUTCROP
- ⊕ BOREHOLE
- ▼ MEASURED WATER LEVEL - (S) SHALLOW, (D) DEEP

REFERENCE

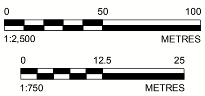
1. PROPERTY LINES FROM CITY OF CALGARY DIGITAL DATA, 2009.
2. LIDAR DATA PROVIDED BY CITY OF CALGARY, SEPTEMBER 9 - OCTOBER 7, 2013.
3. FIELD OBSERVATION DATA BY GOLDER BETWEEN 2006 AND 2014.
4. 100 YEAR FLOOD LEVEL FROM BOW AND ELBOW RIVER HYDRAULIC MODELLING AND INUNDATION MAPPING PROJECT PREPARED FOR THE CITY OF CALGARY BY GOLDER 2012.
5. WATER SURFACE OBTAINED FROM LIDAR DATA, SEPTEMBER 9 - OCTOBER 7, 2013.



PLAN
SCALE 1:2500



PROFILE
HOR. SCALE 1:2500
VERT. SCALE 1:750



CLIENT
CITY OF CALGARY

CONSULTANT

YYYY-MM-DD	2015-06-19
PREPARED	DW
DESIGN	AW
REVIEW	AE
APPROVED	DEB

PROJECT
BOW RIVER REGIONAL PATHWAY
DOUGLASDALE / MCKENZIE LAKE FEASIBILITY STUDY

TITLE
SITE PLAN AND PROFILE *STA 2+800 TO 3+525*

PROJECT No. 11-1321-0003.2200
CONTROL
Rev. 0
FIGURE 7

PFC2020-0510
ATTACHMENT 2

PATH: \\golder.gds\calgary\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\Hydrology - River Assessment\Mapping\HISTORIC BANK LINES.mxd

LEGEND

▬ Estimated Bank - 1966
▬ Estimated Bank - 1974
▬ Estimated Bank - 1998
▬ Estimated Bank - 2011
▬ Existing Bank - 2013

FOR DISCUSSION PURPOSES ONLY

0 500 1,000

1:15,000 METERS

NOTE(S)

REFERENCE(S)

CLIENT
CITY OF CALGARY

PROJECT
CITY OF CALGARY
SLOPE STABILITY PROGRAM
DOUGLASDALE SITE

CONSULTANT

Golder Associates

YYYY-MM-DD	27 APRIL 2015
DESIGNED	NG
PREPARED	BR
REVIEWED	AO
APPROVED	MB

TITLE
HISTORIC BANK LINE COMPARISON (1966-2013)

PROJECT NO.	CONTROL	REV.	FIGURE
11-1321-0003.2200		0	12

ISC: UNRESTRICTED

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25mm

0

PATH: \\golder.gds\calgary\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\Hydrology - River Assessment\Mapping\BED ELEVATION CHANGE.mxd

LEGEND

Channel Thalweg

Bed Elevation Change

🟥	-4 m to -2 m
🟧	-2 m to -1 m
🟨	-1 m to -0.5 m
🟩	0.5 m to 1 m
🟦	1 m to 2 m
🟦	2 m to 3 m

ISC: UNRESTRICTED

FOR DISCUSSION PURPOSES ONLY

0 500 1,000

1:22,000 METERS

NOTE(S)

REFERENCE(S)

CLIENT
CITY OF CALGARY

PROJECT
CITY OF CALGARY
SLOPE STABILITY PROGRAM
DOUGLASDALE SITE

CONSULTANT

Golder Associates

YYYY-MM-DD	27 APRIL 2015
DESIGNED	NG
PREPARED	BR
REVIEWED	AO
APPROVED	MB

TITLE
BED ELEVATION CHANGE AND POST-FLOOD CHANNEL THALWEG (PRE-FLOOD 2011 & POST-FLOOD 2013)

PROJECT NO.	CONTROL	REV.	FIGURE
11-1321-0003.2200		0	**13**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25mm
0

PFC2020-0510
ATTACHMENT 2

ISC: UNRESTRICTED

LEGEND

➤	Swales
—	Draiange Path
→	Flow Direction
▭	Drainage Area to Bow River

City of Calgary Infrastructures

-·-	Stormwater Pipe
⊗	Stormwater Manhole
⊙	Stormwater Catch Basin
▲	Stormwater Outfall

KEY MAP

FOR DISCUSSION PURPOSES ONLY

0 100 200
1:4,500 METERS

CLIENT
CITY OF CALGARY

CONSULTANT
Golder Associates

YYYY-MM-DD	07 MAY 2015
DESIGNED	NG
PREPARED	NG
REVIEWED	AO
APPROVED	MB

NOTE(S)

REFERENCE(S)

PROJECT
CITY OF CALGARY
SLOPE STABILITY PROGRAM
DOUGLASDALE SITE

TITLE
SURFACE DRAINAGE FEATURES
(FIGURE 1 OF 4)

PROJECT NO.	CONTROL	REV.	FIGURE
11-1321-0003,2200		0	17

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25mm

PATH: \\golder.gds\calgary\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\Hydrology - River Assessment\Mapping\DRAINAGE_ALAYSIS_FIG01of4.mxd

PFC2020-0510
ATTACHMENT 2

LEGEND

- Swales
- Draiange Path
- Flow Direction
- Drainage Area to Bow River

City of Calgary Infrastructures

- Stormwater Pipe
- ⊗ Stormwater Manhole
- ⊙ Stormwater Catch Basin
- ▲ Stormwater Outfall

FOR DISCUSSION PURPOSES ONLY

0 100 200
1:4,500 METERS

NOTE(S)

REFERENCE(S)

CLIENT
CITY OF CALGARY

PROJECT
CITY OF CALGARY
SLOPE STABILITY PROGRAM
DOUGLASDALE SITE

CONSULTANT
Golder Associates

YYYY-MM-DD	07 MAY 2015
DESIGNED	NG
PREPARED	NG
REVIEWED	AO
APPROVED	MB

TITLE
SURFACE DRAINAGE FEATURES
(FIGURE 2 OF 4)

PROJECT NO.	CONTROL	REV.	FIGURE
11-1321-0003.2200		0	18

PATH: \\golder.gds\calgary\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\Hydrology - River Assessment\Mapping\FIG_18_DRAINAGE_ALAYSIS_FIG02of4.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B
0 25mm

PFC2020-0510
ATTACHMENT 2

ISC: UNRESTRICTED

LEGEND

- ▶ Swales
- Draiange Path
- → Flow Direction
- ▭ Drainage Area to Bow River

City of Calgary Infrastructures

- Stormwater Pipe
- ⊗ Stormwater Manhole
- ⊙ Stormwater Catch Basin
- ▲ Stormwater Outfall

KEY MAP

FOR DISCUSSION PURPOSES ONLY

0 100 200
1:4,500 METERS

CLIENT
CITY OF CALGARY

CONSULTANT
Golder Associates

YYYY-MM-DD	07 MAY 2015
DESIGNED	NG
PREPARED	NG
REVIEWED	AO
APPROVED	MB

NOTE(S)

REFERENCE(S)

PROJECT
CITY OF CALGARY
SLOPE STABILITY PROGRAM
DOUGLASDALE SITE

TITLE
SURFACE DRAINAGE FEATURES
(FIGURE 3 OF 4)

PROJECT NO.	CONTROL	REV.	FIGURE
11-1321-0003,2200		0	19

PATH: \\golder.gds\calgary\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\Hydrology - River Assessment\Mapping\FIG_19_DRAINAGE_ALAYSIS_FIG03of4.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B
0 25mm

PFC2020-0510
ATTACHMENT 2

ISC: UNRESTRICTED

LEGEND

▶	Swales
—	Draiange Path
→	Flow Direction
▭	Drainage Area to Bow River

City of Calgary Infrastructures

— · —	Stormwater Pipe
⊗	Stormwater Manhole
⊙	Stormwater Catch Basin
▲	Stormwater Outfall

FOR DISCUSSION PURPOSES ONLY

0 100 200
1:4,500 METERS

CLIENT
CITY OF CALGARY

CONSULTANT
Golder Associates

YYYY-MM-DD	07 MAY 2015
DESIGNED	NG
PREPARED	NG
REVIEWED	AO
APPROVED	MB

NOTE(S)

REFERENCE(S)

PROJECT
CITY OF CALGARY
SLOPE STABILITY PROGRAM
DOUGLASDALE SITE

TITLE
SURFACE DRAINAGE FEATURES
(FIGURE 4 OF 4)

PROJECT NO.	CONTROL	REV.	FIGURE
11-1321-0003.2200		0	**20**

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25mm

0

PATH: \\golder.gds\calgary\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\Hydrology - River Assessment\Mapping\FIG_20_DRAINAGE_ALAYSIS_FIG04of4.mxd

PFC2020-0510
ATTACHMENT 2

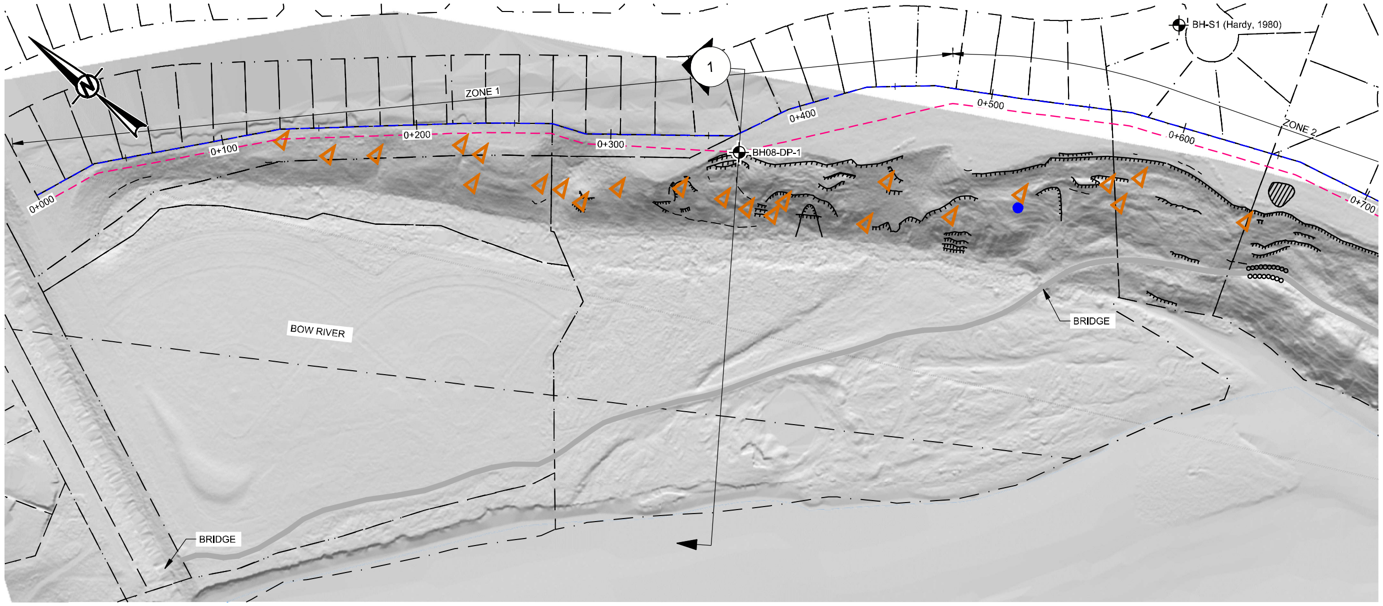
ISC: UNRESTRICTED

LEGEND

- - - -	CALCULATED FACTOR OF SAFETY - 1.3
- - - -	CALCULATED FACTOR OF SAFETY - 1.5
┬┬┬┬┬┬	SCARP
— — —	TENSION CRACKS
∞∞∞∞∞	RIP RAP
▨	ANCHORED CAISSON WALL
▷	EROSION AND DRAINAGE ZONES
⩡	PONDED WATER
●	SEEPAGE
▨	POSSIBLE ACTIVE SLIDE AREA
⪢	LEANING TREES
✗	PATHWAY DAMAGE OR REPAIR
▬	OBSERVED BEDROCK OUTCROP
⊕	BOREHOLE
▼	MEASURED WATER LEVEL - (S) SHALLOW, (D) DEEP

REFERENCE

1. PROPERTY LINES FROM CITY OF CALGARY DIGITAL DATA, 2009.
2. LIDAR DATA PROVIDED BY CITY OF CALGARY, SEPTEMBER 9 - OCTOBER 7, 2013.
3. FIELD OBSERVATION DATA BY GOLDER BETWEEN 2006 AND 2014.



PLAN
SCALE 1:2500

0 50 100
1:2,500 METRES

CLIENT
CITY OF CALGARY

CONSULTANT

YYYY-MM-DD	2015-06-19
PREPARED	DW
DESIGN	AW
REVIEW	AE
APPROVED	DEB

PROJECT
BOW RIVER REGIONAL PATHWAY
DOUGLASDALE / MCKENZIE LAKE FEASIBILITY STUDY

TITLE
FACTOR OF SAFETY DELINEATION *STA 0+000 TO 0+700*

PROJECT No.	CONTROL	Rev.	FIGURE
11-1321-0003.2200		0	21

25 mm
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

Path: \\golder.gds\calgary\Active\EDCAD\2011\11-1321-0003\PRODUCTION\FIGURES\ | File Name: 1113210003FG006.dwg

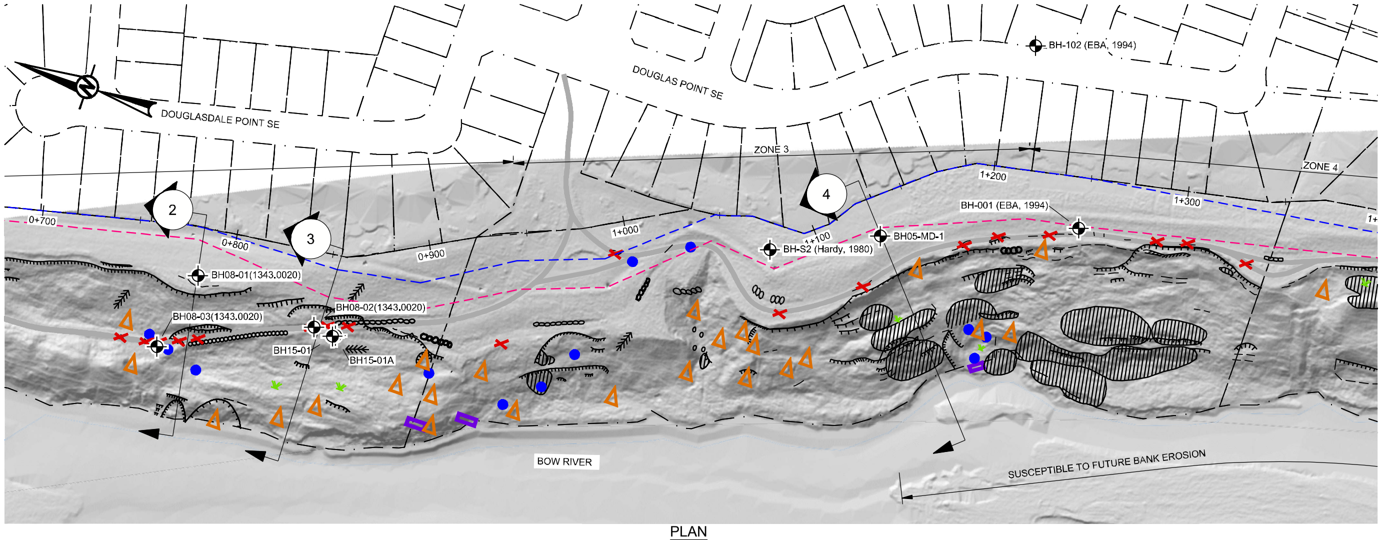
ISC: UNRESTRICTED

LEGEND

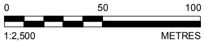
- - -	CALCULATED FACTOR OF SAFETY - 1.3
- - -	CALCULATED FACTOR OF SAFETY - 1.5
┬┬┬┬┬┬	SCARP
— — —	TENSION CRACKS
oooooooo	RIP RAP
▨	ANCHORED CAISSON WALL
▷	EROSION AND DRAINAGE ZONES
✻	PONDED WATER
●	SEEPAGE
▤	POSSIBLE ACTIVE SLIDE AREA
⋙	LEANING TREES
✗	PATHWAY DAMAGE OR REPAIR
▭	OBSERVED BEDROCK OUTCROP
⊕	BOREHOLE
▼	MEASURED WATER LEVEL - (S) SHALLOW, (D) DEEP

REFERENCE

1. PROPERTY LINES FROM CITY OF CALGARY DIGITAL DATA, 2009.
2. LIDAR DATA PROVIDED BY CITY OF CALGARY, SEPTEMBER 9 - OCTOBER 7, 2013.
3. FIELD OBSERVATION DATA BY GOLDER BETWEEN 2006 AND 2014.



PLAN
SCALE 1:2500



CLIENT
CITY OF CALGARY

CONSULTANT

YYYY-MM-DD	2015-06-19
PREPARED	DW
DESIGN	AW
REVIEW	AE
APPROVED	DEB

PROJECT
BOW RIVER REGIONAL PATHWAY
DOUGLASDALE / MCKENZIE LAKE FEASIBILITY STUDY

TITLE
FACTOR OF SAFETY DELINEATION STA 0+700 TO 1+400

PROJECT No.	CONTROL	Rev.	FIGURE
11-1321-0003.2200		0	22

PFC2020-0510
ATTACHMENT 2

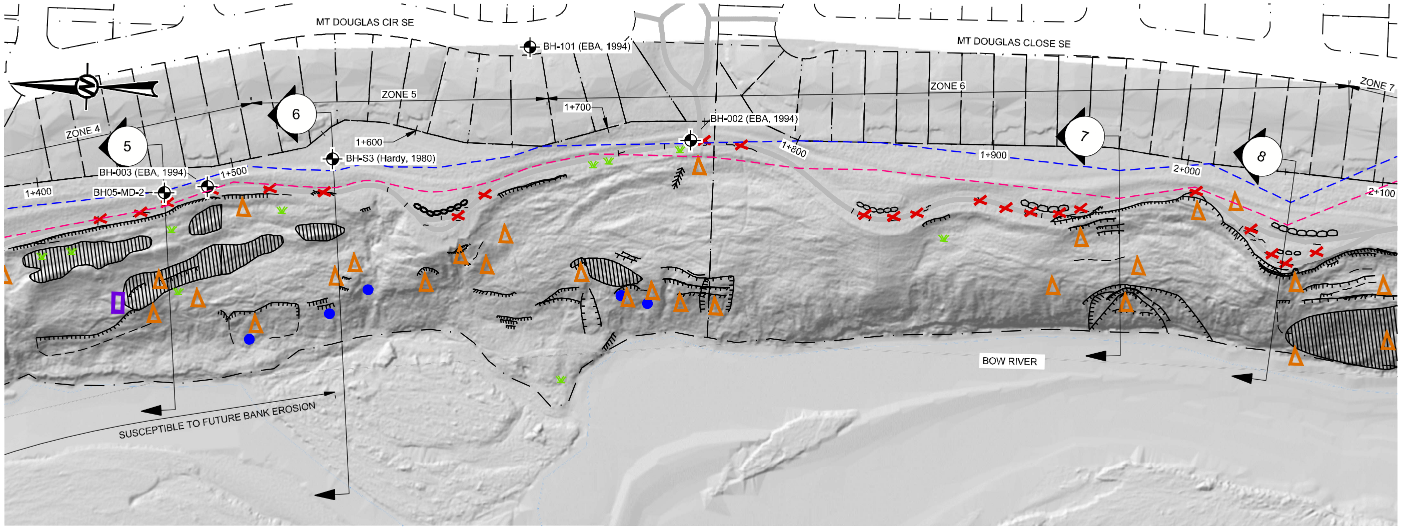
ISC: UNRESTRICTED

LEGEND

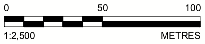
- - -	CALCULATED FACTOR OF SAFETY - 1.3
- - -	CALCULATED FACTOR OF SAFETY - 1.5
┬┬┬┬┬	SCARP
— — —	TENSION CRACKS
○○○○○	RIP RAP
▨	ANCHORED CAISSON WALL
▷	EROSION AND DRAINAGE ZONES
✳	PONDED WATER
●	SEEPAGE
▨	POSSIBLE ACTIVE SLIDE AREA
⋙	LEANING TREES
✗	PATHWAY DAMAGE OR REPAIR
▭	OBSERVED BEDROCK OUTCROP
⊕	BOREHOLE
▼	MEASURED WATER LEVEL - (S) SHALLOW, (D) DEEP

REFERENCE

1. PROPERTY LINES FROM CITY OF CALGARY DIGITAL DATA, 2009.
2. LIDAR DATA PROVIDED BY CITY OF CALGARY, SEPTEMBER 9 - OCTOBER 7, 2013.
3. FIELD OBSERVATION DATA BY GOLDER BETWEEN 2006 AND 2014.



PLAN
SCALE 1:2500



CLIENT
CITY OF CALGARY

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-06-19
PREPARED	DW
DESIGN	AW
REVIEW	AE
APPROVED	DEB

PROJECT
BOW RIVER REGIONAL PATHWAY
DOUGLASDALE / MCKENZIE LAKE FEASIBILITY STUDY

TITLE
FACTOR OF SAFETY DELINEATION STA 1+400 TO 2+100

PROJECT No.	CONTROL	Rev.	FIGURE
11-1321-0003.2200		0	23

PFC2020-0510
ATTACHMENT 2

25 mm
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

Path: \\golder.gds\calgary\Active\EDCAD\2011\11-1321-0003\PRODUCTION\FIGURES\ | File Name: 1113210003F0006.dwg

ISC: UNRESTRICTED

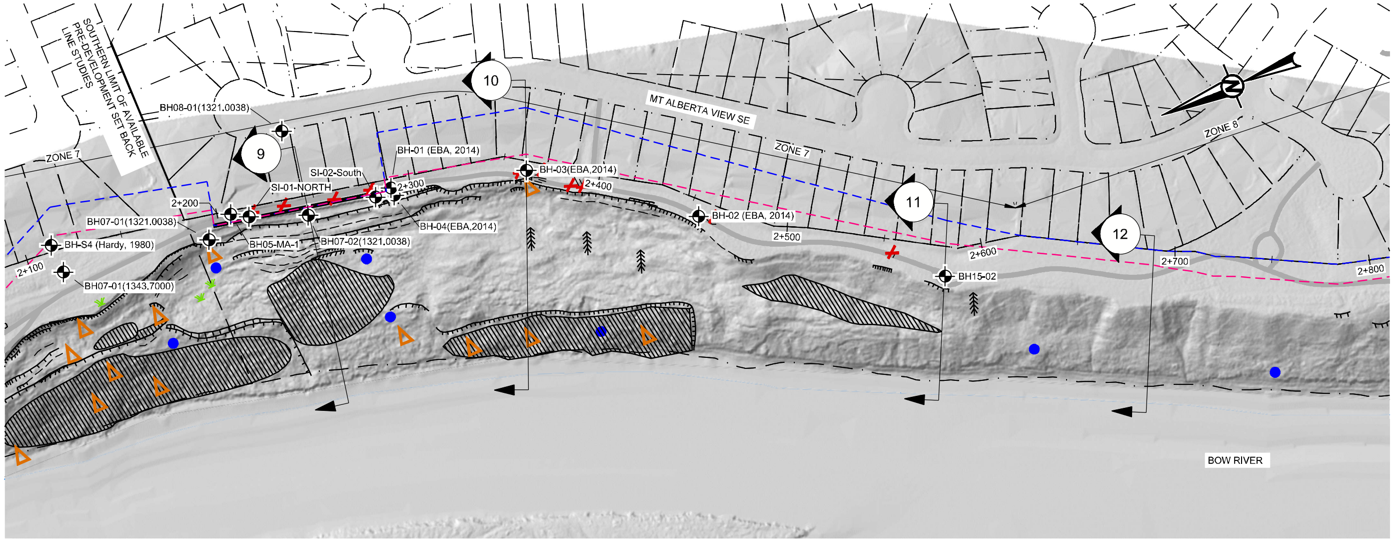
PFC2020-0510
ATTACHMENT 2

LEGEND

- - -	CALCULATED FACTOR OF SAFETY - 1.3
- - -	CALCULATED FACTOR OF SAFETY - 1.5
┬┬┬┬┬	SCARP
— — —	TENSION CRACKS
∞∞∞∞	RIP RAP
▨	ANCHORED CAISSON WALL
▷	EROSION AND DRAINAGE ZONES
⁎	PONDED WATER
●	SEEPAGE
▨	POSSIBLE ACTIVE SLIDE AREA
⋙	LEANING TREES
✗	PATHWAY DAMAGE OR REPAIR
▬	OBSERVED BEDROCK OUTCROP
⊕	BOREHOLE
▼	MEASURED WATER LEVEL - (S) SHALLOW, (D) DEEP

REFERENCE

1. PROPERTY LINES FROM CITY OF CALGARY DIGITAL DATA, 2009.
2. LIDAR DATA PROVIDED BY CITY OF CALGARY, SEPTEMBER 9 - OCTOBER 7, 2013.
3. FIELD OBSERVATION DATA BY GOLDER BETWEEN 2006 AND 2014.



PLAN
SCALE 1:2500

CLIENT
CITY OF CALGARY

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-06-19
PREPARED	DW
DESIGN	AW
REVIEW	AE
APPROVED	DEB

PROJECT
BOW RIVER REGIONAL PATHWAY
DOUGLASDALE / MCKENZIE LAKE FEASIBILITY STUDY

TITLE
FACTOR OF SAFETY DELINEATION *STA 2+100 TO 2+800*

PROJECT No. 11-1321-0003.2200
CONTROL
Rev. 0
FIGURE 24

PFC2020-0510
ATTACHMENT 2

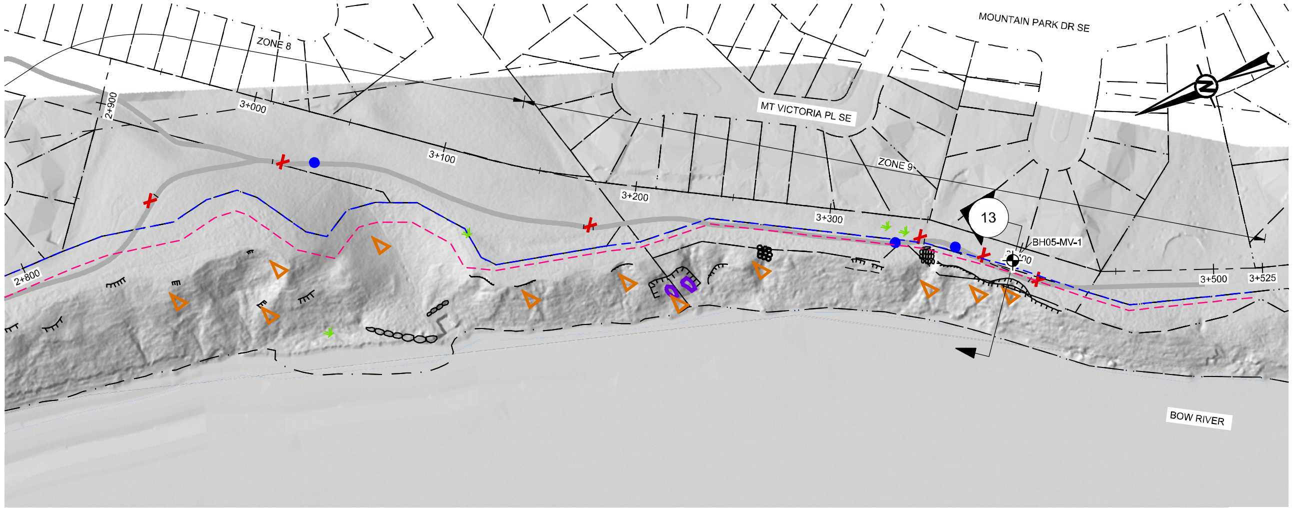
ISC: UNRESTRICTED

LEGEND

- - - -	CALCULATED FACTOR OF SAFETY - 1.3
- - - -	CALCULATED FACTOR OF SAFETY - 1.5
┬┬┬┬┬┬	SCARP
— — —	TENSION CRACKS
∞∞∞∞	RIP RAP
▨	ANCHORED CAISSON WALL
▷	EROSION AND DRAINAGE ZONES
✳	PONDED WATER
●	SEEPAGE
▥	POSSIBLE ACTIVE SLIDE AREA
⋙	LEANING TREES
✗	PATHWAY DAMAGE OR REPAIR
▬	OBSERVED BEDROCK OUTCROP
⊕	BOREHOLE
▼	MEASURED WATER LEVEL - (S) SHALLOW, (D) DEEP

REFERENCE

1. PROPERTY LINES FROM CITY OF CALGARY DIGITAL DATA, 2009.
2. LIDAR DATA PROVIDED BY CITY OF CALGARY, SEPTEMBER 9 - OCTOBER 7, 2013.
3. FIELD OBSERVATION DATA BY GOLDER BETWEEN 2006 AND 2014.



PLAN
SCALE 1:2500

0 50 100
1:2,500 METRES

CLIENT
CITY OF CALGARY

CONSULTANT

YYYY-MM-DD	2015-06-19
PREPARED	DW
DESIGN	AW
REVIEW	AE
APPROVED	DEB

PROJECT
BOW RIVER REGIONAL PATHWAY
DOUGLASDALE / MCKENZIE LAKE FEASIBILITY STUDY

TITLE
FACTOR OF SAFETY DELINEATION *STA 2+800 TO 3+525*

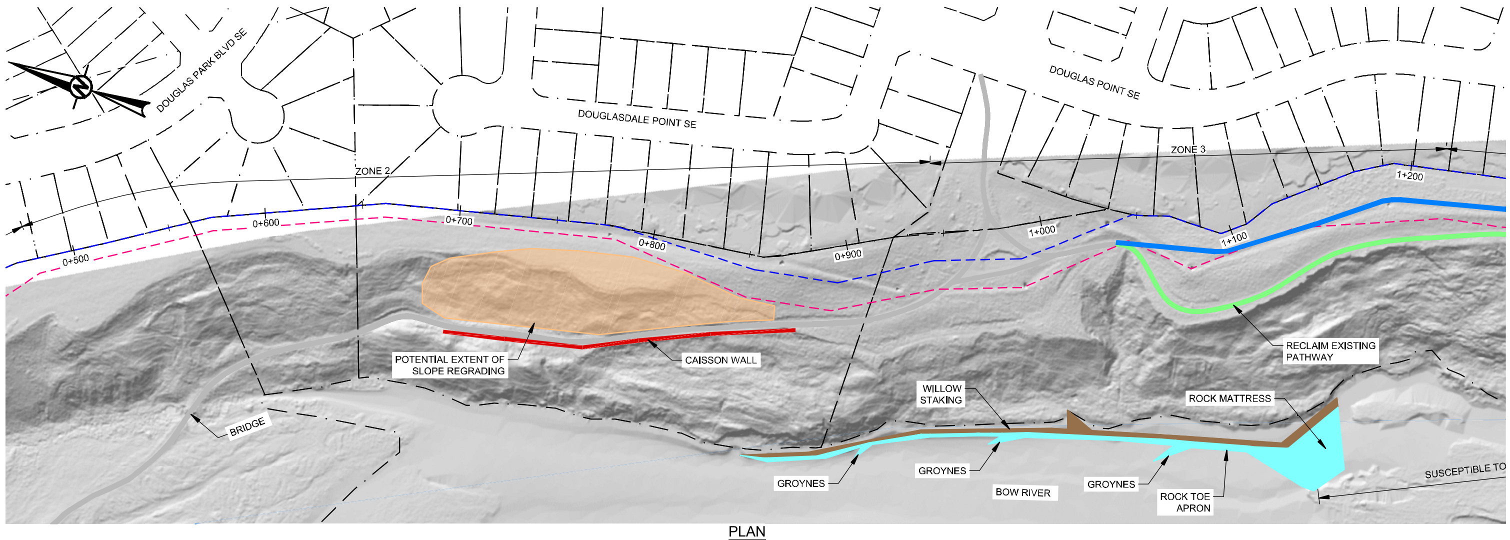
PROJECT No.	CONTROL	Rev.	FIGURE
11-1321-0003.2200		0	25

0 25 mm
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

Path: \\golder.gds\calgary\Active\EDCAD\2011\11-1321-0003\PRODUCTION\FIGURES\ | File Name: 1113210003FG006.dwg

PFC2020-0510
ATTACHMENT 2

ISC: UNRESTRICTED



PLAN
SCALE 1:2500

LEGEND

- - - (pink)	CALCULATED FACTOR OF SAFETY - 1.3
- - - (blue)	CALCULATED FACTOR OF SAFETY - 1.5
🟦	PATHWAY REALIGNMENT
🟩	EXISTING PATHWAY RECLAMATION

REFERENCE

1. PROPERTY LINES FROM CITY OF CALGARY DIGITAL DATA, 2009.
2. LIDAR DATA PROVIDED BY CITY OF CALGARY, SEPTEMBER 9 - OCTOBER 7, 2013.
3. FIELD OBSERVATION DATA BY GOLDER BETWEEN 2006 AND 2014.

CLIENT
CITY OF CALGARY

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-07-31
PREPARED	TF
DESIGN	RC
REVIEW	AE
APPROVED	DEB

PROJECT
BOW RIVER REGIONAL PATHWAY
DOUGLASDALE / MCKENZIE LAKE FEASIBILITY STUDY

TITLE
CONCEPTUAL DESIGN *STA 0+700 TO 1+250*
ZONE 2 AND 3

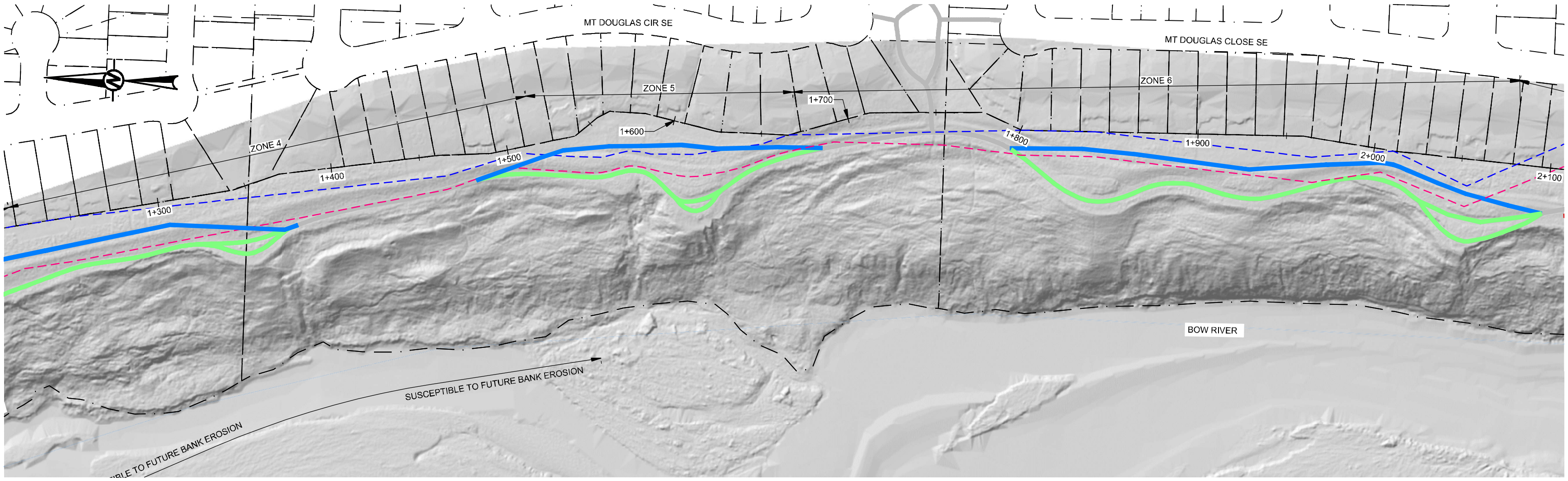
PROJECT No.	CONTROL	Rev.	FIGURE
11-1321-0003.2200		A	26

Path: \\golder.gds\calgary\EDCAD\2011\11-1321-0003\PRODUCTION\FIGURES\ | File Name: 1113210003FG008.dwg

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B
25 mm
0

PFC2020-0510
ATTACHMENT 2

ISC: UNRESTRICTED



PLAN
SCALE 1:2500

LEGEND

- - -	CALCULATED FACTOR OF SAFETY - 1.3
- - -	CALCULATED FACTOR OF SAFETY - 1.5
🟦	PATHWAY REALIGNMENT
🟩	EXISTING PATHWAY RECLAMATION

REFERENCE

1. PROPERTY LINES FROM CITY OF CALGARY DIGITAL DATA, 2009.
2. LIDAR DATA PROVIDED BY CITY OF CALGARY, SEPTEMBER 9 - OCTOBER 7, 2013.
3. FIELD OBSERVATION DATA BY GOLDER BETWEEN 2006 AND 2014.

0 50 100
1:2,500 METRES

CLIENT
CITY OF CALGARY

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-07-31
PREPARED	TF
DESIGN	RC
REVIEW	AE
APPROVED	DEB

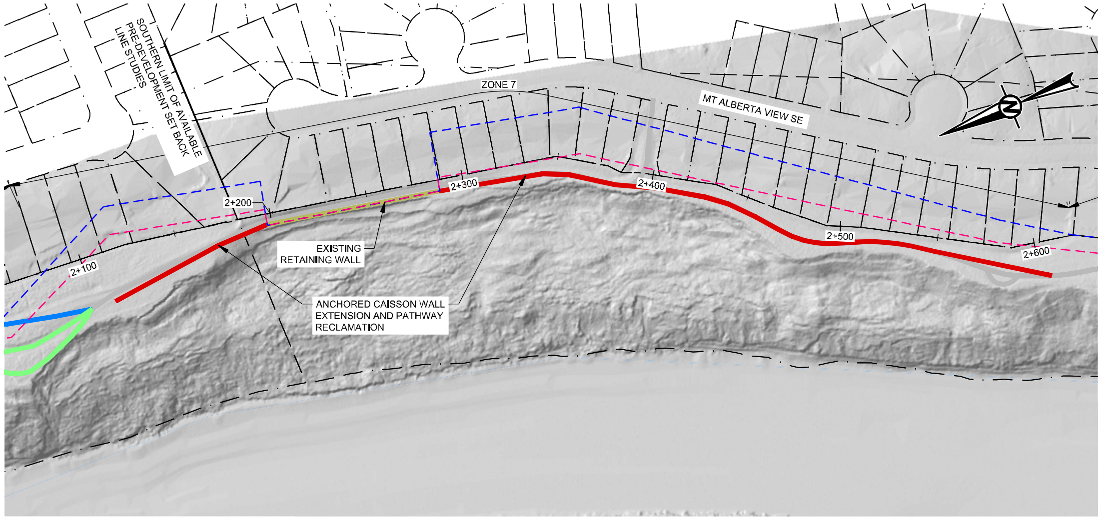
PROJECT
BOW RIVER REGIONAL PATHWAY
DOUGLASDALE / MCKENZIE LAKE FEASIBILITY STUDY

TITLE
CONCEPTUAL DESIGN *STA 1+250 TO 2+100*
ZONES 4, 5 AND 6

PROJECT No.	CONTROL	Rev.	FIGURE
11-1321-0003.2200		A	27

ISC: UNRESTRICTED

PFC2020-0510
ATTACHMENT 2



PLAN
SCALE 1:2500

LEGEND

- - - - CALCULATED FACTOR OF SAFETY - 1.3
- - - - CALCULATED FACTOR OF SAFETY - 1.5
▬ PATHWAY REALIGNMENT

REFERENCE

1. PROPERTY LINES FROM CITY OF CALGARY DIGITAL DATA, 2009.
2. LIDAR DATA PROVIDED BY CITY OF CALGARY, SEPTEMBER 9 - OCTOBER 7, 2013.
3. FIELD OBSERVATION DATA BY GOLDER BETWEEN 2006 AND 2014.

0 50 100
1:2,500 METRES

CLIENT
CITY OF CALGARY

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-07-31
PREPARED	TF
DESIGN	RC
REVIEW	AE
APPROVED	DEB

PROJECT
BOW RIVER REGIONAL PATHWAY
DOUGLASDALE / MCKENZIE LAKE FEASIBILITY STUDY

TITLE
CONCEPTUAL DESIGN *STA 2+100 TO 2+800*
ZONE 7

PROJECT No.	CONTROL	Rev.	FIGURE
11-1321-0003.2200		A	28

APPENDIX A

Table A1 – List of Available Geotechnical Reports
Table A2 – Summary of Relevant Information from Geotechnical Reports

APPENDIX A
BOW RIVER REGIONAL PATHWAY FEASIBILITY STUDY

Table A1: List of Available Existing Geotechnical Reports

Year	Title of Report
1980	Geotechnical Investigation CIL Plant Site. Hardy Associates (1978) Ltd.
1994	Slope Stability Evaluation South Douglasdale Calgary, Alberta. EBA Engineering Consultants Ltd.
1999	Geotechnical Evaluation of Slope Erosion/Movement of River Valley Slopes Douglasdale and Mountain Park Subdivisions. Agra Earth and Environmental Ltd.
2003	Geotechnical and Slope Stability Assessment 130th Ave and Mount Douglas Point SE Calgary, AB. Golder Associates Ltd.
2006	Slope Stability Evaluation 130th Avenue and Mount Douglas Point Calgary, Alberta. Golder Associates Ltd.
2006	Slope Stability Evaluation 323 Mt. Victoria Place SE and Nearby Area Calgary, AB. Golder Associates Ltd.
2006	Slope Stability Evaluation 133 Mt. Alberta View Se and Nearby Area Calgary, AB. Golder Associates Ltd.
2007	2006 Slope Monitoring Program Mt Douglas, Mt. Alberta View, Mt. Victoria and Nearby Areas. Golder Associates Ltd.
2007	Evaluation of Design Options to Protect the City of Calgary Pathway System Near 133 Mt. Alberta View SE and Vicinity, Calgary, AB. Golder Associates Ltd.
2007	2007 Slope Monitoring Program Mt. Douglas Point, Mt. Alberta View, Mt. Victoria Place and Nearby Areas. Golder Associates Ltd.
2008	Pathway Setback Study North of 133 Mt. Alberta View SE, Calgary, Alberta. Golder Associates Ltd.
2008	Slope Stability Evaluation 233 Douglas Park Boulevard SE and Nearby Area, Calgary, AB. Golder Associates Ltd.
2008	Geotechnical Instrumentation Monitoring (Slope Inclinometers and Piezometers) in the Douglasdale Area. Golder Associates Ltd.
2009	Slope Stability Studies and Pathway Remediation Options Douglasdale Escarpment Regional Pathway Calgary, Alberta. Golder Associates Ltd.
2009	Slope Stabilization at Mt. Alberta View SE, Calgary, Alberta. Golder Associates Ltd. and City of Calgary. GeoHalifax Conference.
2009	Construction Report Mt. Alberta View SE Pathway Protection Project. Golder Associates Ltd.
2010	2010 Slope Monitoring Program From Douglas Park Blvd. to Mt. Victoria Place, Calgary, Alberta. Golder Associates Ltd.
2011	2011 Slope Monitoring Program From Douglas Park Blvd. to Mt. Victoria Place, Calgary, Alberta
2012	2012 Slope Monitoring Program from Douglas Park Blvd. to Mt. Victoria Place, Calgary, Alberta
2013	2013 Slope Monitoring Program From Douglas Park Blvd. to Mt. Victoria Place, Calgary
2014	Slope Stability Assessment Portion of Bow River Pathway Mt. Alberta View SE Calgary, Alberta. Tetra Tech EBA Inc.
2014	2014 Pathway Escarpment Observation Summary Report. NRG Research Group.
2014	2014 Slope Monitoring Program From Douglas Park Blvd. to Mt. Victoria Place, Calgary, Alberta. Golder Associates Ltd.

Table A2: Summary of Relevant Information from Geotechnical Reports

Report	Station	Relevant Information
1980 Hardy Geotechnical Investigation CIL Plant Site	0+450 to 2+200	Subsurface soil information collected in four boreholes drilled to a maximum depth of 24.6 mbgs. Standpipes installed in all holes. Two triaxial strength tests performed. Seepage and bedrock field observations. Proposed residential development setback line drawn.
1994 EBA Slope Stability Evaluation South Douglasdale	0+450 to 2+200	Subsurface soil information collected in five boreholes drilled to a maximum depth of 17.1 mbgs. Standpipes installed in all holes. Two triaxial strength tests performed. Post development setback line drawn.
1999 Agra Geotechnical Evaluation of Slope Erosion/Movement of River Valley Slopes Douglasdale and Mountain Park Subdivisions	0+700 to 2+200	Reviewed aerial photographs and recorded field observations. Identified areas where surface runoff was contributing to slope instability. Slope movements appeared to be causing cracking on the existing pathway. Expected that over time other sections of the path would also experience cracking due to slope movement. Recommended to relocate short sections of pathway over time rather than attempt to prevent slope movement along the valley wall as it was more economical. Loss of ground due to soil erosion was noted to be an active process, with potential to affect significant amount of the slope over a short period of time. Reconfiguration of roof drainage from private lots to the front of the lots and seeding areas within the environmental reserve where grass cover had not yet been established recommended to reduce erosion. Detailed recommendations for erosion mitigation due to over-slope drainage were made including installation of catch basins and drainage pipes, minor re-grading and use of erosion control blankets to re-vegetate eroded areas.
Golder 2003 Geotechnical and Slope Stability Assessment 130th Ave and Mount Douglas Point	0+900 to 1+725	Reviewed aerial photographs and recorded field observations. Identified areas of slope failures/retrogression and factors associated with slope retrogression, including surface gradient, soil conations, vegetation cover, groundwater, drainage, and potential of toe erosion. Slope stability analyses to evaluate stability of slope and to better understand the associated instability mechanisms. Recommended a review of the storm sewer collection/ drainage system, regular slope monitoring, and installation of groundwater monitoring wells.
Golder 2006 Slope Stability Evaluation 130th Avenue and Mount Douglas Point Calgary	0+975 to 1+925	Geotechnical desk study including review of aerial photographs, and surficial and bedrock geology. Visual inspection of slope. Subsurface soil information collected in two boreholes, drilled to a maximum depth of 31.7 mbgs. Slope inclinometers and standpipes installed at each drill location. Slope stability analyses to calculate setback distances. Recommendations for passive and active slope stabilization options.
Golder 2006 Slope Stability Evaluation 323 Mt. Victoria Place	3+325 to 3+525	Geotechnical desk study including review of aerial photographs, and surficial and bedrock geology. Visual inspection of slope. Subsurface soil information collected in one borehole, drilled to of 22.6 mbgs. Slope inclinometer and standpipes installed at drill location. Slope stability analyses to calculate setback distances. Recommendations for slope stabilization options.

Table A2: Summary of Relevant Information from Geotechnical Reports

Report	Station	Relevant Information
Golder 2006 Slope Stability Evaluation 133 Mt. Alberta View	2+125 to 2+325	Geotechnical desk study including review of aerial photographs, and surficial and bedrock geology. Visual inspection of slope. Subsurface soil information collected in one borehole, drilled to of 37.9 mbgs. Slope inclinometer and standpipes installed at drill location. Slope stability analyses to calculate setback distances. Recommendations for slope stabilization options.
Golder 2006 Slope Monitoring Program Mt. Douglas Point, Mt. Alberta View, Mt. Victoria Place	0+000 to 3+525	Two site reconnaissance programs to inspect previous instabilities and identify significant signs of new slope movement, obtained readings from slope inclinometers and standpipes installed by Golder in 2005, recommended installation of additional slope inclinometer.
Golder 2007 Evaluation of Design Options to Protect the City of Calgary Pathway System Near 133 Mt. Alberta View	2+200 to 2+300	Provided design options and construction cost estimate to protect pathway in vicinity of 133 Mt. Alberta View. Options included “do nothing”, MSE wall and anchored caisson wall. Subsurface information collected in three boreholes, drilled to a maximum depth of 16.4 mbgs. Standpipes installed in all holes.
Golder 2007 Slope Monitoring Program Mt. Douglas Point, Mt. Alberta View, Mt. Victoria Place	0+000 to 3+525	Site reconnaissance program to inspect previous instabilities and identify significant signs of new slope movement, obtained readings from slope inclinometers and standpipes installed by Golder in 2005, summarized remedial measures taken to date, recommended regular monitoring.
Golder 2008 Pathway Setback Study North of 133 Mt. Alberta View	1+925 to 2+125	Site reconnaissance to observe slope conditions, Subsurface soil information collected in one borehole, drilled to of 19.8 mbgs. Standpipes installed at drill location. Slope stability analyses to calculate setback distances. Recommended pathway relocation.
Golder 2008 Slope Stability Evaluation 233 Douglas Park Boulevard	0+200 to 0+625	Review available background information. Site reconnaissance to observe slope conditions. Subsurface soil information collected in one borehole, drilled to of 24.4 mbgs. Slope inclinometer and standpipes installed at drill location. Slope stability analyses to calculate setback distances. Recommendations for slope stabilization options.
Golder 2008 Geotechnical Instrumentation Monitoring (Slope Inclinometers and Piezometers) in the Douglasdale Area	0+000 to 3+525	Monitoring slope inclinometers and piezometers installed by Golder from 2005 to 2008. Recommended regular monitoring.
Golder 2009 Slope Stability Studies and Pathway Remediation Options Douglasdale Escarpment Regional Pathway	0+675 to 1+025	Review available background information. Site reconnaissance to observe slope conditions. Subsurface soil information collected in three boreholes, drilled to a maximum depth of 18.6 mbgs. One direct shear strength test performed. Slope stability analyses. Options and construction costing for slope stabilization including slope regrading, MSE wall and anchored caisson wall.
Golder 2009 Construction Report Mt. Alberta View Pathway Protection Project	2+200 to 2+300	Detailed construction information on Mt. Alberta View caisson wall installation. Two slope inclinometers installed at wall.

Table A2: Summary of Relevant Information from Geotechnical Reports

Report	Station	Relevant Information
Golder 2010 Slope Monitoring Program From Douglas Park Blvd. to Mt. Victoria Place	0+000 to 3+525	Site reconnaissance program to inspect previous instabilities and identify significant signs of new slope movement. Obtained readings from slope inclinometers and standpipes installed by Golder from 2005 to 2008, recommended regular monitoring.
Golder 2011 Slope Monitoring Program From Douglas Park Blvd. to Mt. Victoria Place	0+000 to 3+525	Site reconnaissance program to inspect previous instabilities and identify significant signs of new slope movement. Obtained readings from slope inclinometers and standpipes installed by Golder from 2005 to 2008, recommended regular monitoring.
Golder 2012 Slope Monitoring Program From Douglas Park Blvd. to Mt. Victoria Place	0+000 to 3+525	Site reconnaissance program to inspect previous instabilities and identify significant signs of new slope movement. Obtained readings from slope inclinometers and standpipes installed by Golder from 2005 to 2008, recommended regular monitoring.
Golder 2013 Slope Monitoring Program From Douglas Park Blvd. to Mt. Victoria Place	0+000 to 3+525	Site reconnaissance program to inspect previous instabilities and identify significant signs of new slope movement. Obtained readings from slope inclinometers and standpipes installed by Golder from 2005 to 2008, recommended regular monitoring and inventory of sewer and underground pipe infrastructure.
EBA 2014 Slope Stability Assessment Portion of Bow River Pathway Mt. Alberta View	2+300 to 2+475	Review of available background information. Site reconnaissance to observe slope conditions. Subsurface soil information collected in four boreholes, drilled to a maximum depth of 45.1 mbgs. Four CPT locations, pushed to a maximum depth of 6.8 mbgs. Geophysical borehole logging and electrical resistivity. One direct shear strength test performed. Slope stability analyses. Options and construction costing for slope stabilization including short term options of MSE walls, cement columns, shallow piles or pathway relocation and long term option of a deep pile wall.
Golder 2014 Slope Monitoring Program From Douglas Park Blvd. to Mt. Victoria Place	0+000 to 3+525	Site reconnaissance program to inspect previous instabilities and identify significant signs of new slope movement. Obtained readings from slope inclinometers and standpipes installed by Golder from 2005 to 2008, classified slope instability areas, recommended regular monitoring, inventory of sewer and underground pipe infrastructure, updating topographic maps and bathymetric surveys in Site, and a study to asses long-term use of pathway.

APPENDIX B

Geotechnical Investigation Methodology (2015)
Golder Associates Soil Classification System
List of Symbols
Record of Borehole Sheets
Laboratory Test Results (2015)
Slope Inclinometer Readings (2015)

MARCH 2015 GEOTECHNICAL INVESTIGATION

Golder Associates Ltd. (Golder) was retained by the City of Calgary (the City) to carry out a geotechnical drilling program and installation of two slope inclinometers (SI) as part of the Bow River Regional Pathway Feasibility Study in the Douglasdale and Mt. Alberta View area in Southeast Calgary, Alberta.

Borehole Drilling Program

A geotechnical drilling investigation was carried out from March 2 to March 5, 2015. A total of three boreholes were drilled near the crest of the slope on the east bank of the Bow River in the Douglasdale and Mt. Alberta View area. Boreholes BH15-01, BH15-01A (Location 1) and BH15-02 (Location 2) are identified on Figure 4 and Figure 6, respectively.

Alberta One-Call tickets were initiated for each drilling location. Prior to the commencement of drilling, underground utilities were located by Alberta One-Call and a private utility locating contractor who was sub-contracted to Golder. Boreholes were then drilled with a track-mounted resonant sonic drill rig operated by Mobile Augers and Research Ltd. (Mobile Augers) from Edmonton, Alberta.

Boreholes BH15-01 and BH15-02 were advanced to 24.4 mbgs and 22.9 mbgs, respectively. Borehole BH15-01A was located approximately 2 m south of borehole BH15-01. It was advanced to 2.7 mbgs to obtain supplemental information due to poor soil recovery between 1.5 to 3 mbgs in Borehole BH15-01.

Drilling was supervised by a member of Golder's geotechnical engineering staff who visually observed and logged in detail the soil conditions encountered. Undisturbed Shelby Tube samples were collected and in-situ Standard Penetration Testing (SPT) was carried out at regular depth intervals. Soil samples were collected from the material recovered in the core barrel and 50 mm SPT split spoon sampler.

Upon completion of drilling, the SIs were installed in Boreholes BH15-01 and BH15-02. Detailed descriptions of the subsurface conditions encountered and the SI installations in the boreholes are presented in the Record of Borehole Sheets within this appendix.

All soil and bedrock cores were transported in cardboard core boxes to Golder's Calgary geotechnical laboratory.

Laboratory Testing

Following the field program, all soil samples were sent to Golder's geotechnical laboratory in Calgary for further examination, classification and laboratory testing. The laboratory testing program included water content determination and Atterberg Limits testing.

Testing was completed by Golder's Calgary geotechnical laboratory. All tests were carried out following applicable CSA/ASTM procedures.

Detailed laboratory testing results are presented within this appendix. A summary of the results are provided on the Record of Borehole Sheets.

Slope Inclinometer Installation

Boreholes BH15-01 and BH15-02 were completed with flush mounted road boxes so that no protrusions exist above ground surface. SI casing was installed inside the flush mounted road boxes.

85 mm SI casing was installed in Borehole BH15-01 to 24.28 mbgs and in Borehole BH15-02 to 22.86 mbgs. Both casings were oriented parallel with the downslope direction. Each SI casing was fully grouted in place with a grout mixture of approximately 115 L, 80 kg cement and 40 kg bentonite gel. The grout was mixed and installed by Mobile Augers.

Baseline SI data was collected for both SIs on March 7, 2015. Subsequent readings of each SI were carried out on April 27, 2015. The SI data plots are presented in this appendix. This data will be used as a reference for future readings.

Subsurface Conditions

Detailed descriptions of the subsurface conditions encountered in each borehole are presented on the Record of Borehole Sheets. The soil and bedrock descriptions provided in this report are based on accepted standard methods of classification and identification routinely used in current geotechnical state-of-practice.

The stratigraphic boundaries shown on the Record of Borehole Sheets were inferred from non-continuous sampling, observations of drilling progress, SPT N-values, and observations of ground exposures within the slope failure area. These boundaries typically represent transitions between soil and bedrock types rather than exact planes of geological change. Subsurface conditions vary both with depth and laterally across the site. The following is a summary of the subsurface conditions encountered during this geotechnical investigation.

Location 1 (Boreholes BH15-01 and BH15-01A)

In general, the subsurface conditions encountered during drilling of boreholes BH15-01 and BH15-01A consisted of brown becoming grey, firm becoming hard, low to medium plastic, silty clay till to a depth of 10.2 mbgs.

The till contained trace to some sand, trace gravel and trace coal. The silty clay till was underlain by a fluvial gravel deposit to 13.6 mbgs. Up to 50% (by volume) cobbles were observed in this layer.

The fluvial deposit was underlain by extremely weak to medium strong, weathered, interbedded sedimentary bedrock consisting of claystone, siltstone and sandstone.

Location 2 (Borehole BH15-02)

In general, the subsurface conditions encountered during drilling of borehole BH15-02 consisted of brown, stiff becoming hard, medium plastic, silty clay till to a depth of 11.3 mbgs. The till contained varying amounts of sand, trace gravel, and trace coal.

The silty clay till was underlain by a grey, hard, silt with some plastic fines and some sand to 13.65 mbgs. Underlying the silt were three thin layers of gravel, silty clay till and clayey silt, respectively, to 14.3 mbgs.

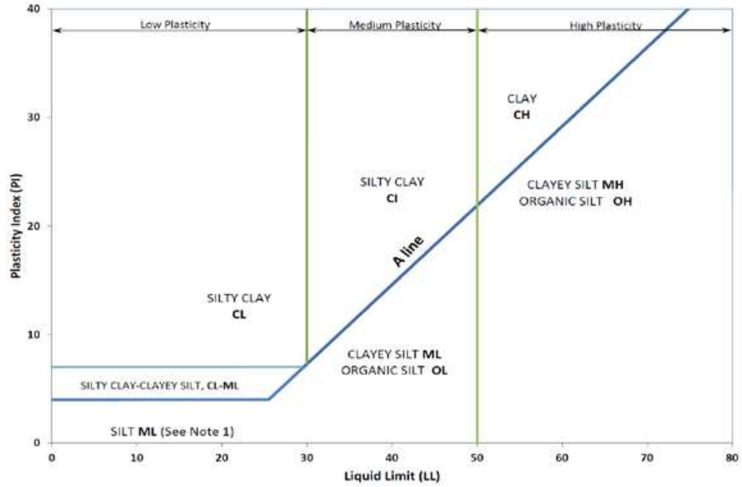
The overburden was underlain by extremely weak to medium strong, weathered, interbedded sedimentary bedrock consisting of claystone, siltstone and sandstone.

METHOD OF SOIL CLASSIFICATION

The Golder Associates Ltd. Soil Classification System is based on the Unified Soil Classification System (USCS)

Organic or Inorganic	Soil Group	Type of Soil		Gradation or Plasticity	$Cu = \frac{D_{60}}{D_{10}}$	$Cc = \frac{(D_{30})^2}{D_{10} x D_{60}}$	Organic Content	USCS Group Symbol	Group Name
INORGANIC (Organic Content ≤30% by mass)	COARSE-GRAINED SOILS (>50% by mass is larger than 0.075 mm)	GRAVELS (>50% by mass of coarse fraction is larger than 4.75 mm)	Gravels with ≤12% fines (by mass)	Poorly Graded	<4	≤1 or ≥3	≤30%	GP	GRAVEL
				Well Graded	≥4	1 to 3		GW	GRAVEL
			Gravels with >12% fines (by mass)	Below A Line	n/a			GM	SILTY GRAVEL
				Above A Line	n/a			GC	CLAYEY GRAVEL
		SANDS (≥50% by mass of coarse fraction is smaller than 4.75 mm)	Sands with ≤12% fines (by mass)	Poorly Graded	<6	≤1 or ≥3		SP	SAND
				Well Graded	≥6	1 to 3		SW	SAND
			Sands with >12% fines (by mass)	Below A Line	n/a			SM	SILTY SAND
				Above A Line	n/a			SC	CLAYEY SAND

Organic or Inorganic	Soil Group	Type of Soil	Laboratory Tests	Field Indicators					Organic Content	USCS Group Symbol	Primary Name
				Dilatancy	Dry Strength	Shine Test	Thread Diameter	Toughness (of 3 mm thread)			
INORGANIC (Organic Content ≤30% by mass)	FINE-GRAINED SOILS (≥50% by mass is smaller than 0.075 mm)	SILTS (Non-Plastic or PI and LL plot below A-Line on Plasticity Chart below)	Liquid Limit <50	Rapid	None	None	>6 mm	N/A (can't roll 3 mm thread)	<5%	ML	SILT
				Slow	None to Low	Dull	3mm to 6 mm	None to low	<5%	ML	CLAYEY SILT
				Slow to very slow	Low to medium	Dull to slight	3mm to 6 mm	Low	5% to 30%	OL	ORGANIC SILT
			Liquid Limit ≥50	Slow to very slow	Low to medium	Slight	3mm to 6 mm	Low to medium	<5%	MH	CLAYEY SILT
				None	Medium to high	Dull to slight	1 mm to 3 mm	Medium to high	5% to 30%	OH	ORGANIC SILT
		CLAYS (PI and LL plot above A-Line on Plasticity Chart below)	Liquid Limit <30	None	Low to medium	Slight to shiny	~ 3 mm	Low to medium	0% to 30% **(see Note 2)**	CL	SILTY CLAY
			Liquid Limit 30 to 50	None	Medium to high	Slight to shiny	1 mm to 3 mm	Medium		CI	SILTY CLAY
			Liquid Limit ≥50	None	High	Shiny	<1 mm	High		CH	CLAY
HIGHLY ORGANIC SOILS (Organic Content >30% by mass)		Peat and mineral soil mixtures							30% to 75%	PT	SILTY PEAT, SANDY PEAT
		Predominantly peat, may contain some mineral soil, fibrous or amorphous peat							75% to 100%		PEAT



Note 1 – Fine grained materials with PI and LL that plot in this area are named (ML) SILT with slight plasticity. Fine-grained materials which are non-plastic (i.e. a PL cannot be measured) are named SILT.

Note 2 – For soils with <5% organic content, include the descriptor "trace organics" for soils with between 5% and 30% organic content include the prefix "organic" before the Primary name.

Dual Symbol — A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC and CL-ML.
For non-cohesive soils, the dual symbols must be used when the soil has between 5% and 12% fines (i.e. to identify transitional material between "clean" and "dirty" sand or gravel.
For cohesive soils, the dual symbol must be used when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart (see Plasticity Chart at left).

Borderline Symbol — A borderline symbol is two symbols separated by a slash, for example, CL/CI, GM/SM, CL/ML.
A borderline symbol should be used to indicate that the soil has been identified as having properties that are on the transition between similar materials. In addition, a borderline symbol may be used to ~~or~~ indicate~~s~~ a range of similar soil types within a stratum.

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>300	>12
COBBLES	Not Applicable	75 to 300	3 to 12
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
SILT/CLAY	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY AND MINOR CONSTITUENTS

Percentage by Mass	Modifier
>35	Use 'and' to combine major constituents (*i.e.,* SAND and GRAVEL, SAND and CLAY)
> 12 to 35	Primary soil name prefixed with "gravelly, sandy, SILTY, CLAYEY" as applicable
> 5 to 12	some
≤ 5	trace

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.).

Cone Penetration Test (CPT)

An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q_t), porewater pressure (u) and sleeve frictions are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); N_d:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH:	Sampler advanced by hydraulic pressure
PM:	Sampler advanced by manual pressure
WH:	Sampler advanced by static weight of hammer
WR:	Sampler advanced by weight of sampler and rod

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size
TP	Thin-walled, piston – note size
WS	Wash sample

SOIL TESTS

w	water content
PL , w_p	plastic limit
LL , w_L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, Gs)
DS	direct shear test
GS	specific gravity
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
γ	unit weight

1. Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

NON-COHESIVE (COHESIONLESS) SOILS

Compactness[2]

Term	SPT 'N' (blows/0.3m)[1]
Very Loose	0 - 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	>50

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects.
2. Definition of compactness descriptions based on SPT 'N' ranges from Terzaghi and Peck (1967) and correspond to typical average N_{60} values.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

COHESIVE SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N'[1] (blows/0.3m)
Very Soft	<12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	>200	>30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.

Water Content

Term	Description
w < PL	Material is estimated to be drier than the Plastic Limit.
w ~ PL	Material is estimated to be close to the Plastic Limit.
w > PL	Material is estimated to be wetter than the Plastic Limit.

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
ln x	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\,\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_3	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index $= (w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index $= (w - w_p) / I_p$
I_C	consistency index $= (w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index $= (e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
c_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio $= \sigma'_p / \sigma'_{vo}$

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction $= \tan\delta$
c′	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p′	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes: 1 $\tau = c' + \sigma' \tan\phi'$
2 shear strength = (compressive strength)/2

PEC2020-0510
ATTACHMENT 2

DATA ENTRY: AW

PROJECT No.: 1113210003.2200

RECORD OF BOREHOLE: BH15-01

SHEET 1 OF 3

LOCATION: See Location Plan

N: 5646589 E: 289899

BORING DATE: 02-04 March, 2015

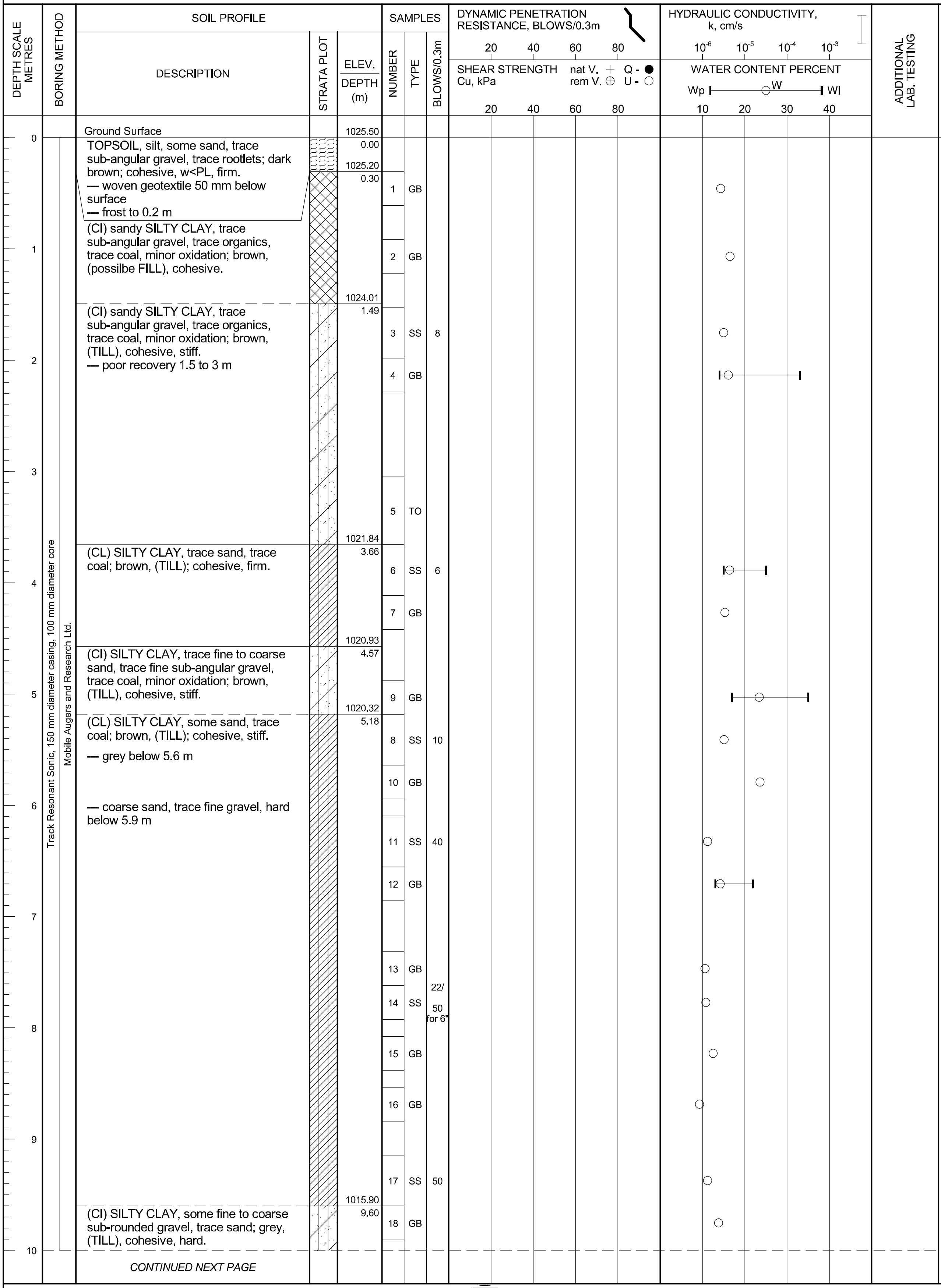
DATUM: NAD 83 UTM
Zone 12

BORING METHOD: Track Resonant Sonic, 150 mm diameter casing, 100 mm diameter core
Mobile Augers and Research Ltd.

SOIL PROFILE – DESCRIPTION	ELEV. / DEPTH (m)
Ground Surface	1025.50
TOPSOIL, silt, some sand, trace sub-angular gravel, trace rootlets; dark brown; cohesive, w<PL, firm. --- woven geotextile 50 mm below surface --- frost to 0.2 m	0.00
(CI) sandy SILTY CLAY, trace sub-angular gravel, trace organics, trace coal, minor oxidation; brown, (possilbe FILL), cohesive.	1025.20 0.30
(CI) sandy SILTY CLAY, trace sub-angular gravel, trace organics, trace coal, minor oxidation; brown, (TILL), cohesive, stiff. --- poor recovery 1.5 to 3 m	1024.01 1.49
(CL) SILTY CLAY, trace sand, trace coal; brown, (TILL); cohesive, firm.	1021.84 3.66
(CI) SILTY CLAY, trace fine to coarse sand, trace fine sub-angular gravel, trace coal, minor oxidation; brown, (TILL), cohesive, stiff.	1020.93 4.57
(CL) SILTY CLAY, some sand, trace coal; brown, (TILL); cohesive, stiff. --- grey below 5.6 m --- coarse sand, trace fine gravel, hard below 5.9 m	1020.32 5.18
(CI) SILTY CLAY, some fine to coarse sub-rounded gravel, trace sand; grey, (TILL), cohesive, hard.	1015.90 9.60

CONTINUED NEXT PAGE

SAMPLES NUMBER	TYPE	BLOWS/0.3m
1	GB	
2	GB	
3	SS	8
4	GB	
5	TO	
6	SS	6
7	GB	
9	GB	
8	SS	10
10	GB	
11	SS	40
12	GB	
13	GB	
14	SS	22/ 50 for 6"
15	GB	
16	GB	
17	SS	50
18	GB	



SLOPE INCLINOMETER INSTALLATION
Sand
Bentonite Chips
Grout

DEPTH SCALE
1 : 50

ISC: UNRESTRICTED

Golder Associates

LOGGED: AW
CHECKED: RC

BOREHOLE - EXPANDED ADD. LAB TESTING DDALE MARCH 2015.GPJ CALGARY.GDT 7/31/15

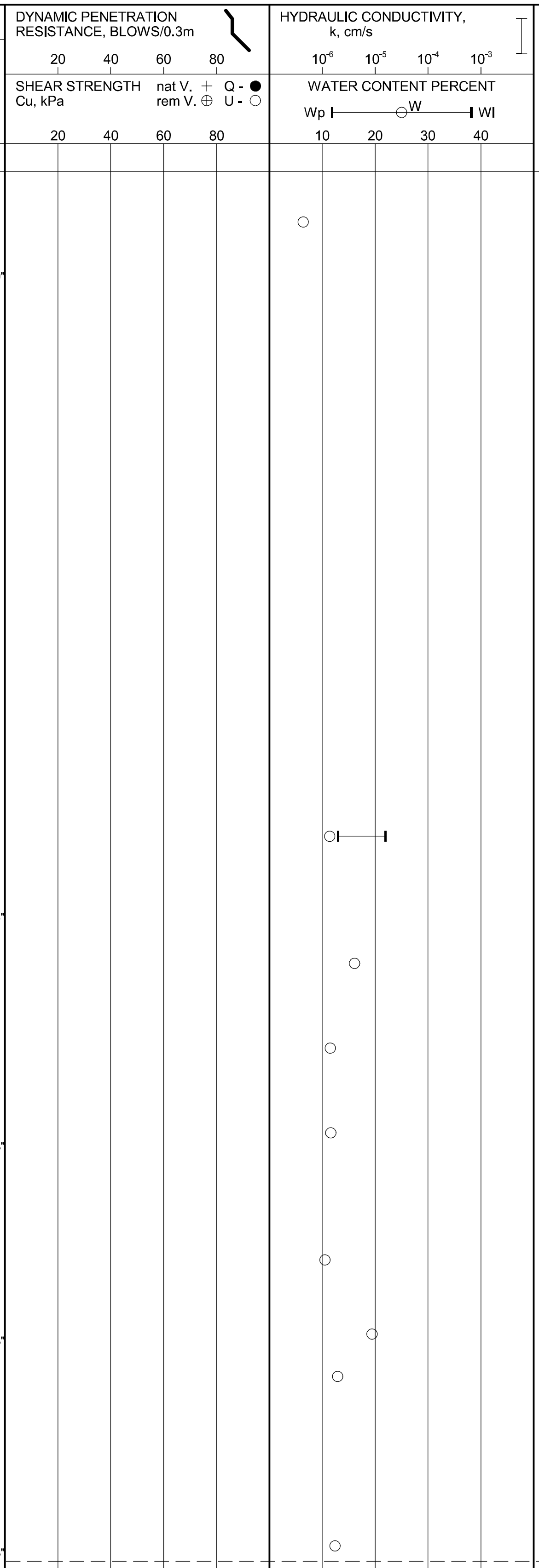
RECORD OF BOREHOLE: BH15-01

PROJECT No.: 1113210003.2200
LOCATION: See Location Plan
N: 5646589 E: 289899
BORING DATE: 02-04 March, 2015
SHEET 2 OF 3
DATUM: NAD 83 UTM Zone 12

BORING METHOD: Track Resonant Sonic, 150 mm diameter casing, 100 mm diameter core
Mobile Augers and Research Ltd.

ELEV. / DEPTH (m)	SOIL PROFILE – DESCRIPTION
1015.29 10.21	(GP) GRAVEL, fine to coarse sub-rounded gravel, grey, non-cohesive, very dense, with COBBLES (~50% by volume). --- very poor recovery 10.7 to 13.6 m. Cobbles up to 100 mm diameter recovered between 11.7 and 13.6 m. Gravel size pieces recovered have fresh fracture faces; broken cobbles inferred.
1011.94 13.56	Medium strong, grey, highly weathered SANDSTONE (BOULDER).
1011.48 14.02	(SM) SILTY SAND; grey; non-cohesive, dense.
1011.02 14.48	Extremely weak, grey, residual soil CLAYSTONE.
1010.26	Medium strong, grey, highly weathered SANDSTONE.
15.39	Extremely weak, grey, completely weathered CLAYSTONE. --- becomes highly weathered, very weak below 18.2 m

NUMBER	TYPE	BLOWS/0.3m
19	GB	
20	SS	50 for 0"
21	GB	
22	GB	
23	GB	
24	SS	50 for 4"
25	GB	
26	GB	
27	SS	31/ 50 for 3"
28	GB	
29	SS	50 for 3"
30	GB	
31	SS	50 for 3"



ADDITIONAL LAB. TESTING

SLOPE INCLINOMETER INSTALLATION: Grout

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50
ISC: UNRESTRICTED

LOGGED: AW
CHECKED: RC

DATA ENTRY: AW

PROJECT No.: 1113210003.2200

RECORD OF BOREHOLE: BH15-01

SHEET 3 OF 3

LOCATION: See Location Plan

N: 5646589 E: 289899

BORING DATE: 02-04 March, 2015

DATUM: NAD 83 UTM
Zone 12

SOIL PROFILE | SAMPLES

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 10 20 30 40

ADDITIONAL LAB. TESTING

BORING METHOD: Track Resonant Sonic, 150 mm diameter casing, 100 mm diameter core — Mobile Augers and Research Ltd.

DEPTH SCALE METRES	DESCRIPTION	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	SLOPE INCLINOMETER INSTALLATION
20	Extremely weak, grey, completely weathered CLAYSTONE. *(continued)*		32	GB		
21			33	SS	11/ 50 for 6"	
22			36	GB		Grout
	Extremely weak, grey, highly weathered CLAYSTONE interbedded with weak, grey, moderately weathered SILTSTONE of varying thickness.	1002.64 22.86				
23			35	GB		
24			38	GB		
	Medium strong, grey, moderately weathered SANDSTONE.	1001.27 24.23	37	SS	50 for 4"	
	End of BOREHOLE. 85 mm slope inclinometer installed to 24.3 m. Backfilled with grout, bentonite and sand. Flush mount protective road box installed at surface. All cuttings removed from site. Location data obtained with hand-held GPS with +/- 5 m accuracy.	1000.97 24.54				
25						
26						
27						
28						
29						
30						

BOREHOLE - EXPANDED ADD. LAB TESTING DDALE MARCH 2015.GPJ CALGARY.GDT 7/31/15

DEPTH SCALE
1 : 50

ISC: UNRESTRICTED

Golder Associates

LOGGED: AW
CHECKED: RC

DATA ENTRY: AW

PROJECT No.: 1113210003.2200

RECORD OF BOREHOLE: BH15-01A

SHEET 1 OF 1

LOCATION: See Location Plan

N: 5646590 E: 289898

BORING DATE: March 4, 2015

DATUM: NAD 83 UTM
Zone 12

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 10 20 30 40	ADDITIONAL LAB. TESTING	SLOPE INCLINOMETER INSTALLATION
		Ground Surface		1025.50							
0	Track Resonant Sonic, 100 mm diameter core Mobile Augers and Research Ltd.	TOPSOIL, silt, some sand, trace sub-angular gravel, trace rootlets; dark brown; cohesive, w<PL.		0.15							
1		(CI) SILTY CLAY, some sand, trace gravel, trace coal, trace organics, minor oxidation; brown, (possible FILL); cohesive, w~PL, firm. --- wood piece at 1.2 m		1024.25 1.25							
2		(CI) SILTY CLAY, some sand, trace gravel, trace coal, trace organics, minor oxidation; brown, (TILL); cohesive, w~PL, stiff.			1	TO					
				1022.76 2.74							
3		End of BOREHOLE. Backfilled with grout and bentonite chips to surface. All cuttings removed from site. Location data obtained with hand-held GPS with +/- 5 m accuracy.									
4											
5											
6											
7											
8											
9											
10											

BOREHOLE - EXPANDED ADD. LAB TESTING DDALE MARCH 2015.GPJ CALGARY.GDT 7/31/15

DEPTH SCALE
1 : 50

ISC: UNRESTRICTED

Golder Associates

LOGGED: AW
CHECKED: RC

DATA ENTRY: AW

PROJECT No.: 1113210003.2200

RECORD OF BOREHOLE: BH15-02

SHEET 1 OF 3

LOCATION: See Location Plan

N: 5644996 E: 289911

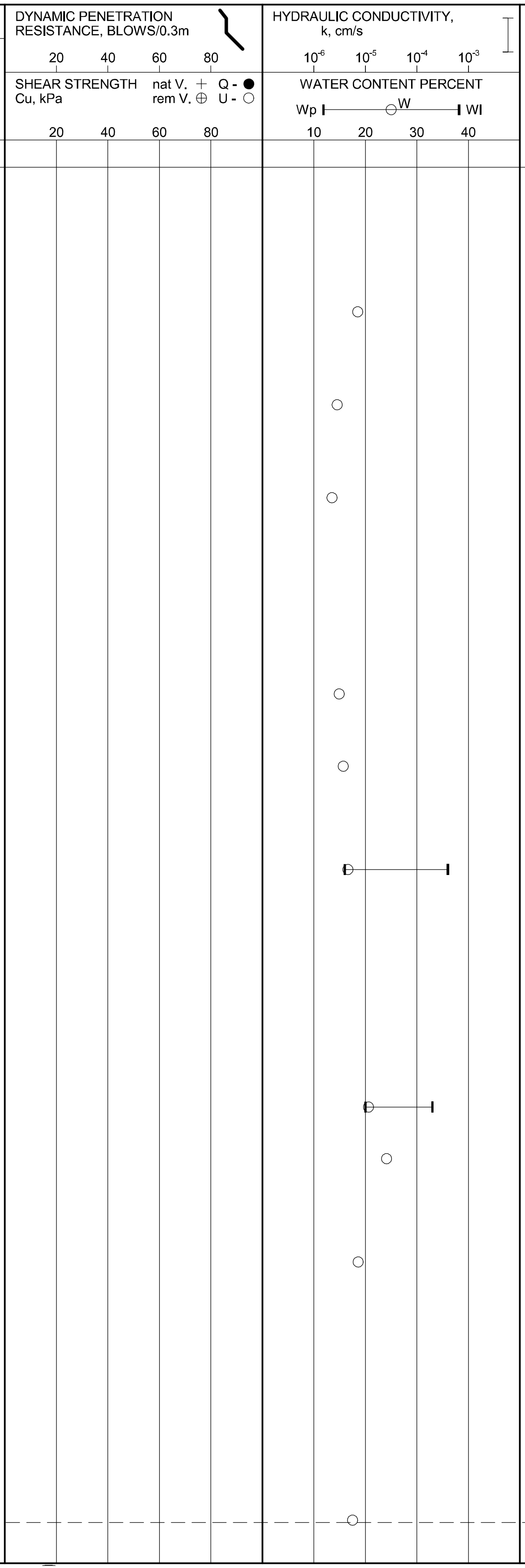
BORING DATE: 05-06 March, 2015

DATUM: NAD 83 UTM
Zone 12

BORING METHOD: Track Resonant Sonic, 150 mm diameter casing, 100 mm diameter core
Mobile Augers and Research Ltd.

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
	Ground Surface	1034.00
0	TOPSOIL, silt. some sand, trace sub-angular gravel, trace rootlets; dark brown, (TOPSOIL); cohesive, w<PL. --- frozen to 0.18 m	0.00
	(CI) sandy SILTY CLAY, trace sub-angular gravel, trace organics, trace coal, minor oxidation; brown, (TILL), cohesive, stiff becoming hard. --- coal pockets, oxidized sand pockets and fine sand partings below 1.5 m --- trace coarse sub-rounded gravel below 4.3 m --- hard below 6.7 m	1033.24 0.76
10	*CONTINUED NEXT PAGE*	

SAMPLES NUMBER	TYPE	BLOWS/0.3m
1	GB	
2	SS	23
3	GB	
4	TO	
5	SS	19
6	GB	
7	GB	
8	TO	
9	SS	31
10	GB	
11	GB	
12	TO	
13	SS	46



ADDITIONAL LAB. TESTING

SLOPE INCLINOMETER INSTALLATION

- Sand
- Bentonite Chips
- Grout

DEPTH SCALE
1 : 50

ISC: UNRESTRICTED

Golder Associates

LOGGED: AW
CHECKED: RC

BOREHOLE - EXPANDED ADD. LAB TESTING DDALE MARCH 2015.GPJ CALGARY.GDT 7/31/15

PFC2020-0510
ATTACHMENT 2

DATA ENTRY: AW

PROJECT No.: 1113210003.2200

RECORD OF BOREHOLE: BH15-02

SHEET 2 OF 3

LOCATION: See Location Plan

N: 5644996 E: 289911

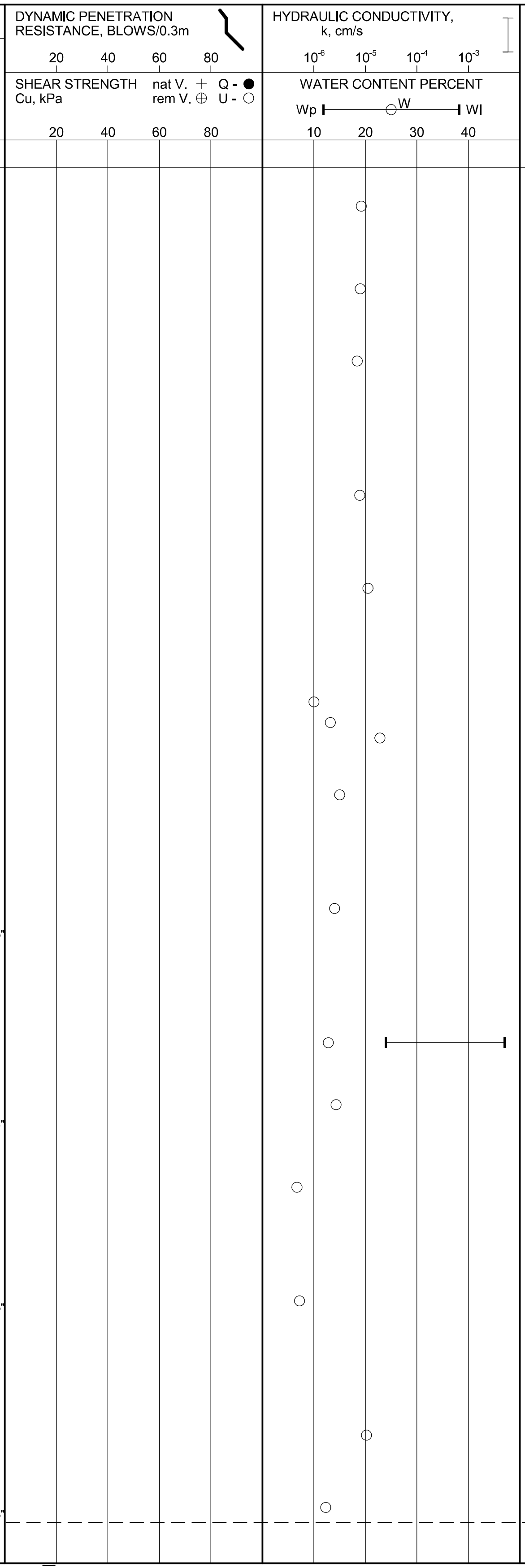
BORING DATE: 05-06 March, 2015

DATUM: NAD 83 UTM
Zone 12

BORING METHOD: Track Resonant Sonic, 150 mm diameter casing, 100 mm diameter core
Mobile Augers and Research Ltd.

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
10	(CI) sandy SILTY CLAY, trace sub-angular gravel, trace organics, trace coal, minor oxidation; brown, (TILL), cohesive, stiff becoming hard. *(continued)*	
	(ML) SILT, some sand, some plastic fines, minor oxidation; brown; cohesive, hard.	1022.72 11.28
	(GP) GRAVEL, fine to coarse grained, some sand, some plastic fines; brown; non-cohesive, very dense.	1020.35 13.72
	(CI) sandy SILTY CLAY, trace coal, trace sub-angular gravel; brown, (TILL); cohesive, hard	
	(ML) CLAYEY SILT; brown; cohesive, hard.	1019.83 14.33
	Extremely weak, grey, completely weathered, CLAYSTONE. --- 2 cm coal seam at 15.2 m --- several sandstone pieces up to 10 mm at 18.1 m	
20	*CONTINUED NEXT PAGE*	

NUMBER	TYPE	BLOWS/0.3m
13	SS	46
14	GB	
15	SS	53
16	GB	
17	SS	55
18	GB	
19	SS	60
20	GB	
21	GB	
22	GB	
23	SS	14/ 30/ 50 for 5"
24	GB	
25	SS	30/ 50 for 4"
26	GB	
27	SS	50 for 5"
28	GB	
29	SS	50 for 3"



ADDITIONAL LAB. TESTING

SLOPE INCLINOMETER INSTALLATION

Grout

BOREHOLE - EXPANDED ADD. LAB TESTING DDALE MARCH 2015.GPJ CALGARY.GDT 7/31/15

DEPTH SCALE
1ISO: UNRESTRICTED

Golder Associates

LOGGED: AW
CHECKED: RC

DATA ENTRY: AW

PROJECT No.: 1113210003.2200

RECORD OF BOREHOLE: BH15-02

SHEET 3 OF 3

LOCATION: See Location Plan

N: 5644996 E: 289911

BORING DATE: 05-06 March, 2015

DATUM: NAD 83 UTM
Zone 12

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80); SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}); WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl (10 20 30 40)	ADDITIONAL LAB. TESTING	SLOPE INCLINOMETER INSTALLATION
20	Track Resonant Sonic, 150 mm diameter casing, 100 mm diameter core Mobile Augers and Research Ltd.			1013.88							
		Medium strong, grey, moderately weathered SANDSTONE		20.12	30	GB			○		
		Extremely weak to very weak, grey, highly weathered, CLAYSTONE		1013.27 20.73							
21					31	GB			○		
		--- shells at 21.3 m			32	SS	43/ 50 for 3"		○		Grout
		Extremely to very weak, grey, completely weathered SILTSTONE		1012.21 21.79							
22					33	GB			○		
		End of BOREHOLE.		1011.14 22.86							
23											
		85 mm slope inclinometer installed to 22.9 m. Backfilled with grout, bentonite and sand. Flush mount protective road box installed at surface. All cuttings removed from site. Location data obtained with hand-held GPS with +/- 5 m accuracy.									
24											
25											
26											
27											
28											
29											
30											

BOREHOLE - EXPANDED ADD. LAB TESTING DDALE MARCH 2015.GPJ CALGARY.GDT 7/31/15

DEPTH SCALE
1 : 50

ISC: UNRESTRICTED

Golder Associates

LOGGED: AW
CHECKED: RC

Golder Associates

General Lab Testing Summary

Project No.: 11-1321-0003
Short Title: City of Calgary/Slope Stability/Douglasdale Feasibility
Tested By: DS

Phase: 2200
Sched: B422
Date: 18-Mar-15

Sample Identification					Laboratory Test Results						
Borehole No.	Sample No.	Depth (m)		Lab No.	Water Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index	Passing 75 µm (%)	SPMDD (kg/m³)	Optimum w (%)
		from	to								
BH15-01	GB-1	1.0	2.0	B422-01	14.3						
	GB-2	3.0	4.0	B422-02	16.5						
	SS-3	5.0	6.5	B422-03	15.0						
	GB-4	5.0	6.0	B422-04	16.1	33	14	19			
	TO-5	10.0	12.0	B422-05	-						
	SS-6	12.0	13.5	B422-06	16.4	25	15	10			
	GB-7	13.0	14.0	B422-07	15.3						
	GB-9	16.0	17.0	B422-08	23.4	35	17	18			
	SS-8	17.0	18.5	B422-09	15.1						
	GB-10	18.0	19.0	B422-10	23.6						
	SS-11	20.0	21.5	B422-11	11.2						
	GB-12	21.0	22.0	B422-12	14.2	22	13	9			
	GB-13	24.0	25.0	B422-13	10.6						
	SS-14	25.0	26.0	B422-14	10.8						
	GB-15	26.0	27.0	B422-15	12.5						
	GB-16	28.0	29.0	B422-16	9.3						
	SS-17	30.0	31.5	B422-17	11.2						
	GB-18	31.0	32.0	B422-18	13.8						
	GB-19	33.5	34.5	B422-19	6.4						
	SS-20	35.0	35.0	B422-20	-						
	GB-21	38.0	40.0	B422-21	-						
	GB-22	40.0	44.5	B422-22	-						

Reviewed By:

Golder Associates

General Lab Testing Summary

Project No.: 11-1321-0003
Short Title: City of Calgary/Slope Stability/Douglasdale Feasibility
Tested By: DS

Phase: 2200
Sched: B422
Date: 18-Mar-15

Sample Identification					Laboratory Test Results						
Borehole No.	Sample No.	Depth (m)		Lab No.	Water Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index	Passing 75 μm (%)	SPMDD (kg/m³)	Optimum w (%)
		from	to								
BH15-01	GB-23	48.0	49.0	B422-23	11.4	22	13	9			
	SS-24	50.0	50.5	B422-24	-						
	GB-25	51.0	52.0	B422-25	16.1						
	GB-26	53.0	54.0	B422-26	11.5						
	SS-27	55.0	56.0	B422-27	11.6						
	GB-28	58.0	59.0	B422-28	10.5						
	SS-29	60.0	60.5	B422-29	19.4						
	GB-30	61.0	61.5	B422-30	12.9						
	SS-31	65.0	65.5	B422-31	12.4						
	GB-32	66.0	67.0	B422-32	15.6						
	SS-33	70.0	71.0	B422-33	14.6						
	GB-36	74.0	74.5	B422-34	4.6						
	GB-35	75.5	76.0	B422-35	9.6						
	GB-38	79.0	80.0	B422-36	-						
	SS-37	80.0	80.5	B422-37	-						
BH15-01A	TO-1	7.0	9.0	B422-38	-						

Reviewed By:

Golder Associates

General Lab Testing Summary

Project No.:	11-1321-0003	Phase:	2200
Short Title:	City of Calgary/Slope Stability/Douglasdale Feasibility	Sched:	B422
Tested By:	DS	Date:	18-Mar-15

Sample Identification					Laboratory Test Results						
		Depth (m)									
Borehole No.	Sample No.	from	to	Lab No.	Water Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index	Passing 75 µm (%)	SPMDD (kg/m^3)	Optimum w (%)
BH15-02	GB-1	3.0	4.0	B422-39	18.5						
	SS-2	5.0	6.5	B422-40	14.5						
	GB-3	7.5	8.5	B422-41	13.5						
	TO-4	10.0	12.0	B422-42	-						
	SS-5	12.0	13.5	B422-43	14.9						
	GB-6	14.0	15.0	B422-44	15.7						
	GB-7	16.5	17.5	B422-45	16.6	36	16	20			
	TO-8	20.0	22.0	B422-46	-						
	SS-9	22.0	23.5	B422-47	20.6	33	20	13			
	GB-10	23.5	24.5	B422-48	24.1						
	GB-11	26.0	27.0	B422-49	18.6						
	TO-12	30.0	35.0	B422-50	-						
	SS-13	32.0	33.5	B422-51	17.5						
	GB-14	33.0	34.0	B422-52	19.2						
	SS-15	35.0	36.5	B422-53	19.0						
	GB-16	37.0	38.0	B422-54	18.4						

Reviewed By:__________________

General Lab Testing Summary

Project No.: 11-1321-0003
Short Title: City of Calgary/Slope Stability/Douglasdale Feasibility
Tested By: DS

Phase: 2200
Sched: B422
Date: 18-Mar-15

Sample Identification					Laboratory Test Results						
Borehole No.	Sample No.	Depth (m) from	Depth (m) to	Lab No.	Water Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index	Passing 75 μm (%)	SPMDD (kg/m^3)	Optimum w (%)
BH15-02	SS-17	40.0	41.5	B422-55	18.9						
	GB-18	42.5	43.5	B422-56	20.5	NP	NP	NP			
	SS-19	45.0	46.5	B422-57	10.0						
	GB-20	46.0	46.5	B422-58	13.2						
	GB-21	46.5	46.8	B422-59	22.8						
	GB-22	47.5	48.5	B422-60	15.0						
	SS-23	50.0	51.5	B422-61	14.0						
	GB-24	53.0	55.0	B422-62	12.8	47	24	23			
	SS-25	55.0	56.0	B422-63	14.3						
	GB-26	57.0	58.0	B422-64	6.7						
	SS-27	60.0	60.5	B422-65	7.2						
	GB-28	63.0	64.0	B422-66	20.2						
	SS-29	65.0	65.5	B422-67	12.3						
	GB-30	66.0	67.0	B422-68	3.8						
	GB-31	69.0	70.0	B422-69	14.5						
	SS-32	70.0	70.8	B422-70	14.0						
	GB-33	72.0	73.0	B422-71	12.9						

Reviewed By:

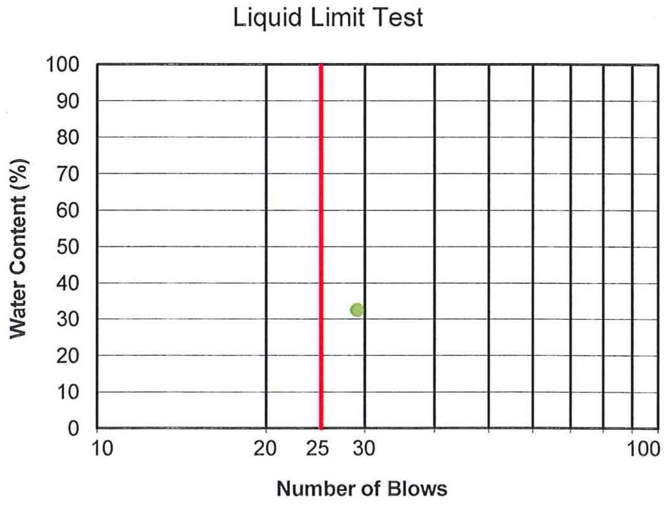
Golder Associates

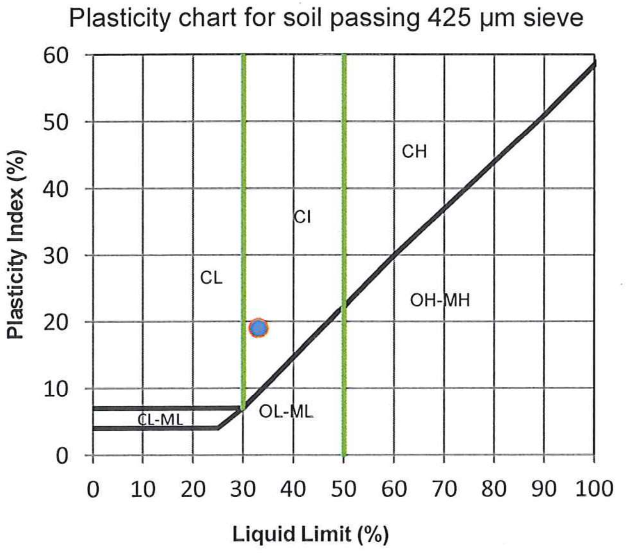
Atterberg Limits
(ASTM D 4318)

Project No.:	11-1321-0003	Phase:	2200
Short Title:	City of Calgary/Slope Stability/Douglasdale Feasibility	Lab No.:	B422-04
Tested By:	DS	Date:	18-Mar-15

Borehole: BH15-01 Sample No.: GB-4 Depth: 5.0 - 6.0 ft

Liquid Limit Determination:			Natural Water Content:		
Number of Blows	29	29	As Received Water Content (%)		16.1%
Blow Correction Factor	1.02	1.02	**Plastic Limit Determination:**		
Mass of wet sample + tare (g)	38.07	45.30	Mass of wet sample + tare (g)	21.86	19.75
Mass of dry sample + tare (g)	33.67	40.95	Mass of dry sample + tare (g)	20.52	18.61
Mass of tare (g)	20.18	27.63	Mass of tare (g)	11.10	10.61
Weight of Water (g)	4.4	4.35	Weight of Water (g)	1.34	1.14
Weight of dry soil (g)	13.49	13.32	Weight of dry soil (g)	9.42	8.00
Water Content (%)	32.6	32.7	Water Content (%)	14.23	14.25
Liquid Limit	33.0	33.0	Average Water Content (%)		14.24





Liquid Limit = 33 %
Plastic Limit = 14 %
Plasticity Index = 19

Comments:

Reviewed:

Golder Associates

Atterberg Limits (ASTM D 4318)

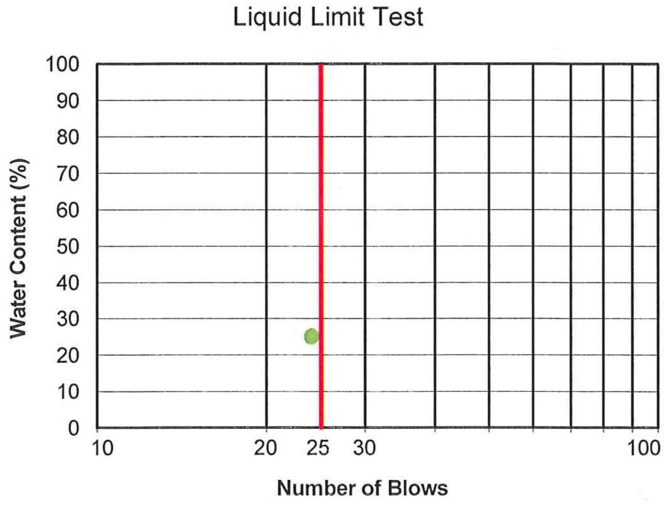
Project No.:	11-1321-0003	Phase:	2200
Short Title:	City of Calgary/Slope Stability/Douglasdale Feasibility	Lab No.:	B422-06
Tested By:	DS	Date:	18-Mar-15

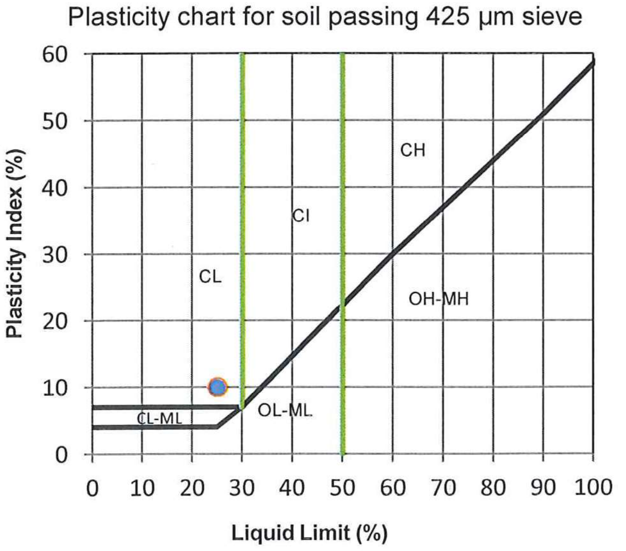
Borehole: BH15-01 Sample No.: SS-6 Depth: 12.0 - 13.5 ft

Liquid Limit Determination:		
Number of Blows	24	24
Blow Correction Factor	1.00	1.00
Mass of wet sample + tare (g)	41.53	32.05
Mass of dry sample + tare (g)	38.26	29.39
Mass of tare (g)	25.31	18.72
Weight of Water (g)	3.27	2.66
Weight of dry soil (g)	12.95	10.67
Water Content (%)	25.3	24.9
Liquid Limit	25.0	25.0

Natural Water Content:	
As Received Water Content (%)	16.4%

Plastic Limit Determination:		
Mass of wet sample + tare (g)	18.59	18.83
Mass of dry sample + tare (g)	17.57	17.74
Mass of tare (g)	10.72	10.40
Weight of Water (g)	1.02	1.09
Weight of dry soil (g)	6.85	7.34
Water Content (%)	14.89	14.85
Average Water Content (%)		14.87





Liquid Limit = 25 %
Plastic Limit = 15 %
Plasticity Index = 10

Comments: ______________________________

Reviewed: ______________

ISC: UNRESTRICTED

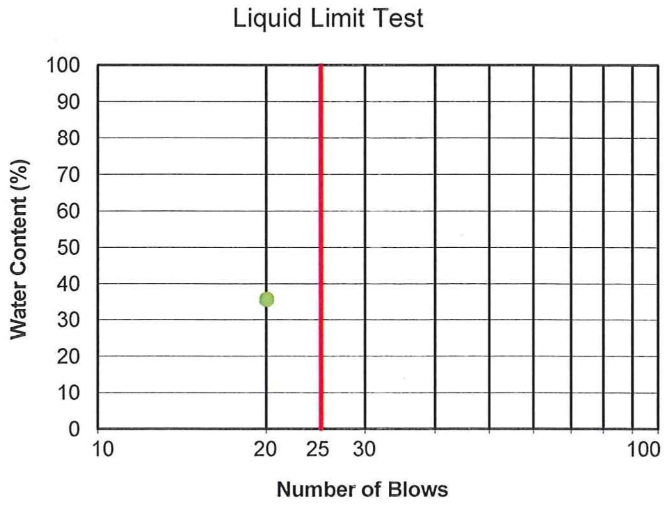
Golder Associates

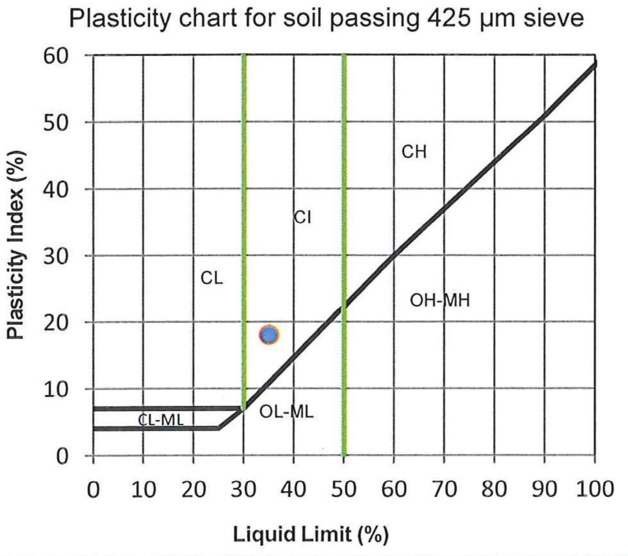
Atterberg Limits (ASTM D 4318)

Project No.:	11-1321-0003	Phase:	2200
Short Title:	City of Calgary/Slope Stability/Douglasdale Feasibility	Lab No.:	B422-08
Tested By:	DS	Date:	18-Mar-15

Borehole: BH15-01 Sample No.: GB-9 Depth: 16.0 - 17.0 ft

Liquid Limit Determination:			Natural Water Content:		
Number of Blows	20	20	As Received Water Content (%)	23.4%	
Blow Correction Factor	0.97	0.97	**Plastic Limit Determination:**		
Mass of wet sample + tare (g)	38.35	34.18	Mass of wet sample + tare (g)	19.83	19.02
Mass of dry sample + tare (g)	34.31	30.22	Mass of dry sample + tare (g)	18.46	17.79
Mass of tare (g)	23.05	19.14	Mass of tare (g)	10.29	10.49
Weight of Water (g)	4.04	3.96	Weight of Water (g)	1.37	1.23
Weight of dry soil (g)	11.26	11.08	Weight of dry soil (g)	8.17	7.30
Water Content (%)	35.9	35.7	Water Content (%)	16.77	16.85
Liquid Limit	35.0	35.0	Average Water Content (%)	16.81	





Liquid Limit = 35 %
Plastic Limit = 17 %
Plasticity Index = 18

Comments:

Reviewed:

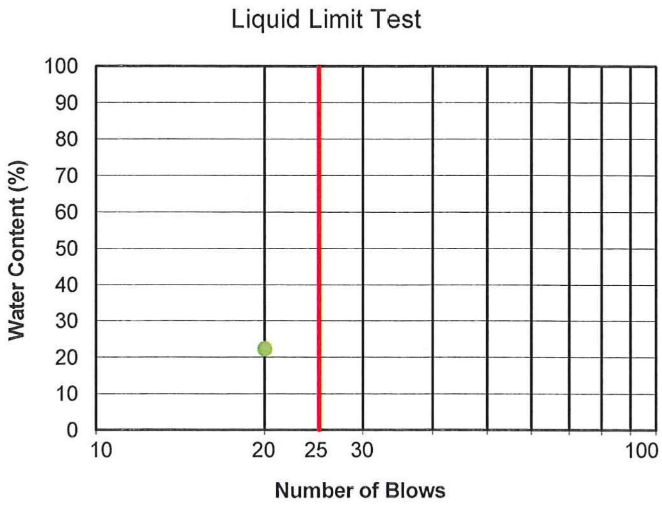
Golder Associates

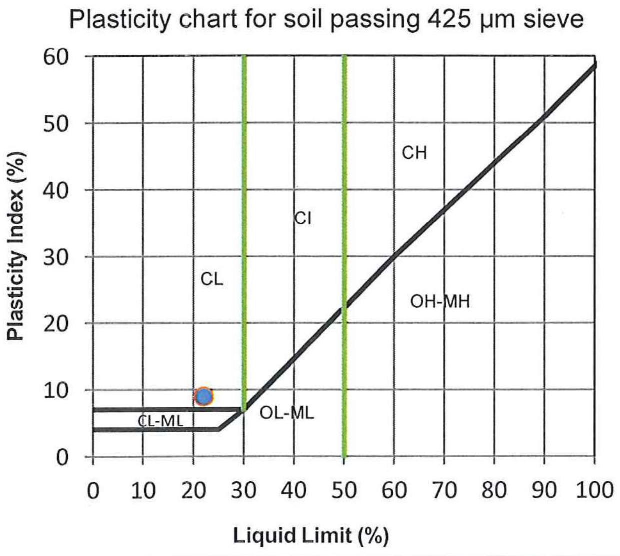
Atterberg Limits
(ASTM D 4318)

Project No.:	11-1321-0003	Phase:	2200
Short Title:	City of Calgary/Slope Stability/Douglasdale Feasibility	Lab No.:	B422-12
Tested By:	DS	Date:	18-Mar-15

Borehole: BH15-01 Sample No.: GB-12 Depth: 21.0 - 22.0 ft

Liquid Limit Determination:			**Natural Water Content:**		
Number of Blows	20	20	As Received Water Content (%)		14.2%
Blow Correction Factor	0.97	0.97	**Plastic Limit Determination:**		
Mass of wet sample + tare (g)	35.55	29.43	Mass of wet sample + tare (g)	21.58	18.91
Mass of dry sample + tare (g)	32.60	26.78	Mass of dry sample + tare (g)	20.30	17.78
Mass of tare (g)	19.46	14.88	Mass of tare (g)	10.79	9.36
Weight of Water (g)	2.95	2.65	Weight of Water (g)	1.28	1.13
Weight of dry soil (g)	13.14	11.9	Weight of dry soil (g)	9.51	8.42
Water Content (%)	22.5	22.3	Water Content (%)	13.46	13.42
Liquid Limit	22.0	22.0	Average Water Content (%)		13.44





Liquid Limit = 22 %
Plastic Limit = 13 %
Plasticity Index = 9

Comments:

Reviewed:

ISC: UNRESTRICTED

Golder Associates

Atterberg Limits
(ASTM D 4318)

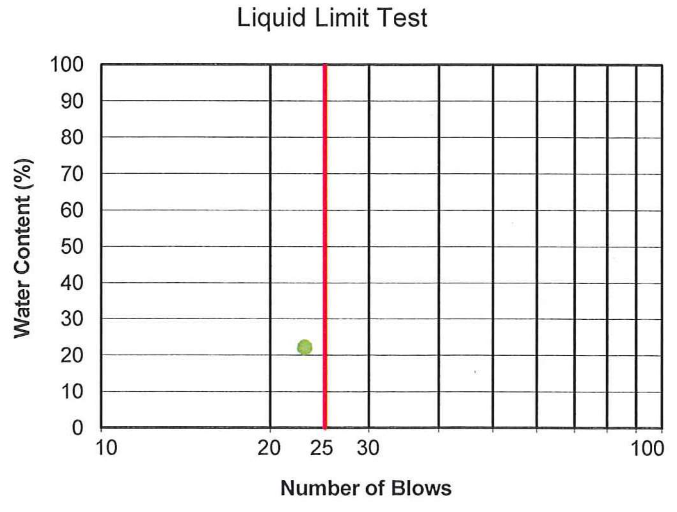
Project No.: 11-1321-0003
Short Title: City of Calgary/Slope Stability/Douglasdale Feasibility
Tested By: DS
Phase: 2200
Lab No.: B422-23
Date: 18-Mar-15

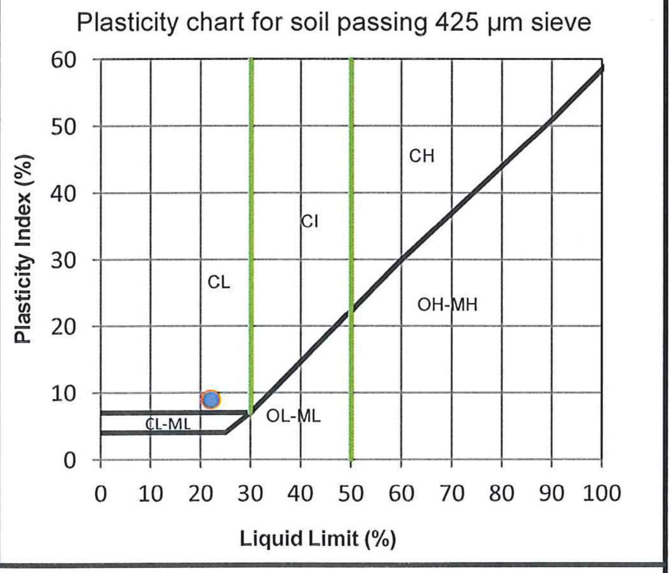
Borehole: BH15-01
Sample No.: GB-23
Depth: 48.0 - 49.0 ft

Liquid Limit Determination:		
Number of Blows	23	23
Blow Correction Factor	0.99	0.99
Mass of wet sample + tare (g)	40.34	34.84
Mass of dry sample + tare (g)	37.26	31.90
Mass of tare (g)	23.41	18.58
Weight of Water (g)	3.08	2.94
Weight of dry soil (g)	13.85	13.32
Water Content (%)	22.2	22.1
Liquid Limit	22.0	22.0

Natural Water Content:	
As Received Water Content (%)	11.4%

Plastic Limit Determination:		
Mass of wet sample + tare (g)	20.16	20.37
Mass of dry sample + tare (g)	19.07	19.28
Mass of tare (g)	10.80	10.79
Weight of Water (g)	1.09	1.09
Weight of dry soil (g)	8.27	8.49
Water Content (%)	13.18	12.84
Average Water Content (%)		13.01





Liquid Limit = 22 %
Plastic Limit = 13 %
Plasticity Index = 9

Comments:

Reviewed:

Golder Associates

Atterberg Limits
(ASTM D 4318)

Project No.:	11-1321-0003	Phase:	2200
Short Title:	City of Calgary/Slope Stability/Douglasdale Feasibility	Lab No.:	B422-45
Tested By:	DS	Date:	18-Mar-15

Borehole: BH15-02　Sample No.: GB-7　Depth: 16.5 - 17.5 ft

Liquid Limit Determination:

Number of Blows	26	26
Blow Correction Factor	1.01	1.01
Mass of wet sample + tare (g)	44.18	34.79
Mass of dry sample + tare (g)	39.30	30.94
Mass of tare (g)	25.49	20.04
Weight of Water (g)	4.88	3.85
Weight of dry soil (g)	13.81	10.9
Water Content (%)	35.3	35.3
Liquid Limit	36.0	35.0

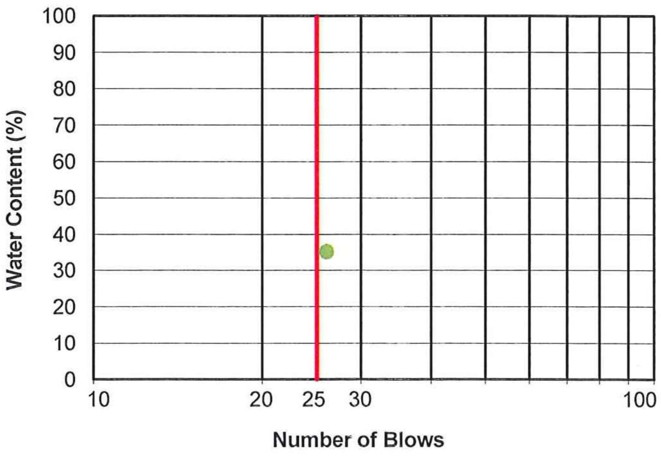
Natural Water Content:

As Received Water Content (%)	16.6%

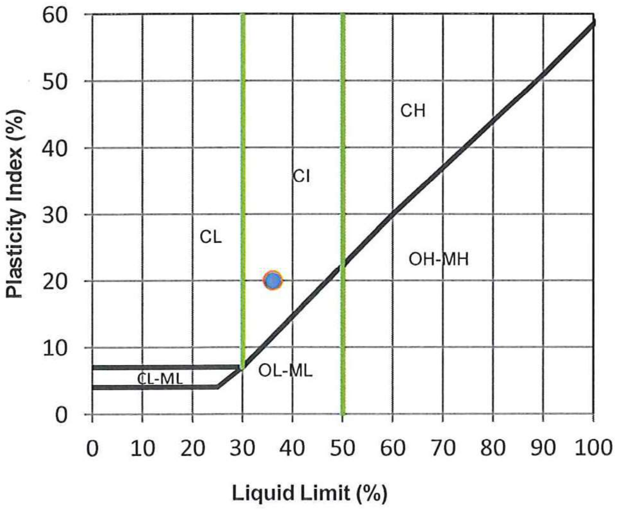
Plastic Limit Determination:

Mass of wet sample + tare (g)	18.58	19.82
Mass of dry sample + tare (g)	17.44	18.59
Mass of tare (g)	10.25	10.74
Weight of Water (g)	1.14	1.23
Weight of dry soil (g)	7.19	7.85
Water Content (%)	15.86	15.67
Average Water Content (%)		15.76

Liquid Limit Test



Plasticity chart for soil passing 425 μm sieve



Liquid Limit = 36 %
Plastic Limit = 16 %
Plasticity Index = 20

Comments: ______

Reviewed: ______

Golder Associates

Atterberg Limits
(ASTM D 4318)

Project No.: 11-1321-0003
Short Title: City of Calgary/Slope Stability/Douglasdale Feasibility
Tested By: DS

Phase: 2200
Lab No.: B422-47
Date: 18-Mar-15

Borehole: BH15-02
Sample No.: SS-9
Depth: 22.0 - 23.5 ft

Liquid Limit Determination:

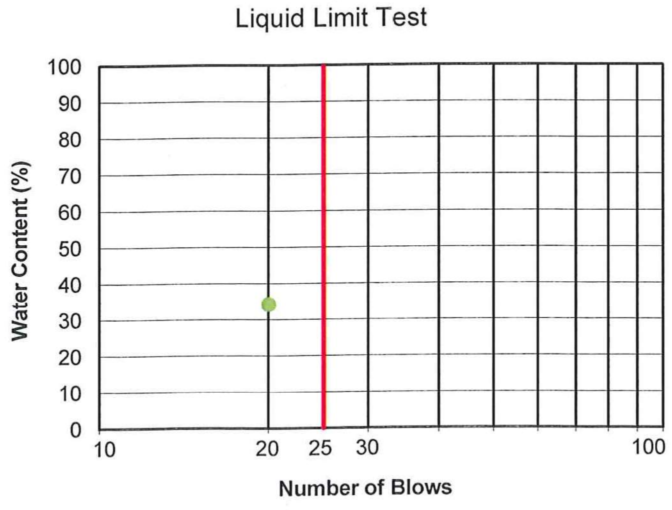
Number of Blows	20	20
Blow Correction Factor	0.97	0.97
Mass of wet sample + tare (g)	40.43	40.87
Mass of dry sample + tare (g)	36.39	36.64
Mass of tare (g)	24.62	24.26
Weight of Water (g)	4.04	4.23
Weight of dry soil (g)	11.77	12.38
Water Content (%)	34.3	34.2
Liquid Limit	33.0	33.0

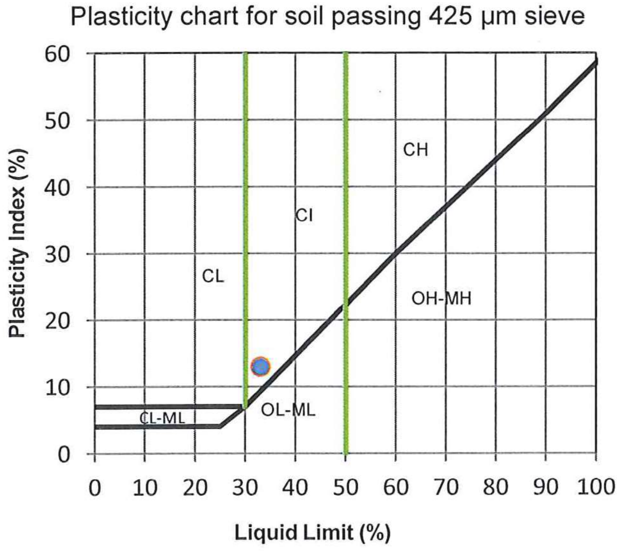
Natural Water Content:

As Received Water Content (%)	20.6%

Plastic Limit Determination:

Mass of wet sample + tare (g)	20.03	20.42
Mass of dry sample + tare (g)	18.46	18.80
Mass of tare (g)	10.74	10.83
Weight of Water (g)	1.57	1.62
Weight of dry soil (g)	7.72	7.97
Water Content (%)	20.34	20.33
Average Water Content (%)		20.33


Liquid Limit Test


Plasticity chart for soil passing 425 µm sieve

Liquid Limit = 33 %
Plastic Limit = 20 %
Plasticity Index = 13

Comments:

Reviewed:

Golder Associates

Atterberg Limits
(ASTM D 4318)

Project No.:	11-1321-0003	Phase:	2200
Short Title:	City of Calgary/Slope Stability/Douglasdale Feasibility	Lab No.:	B422-62
Tested By:	DS	Date:	18-Mar-15

Borehole: BH15-02 Sample No.: GB-24 Depth: 53.0 - 55.0 ft

Liquid Limit Determination:

Number of Blows	22	22
Blow Correction Factor	0.99	0.99
Mass of wet sample + tare (g)	36.83	31.53
Mass of dry sample + tare (g)	32.83	27.34
Mass of tare (g)	24.53	18.57
Weight of Water (g)	4	4.19
Weight of dry soil (g)	8.3	8.77
Water Content (%)	48.2	47.8
Liquid Limit	47.0	47.0

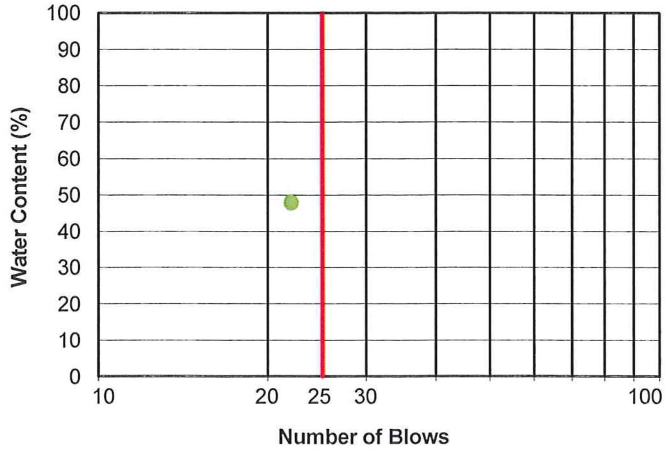
Natural Water Content:

As Received Water Content (%)	12.8%

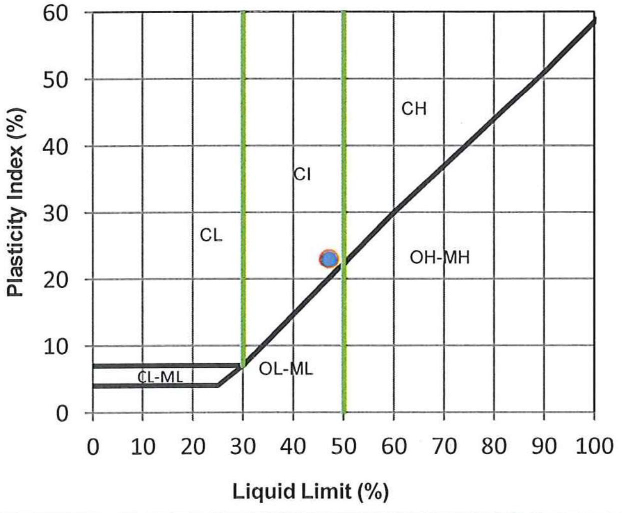
Plastic Limit Determination:

Mass of wet sample + tare (g)	19.47	19.70
Mass of dry sample + tare (g)	17.72	17.98
Mass of tare (g)	10.63	10.83
Weight of Water (g)	1.75	1.72
Weight of dry soil (g)	7.09	7.15
Water Content (%)	24.68	24.06
Average Water Content (%)		24.37

Liquid Limit Test



Plasticity chart for soil passing 425 µm sieve

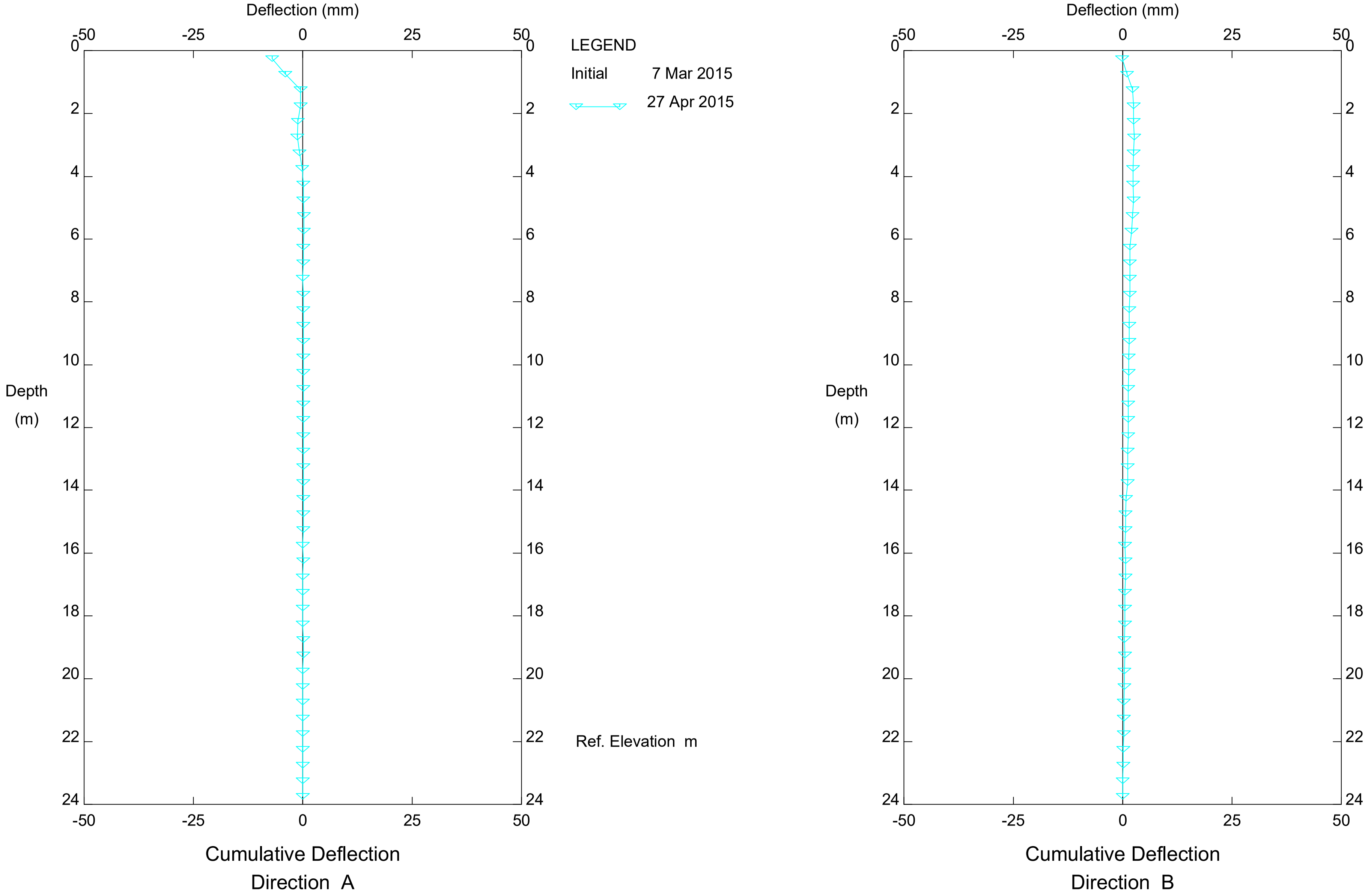


Liquid Limit = 47 %
Plastic Limit = 24 %
Plasticity Index = 23

Comments: ____________________

Reviewed: __________

Golder Associates - Calgary, AB



DOUGLASDALE FEASIBILITY STUDY, Inclinometer BH15-01

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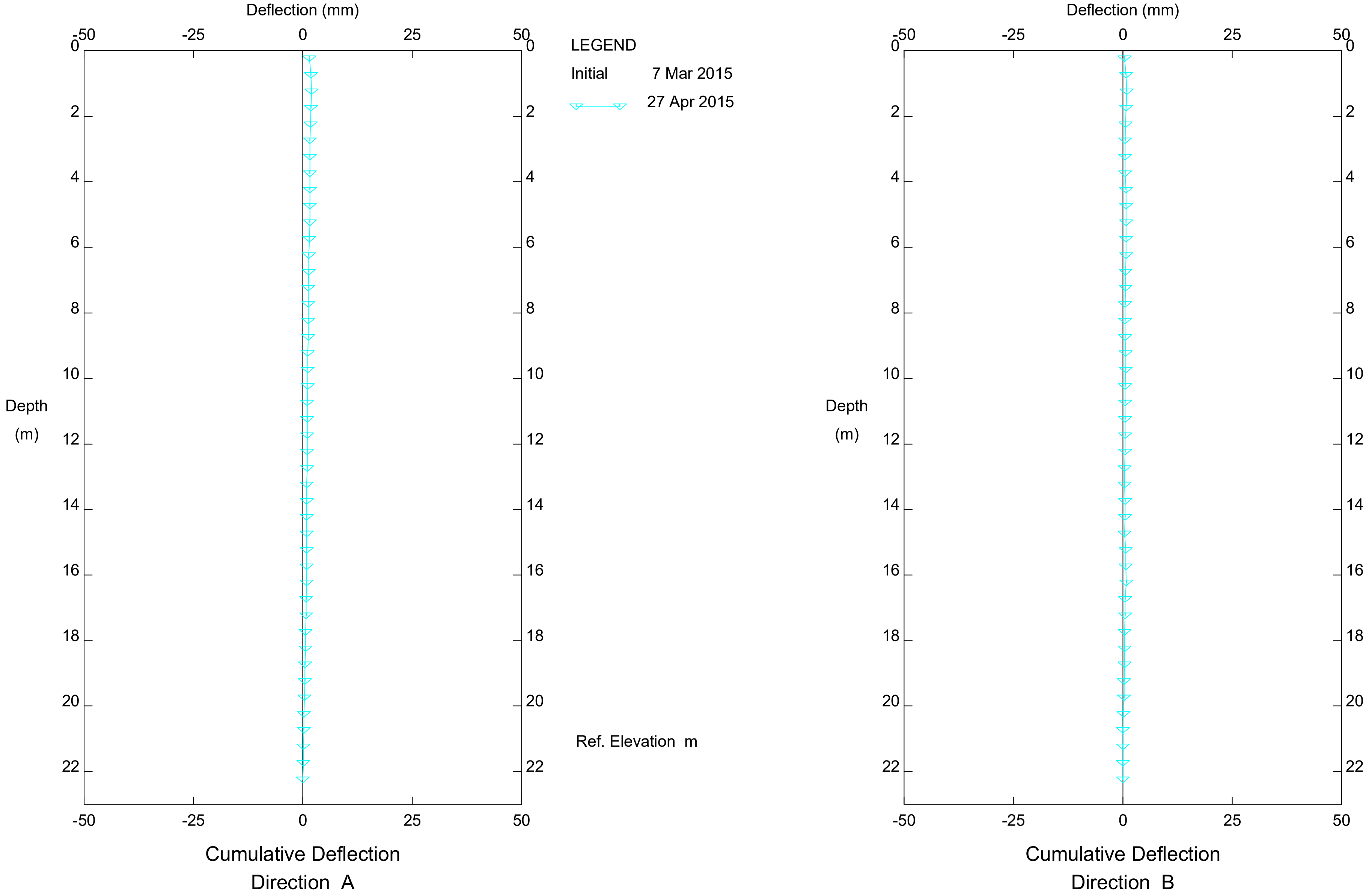
Golder Associates - Calgary, AB



DOUGLASDALE FEASIBILITY STUDY, Inclinometer BH15-02

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APPENDIX C

Detailed Analysis Section Description

The geological and groundwater conditions at each representative cross-section were adopted from borehole records, site observations, instrumentation data, and in some cases modeling historic slope movement. Detailed information on the analyses sections are provided below.

Section 1

Section 1 is located approximately at Station 0+375. At this location, the slope is relatively steep close to the property line area and includes a long flat area of fluvial/colluvium deposits at the toe of the slope and channel connected to the river. The crest elevation decreases from the cross-section location to the north, increasing slope stability.

The pathway is located on the flat fluvial/colluvium area and is far from the toe of the steep slope. Site observations at this location note a main scarp at the slope crest and a minor scarp mid-slope, cracks close to the toe of slope from the section to south. Signs of slope instability are less obvious from the section location to the north. The slope was observed to be relatively dry but signs of surface erosion are observed at steeper local slopes.

Borehole BH08-DP-1 (Golder, 2008) at the slope crest provided subsurface information at this section. Layers of moranial till overlaying basal till were observed in the borehole. A layer of high plastic clay was observed approximately at 1018 masl in the borehole. The till was underlain by a gravel and sand layer approximately at 1013 masl. Weathered claystone/mudstone bedrock was observed at 1008 to 1006 masl. Although the borehole was drilled to 1002 masl, sample below 1006 masl was not recovered. No information was available about the condition of bedrock below 1006 masl. The bedrock lower than 1006 masl was assumed to be competent bedrock.

Groundwater elevations were estimated using data from piezometers installed within the soil layers and bedrock in Borehole BH08-DP-1 (Golder, 2008) and consideration for groundwater fluctuation. Two groundwater elevations were adopted for analysis, one within the soil layers and another one within the bedrock layers.

The modeled subsurface stratigraphy and groundwater conditions for this section are presented in Figures D-1 to D-3 in Appendix D.

Section 2

Section 2 is located approximately at Station 0+785. Site observations at this location note a main scarp and two minor scarps mid-slope and close to the toe. Crest cracking and major damage on the pathway mid-slope indicate slope activity at this area. Signs of high groundwater elevations were noted mid-slope. Signs of surface erosion were noted on locally steeper slopes.

Groundwater elevations were estimated using data from piezometers installed within the soil layers and bedrock in Boreholes BH08-01-1343-0020 and BH08-03-1343-0020 (Golder, 2009), wet areas on the slope, seepage exit points on the slope and consideration of groundwater fluctuation. Two groundwater elevations were adopted for analysis, one within the soil layers and another one within the bedrock layers.

Borehole BH08-01-1343-0020 at the slope crest and Borehole BH08-03-1343-0020 (Golder, 2009) mid-slope and Borehole BH15-01 (Appendix B) (mid-slope, projected to section line) provided subsurface information at the crest and mid-slope area.

Borehole BH08-01-1343-0020 (Golder, 2009) at the slope crest suggests layers of moranial till overlying basal till in this area. A layer of high plastic clay was observed approximately at 1020 masl in this borehole. The till was underlain by a gravel and sand layer approximately at 1014 masl. Borehole BH15-01 (projected to section line) suggested that bedrock in this area consisted of weathered bedrock from approximately 1012 to 1001 masl.

Similar stratigraphy was observed mid-slope in Borehole BH08-03-1343-0020 but at lower elevations. The layers in this borehole were approximately 5 m to 7 m lower than the same layers in the borehole at the crest. The elevation difference is greater than what can be attributed solely to the difference in slope elevation. Considering the signs of previous slope movements in this area, it was concluded that the change in elevation of soil layers from crest to the mid-slope area was due to previous slope movements. A geological cross-section was produced to match the stratigraphy at the borehole locations while resembles previous slope movement along this section.

The modeled subsurface stratigraphy and groundwater conditions for this section are presented in Figures D-4 to D-8 in Appendix D.

Section 3

Section 3 is located approximately at Station 0+865. The crest of the slope at this section has a flatter slope compared to the slope of the crest at Section 2.

Site observations at this location note a scarp just upslope of the pathway location. Leaning trees at the top portion of the slope, cracks on the pathway and smaller cracks on the lower portion of slope are signs of slope movement at this location. Ponded water on the flatter portion of the lower slope was noted. Signs of surface erosion were noted at locally steeper slopes close to the river.

Groundwater elevations were estimated using data from piezometers installed within the soil layers and bedrock in Boreholes BH08-02 -1343-0020 (Golder, 2009), and BH08-01-1343-0020, the location of ponded water on the slope and consideration of groundwater fluctuation. The groundwater elevation within the soil layers were estimated to be at a higher elevation and closer to the slope surface while the groundwater elevation within the bedrock unit was modelled close to the till-bedrock interface.

Boreholes BH08-02-1343-0020, BH15-01 and BH15-01A (Appendix B) mid-slope are directly on the section line. Information from Borehole BH08-01-1343-0020 at the crest of slope, approximately 100 m from the section location was also used in evaluating the subsurface information.

Borehole records at this section show a layer of moranial till overlying basal till. A layer of high plastic clay was observed approximately at 1020 masl. The till layer was underlain by a gravel and sand layer approximately at 1015 masl. The bedrock in this area consisted of weathered bedrock below approximately 1012 masl. Comparison of boreholes from mid-slope (BH08-02-1343-0020, BH15-01 and BH15-01A) with Borehole BH08-01-1343-0020 at the crest of slope suggest that the soil layers are approximately at the same elevation beneath the slope crest and mid-slope. Therefore unlike Section 1, the stratigraphy was not affected by previous slope movements.

The modeled subsurface stratigraphy and groundwater conditions for this section are presented in Figures D-9 to D-11 in Appendix D.

Section 4

Section 4 is located approximately at Station 1+135. The terrace above the slope has a gentle slope toward the slope crest.

Site observations at this location note a main scarp close to the pathway, previous damages to the pathway, signs of slope disturbance on the slope and minor scarps on the slope toe close to the river. Ponded water mid-slope and at the toe, and seepage exit points at the slope toe above the river level were noted. Signs of surface erosion are noted in the area with a steeper slope close to the river.

Borehole BH05-MD-1 (Golder, 2006) at the crest was used to estimate the stratigraphy at this section. In this borehole, a layer of moranial till overlying basal till was observed. The till layer was directly overlying weathered claystone/mudstone bedrock approximately at 1014 masl which was underlain by weathered siltstone/sandstone. Competent bedrock was observed below 1009 masl. Although no boreholes were drilled directly on the slope, there are clear signs of previous slope movement which were used to estimate the stratigraphy.

Groundwater elevations were estimated using data from piezometers installed within the soil layers and bedrock in Borehole BH05-MD-1, the location of ponded water on the slope and consideration of groundwater fluctuation. It was estimated that the groundwater within the soil layers was at higher elevation and closer to the slope surface while the groundwater elevation within the bedrock was close to the till-bedrock interface.

The modeled subsurface stratigraphy and groundwater conditions for this section are presented in Figures D-12 to D-14 in Appendix D.

Section 5

Section 5 is located approximately at Station 1+475. Site observations at this location note a main scarp close to the pathway, previous damage to the pathway, signs of slope instability and minor scarps mid-slope, as well as at the toe. Ponded water was observed on flatter areas on the slope at the crest and mid-slope. Seepage exit points were observed on the lower portion of the slope. Signs of surface erosion were noted on areas with steeper slopes.

Borehole BH05-MD-2 (Golder, 2006) at the crest of the slope was used to estimate the stratigraphy In this borehole, a layer of moranial till overlaying basal till was observed. The till layer was underlain by weathered siltstone/sandstone bedrock approximate at 1020 masl. The weathered bedrock was underlain by competent bedrock approximately at 1018 masl. The weathered bedrock was conservatively modeled as claystone/mudstone at this section to capture possible existence of weaker weathered bedrock layers. Moranial till was assumed to directly overlay weathered bedrock to resemble previous slope movements and disturbance at this area.

Groundwater elevation within the till was estimated using data from piezometers installed within the soil layers in Borehole BH05-MD-2 and Borehole BH-003 (EBA, 1994) as well as the location of ponded water on the slope. Consistent with other sections, the groundwater elevation in the bedrock was assumed to be at the till-bedrock interface.

The modeled subsurface stratigraphy and groundwater conditions for this section are presented in Figures D-15 to D-17 in Appendix D.

Section 6

Section 6 is located approximately at Station 1+565. The terrace above the slope has a gentle slope toward the slope crest.

Site observations note previous minor damage to the pathway, signs of slope disturbance at the slope crest and minor scarps at the slope toe. Ponded water was observed on flatter areas on the slope. Seepage exit points are observed on the lower portion of slope. Signs of surface erosion were noted in areas with steeper slope.

Borehole BH-S3 (Hardy, 1980) at the crest was used to estimate the stratigraphy at this section. In Borehole BH-S3, a layer of moranial till overlaid basal till. The till layer was directly underlain by weathered siltstone/sandstone bedrock at approximately 1022 masl. The weathered bedrock was underlain by competent bedrock at approximately 1021 masl. The weathered bedrock was conservatively modeled as claystone/mudstone at this section to capture possible existence of weaker weathered bedrock layers in this area. The contact between the moranial till and basal till is lowered to resemble the previous slope movements.

Groundwater elevation within the till was estimated using data from piezometers installed within the soil layers in Borehole BH-S3 as well as location of ponded water on the slope. Consistent with other sections, the groundwater elevation in the bedrock was assumed to be at the till-bedrock interface.

The modeled subsurface stratigraphy and groundwater conditions for this section are presented in Figures D-18 to D-20 in Appendix D.

Section 7

Section 7 is located approximately at Station 1+975. The terrace above the slope has a gentle slope toward the slope crest.

Site observations at this location note previous damages to the pathway, a main scarp downslope of the pathway, minor scarps at the slope crest and toe, and tension cracks mid-slope. Ponded water was observed on flatter areas on the slope. Seepage exit points were observed on the lower portion of the slope around Station 1+725. Signs of surface erosion were noted at locally steeper slopes.

Boreholes BH-S3 (Hardy, 1980) and BH-002 (EBA, 1994) at the crest north of the area were used to estimate the stratigraphy at this section. Stratigraphy was modelled to be similar to Section 6 but without adjustments for previous slope instabilities.

Groundwater elevation within the till was estimated using data from piezometers installed within the soil layers in Borehole BH-002, the location of ponded water on the slope, seepage exit points at the toe and consideration of possible groundwater fluctuation. Consistent with other sections, groundwater elevation in the bedrock was assumed to be at till-bedrock interface.

The modeled subsurface stratigraphy and groundwater conditions for this section are presented in Figures D-21 to D-23 in Appendix D.

Section 8

Section 8 is located approximately at Station 2+075. The terrace above the slope has a gentle slope toward the slope crest.

Site observations at this location note previous damages to the pathway, the location of the main scarp downslope of the pathway, minor scarps mid-slope, tension cracks mid-slope, signs of slope movements on the lower half of slope and surface erosion on locally steeper slopes. Seepage or ponded water was not observed at this location.

Boreholes BH05-MD-2 (Golder, 2006) and BH07-01 (Golder, 2007) at the crest north and south of this location were used to estimate the stratigraphy at this section. Stratigraphy was modelled to be similar to Section 7.

Groundwater elevations were estimated using data from piezometers installed within the soil layers in Borehole BH-07-01 (Golder, 2007) and consideration of possible groundwater fluctuation. Due to lack seepage observed on the slope face, groundwater was assumed to be contained within the slope.

The modeled subsurface stratigraphy and groundwater conditions for this section are presented in Figures D-24 to D-26 in Appendix D.

Section 9

Section 9 is located approximately at Station 2+275. In this area, an anchored caisson wall was constructed from approximately Station of 2+225 to 2+295 to improve stability of the slope. Previous analyses showed that the failure surfaces at the location of the caisson wall does not extend beyond the wall. The section was modeled without considering the caisson wall in order to assess the slope north and south of the wall.

Numerous slope stability issues were observed at this location prior to construction of the caisson wall and continue to be observed beyond the limits of the wall. Site observations at this location note previous significant damage to the pathway, the location of the main scarp downslope of pathway, minor scarps mid-slope, minor scarps close to the river, tension cracks mid-slope and signs of slope movements on the lower half of slope above the river level and surface erosion on the locally steeper slopes. Ponded water was observed on flatter areas on the slope at the crest and mid-slope. Seepage exit points were observed on the slope at the crest, mid-slope and close to the toe. Signs of surface erosion were noted at the area with a steeper slope close to the main scarp as well as the steep lower portion clove to the toe.

Boreholes BH07-02 (Golder, 2008) and BH-04 (EBA, 2014) (offset to south) at the crest of the slope were used to estimate the stratigraphy. A layer of moranial till was observed overlying basal till overlying bedrock at approximately 1021 masl. Interbedded layers of weathered claystone/mudstone and siltstone/sandstone were observed underlying the basal till from 1021 to 1007 masl. Competent bedrock was observed below 1007 masl.

Although no boreholes were drilled on the slope, there were clear signs of previous slope movement which were used to estimate the stratigraphy.

Groundwater elevation within the till was estimated using data from piezometers installed within the soil layers in boreholes in this area and consideration of groundwater fluctuation. Based on signs of seepage on the slope, the till groundwater elevation was assumed to be close to the slope face. The bedrock groundwater elevation was estimated to be close to till-bedrock interface.

The modeled subsurface stratigraphy and groundwater condition for this section are presented in Figures D-27 to D-29 in Appendix D.

Section 10

Section 10 is located approximately at Station 2+375. The private property line at this section is approximately 8 m from the slope crest.

Site observations at this location note significant damages to the pathway, the location of the main scarp downslope of the pathway, tension cracks at the crest and upslope of the pathway, leaning trees on the slope (possibly due to slope movement), minor scarps at the toe of the slope close to the river, and surface erosion on the steep lower portion of the slope close to the river. Seepage exit points were observed close to the slope toe above river level.

Borehole BH-03 (EBA, 2014) at the crest was used to define the stratigraphy. Moranial till was observed overlying basal till overlying bedrock at approximately 1020 masl. Interbedded layers of weathered claystone/mudstone and siltstone/sandstone were observed beneath the basal till from 1020 to 1005 masl. Competent bedrock was observed below 1005masl.

Although no borehole was drilled on the slope, there were clear signs of previous slope movement which were also used to estimate the stratigraphy.

Groundwater elevation within the till was estimated using data from a piezometer installed within the soil layers in Borehole BH-03 (EBA, 2014) and consideration of possible groundwater fluctuation. Based on signs of seepage on the slope, the groundwater elevation in the till was assumed to be close to the slope face in the lower portion of the slope. The bedrock groundwater elevation was estimated to be close to the till- bedrock interface.

The modeled subsurface stratigraphy and groundwater conditions for this section are presented in Figures D-30 to D-32 in Appendix D.

Section 11

Section 11 is located approximately at Station 2+595. Site observations at this location note minor damage to the pathway, the location of the main scarp downslope of the pathway, leaning trees on the slope (possibly due to slope movement) and a slope disturbance area at the mid slope. Seepage exit points were observed in the lower portion of the slope, however, the area is steep and heavily vegetated, so through observation was not possible.

Borehole BH15-02 (Appendix B) at the crest of the slope was used to define the stratigraphy. A layer of moranial till was observed overlying basal till layers overlying bedrock at approximately 1021 masl. Interbedded layers of weathered claystone/mudstone and siltstone/sandstone were observed beneath the basal till. The elevation of competent bedrock was estimated at 1009 masl based on change in slope angle close to the toe.

No piezometer was available at this area. The groundwater elevation within the till was assumed to be higher than the groundwater elevation in the bedrock. The groundwater elevation in the till at the crest area was estimated to be at 1029 masl based on average groundwater elevations in boreholes north of this section (Boreholes BH-02 (EBA, 2014), and BH-03 (EBA, 2014)). The bedrock groundwater elevation was assumed to at the competent bedrock elevation above river level.

The modeled subsurface stratigraphy and groundwater conditions for this section are presented in Figures D-33 to D-35 in Appendix D.

Section 12

Section 12 is located at approximately Station 2+705. Site observations note only minor movement and erosion at locally steeper areas. Ponded water was observed in limited areas at the crest and toe.

No borehole information was available for this area. The stratigraphy in this section was modelled to be similar to the stratigraphy in Section 11. The steeper toe area in Section 12 in comparison to Section 11 suggests a better bedrock condition at this area. The weathered bedrock in this area was modelled as weathered siltstone/sandstone.

No piezometer was available in this area. However, similar to the adjacent areas, the till groundwater elevation was estimated to be at 1029 masl (similar to Section 11) and the bedrock groundwater elevation was assumed to be at the till-bedrock interface.

The modeled subsurface stratigraphy and groundwater conditions for this section are presented in Figures D-36 to D-38 in Appendix D.

Section 13

Section 13 is located at approximately Station 3+405. Site observations note minor damages to the pathway, the location of the main scarp downslope of the pathway, minor scarps mid-slope and local surface erosion. Wet areas were observed at the slope crest. Bedrock outcrops were noted mid-slope.

Borehole BH05-MV-1 (Golder, 2006) at the crest was used to define the stratigraphy. A layer of moranial till was observed overlying bedrock at approximately 1016 masl. Interbeded layers of weathered claystone/mudstone and siltstone/sandstone were observed beneath the basal till from 1016 to 1009 masl. Competent bedrock was observed below 1009 masl.

Groundwater elevations were estimated using date from a piezometer installed within Borehole BH05-MV-1 and consideration of possible groundwater fluctuation. Considering no signs of seepage on the slope, the groundwater was assumed to be contained within the slope.

The modeled subsurface stratigraphy and groundwater conditions for this section are presented in Figures D-39 to D-41 in Appendix D.

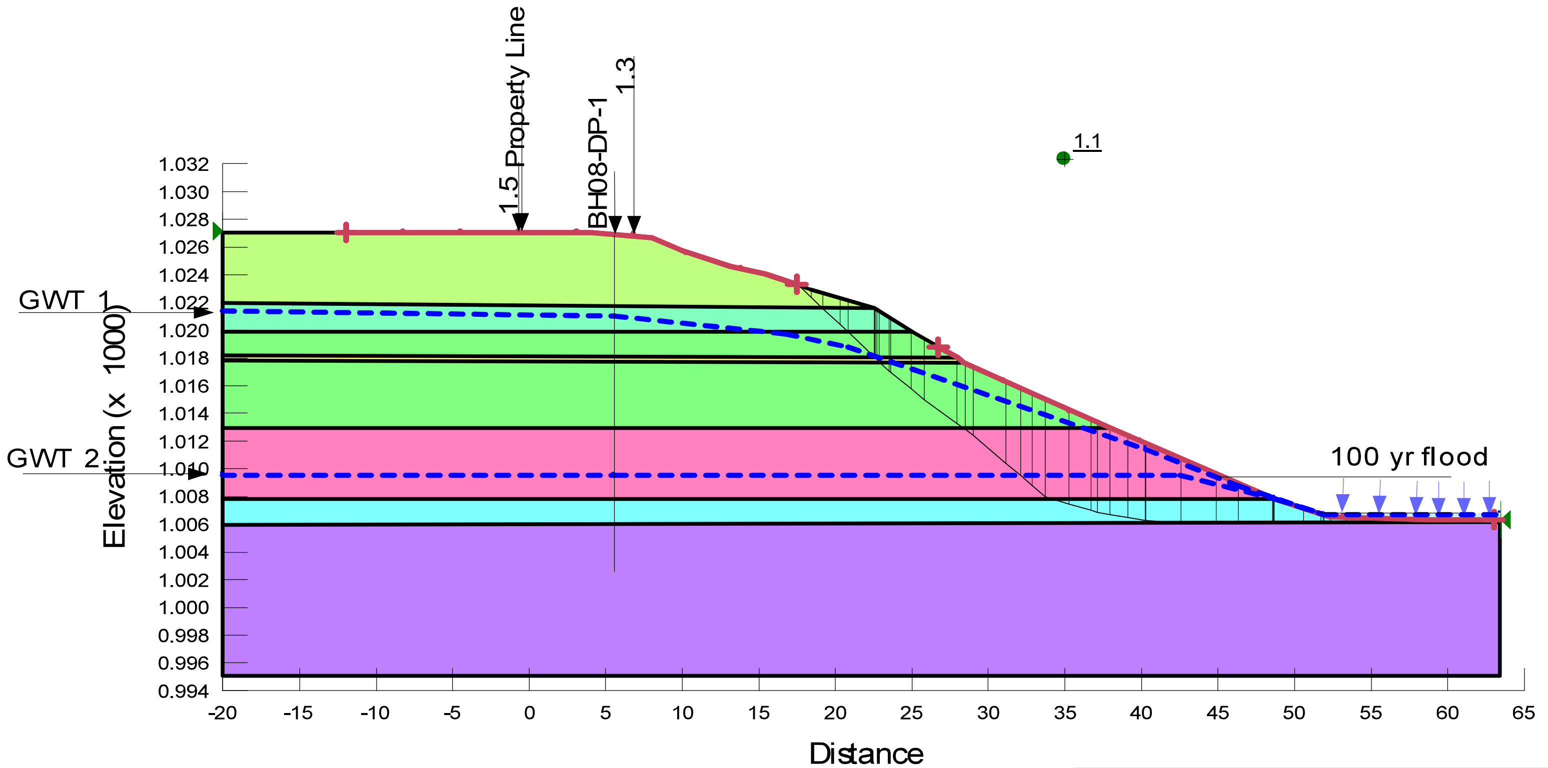
APPENDIX D

Slope Stability Analysis Results

Directory: R:\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\01_Geotechnical\Slope Stability Analysis\Section 1\
File Name: Section 1 AW2-AE2.gsz

ISC: UNRESTRICTED

Name: Till - Clay Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 26 °
Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 °
Name: Till - Silty Clay or Clayey Silt - Hard Unit Weight: 20 kN/m³ Cohesion: 5 kPa Phi: 30 °
Name: Till - Sandy Silt or Silt - Dense Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 33 °
Name: Weathered Claystone or Mudstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 22 ° Piezometric Line: 2
Name: Competent Claystone or Mudstone Piezometric Line: 2
Name: Sand and Gravel Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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CITY OF CALGARY
DOUGLASDALE FEASIBILITY STUDY

SECTION 1 - CONTROLLING CREST FAILURE

Design:	AW	5/8/2015	Project:	11-1321-0003.2200	**Figure: D-1**
Checked:	AE	5/8/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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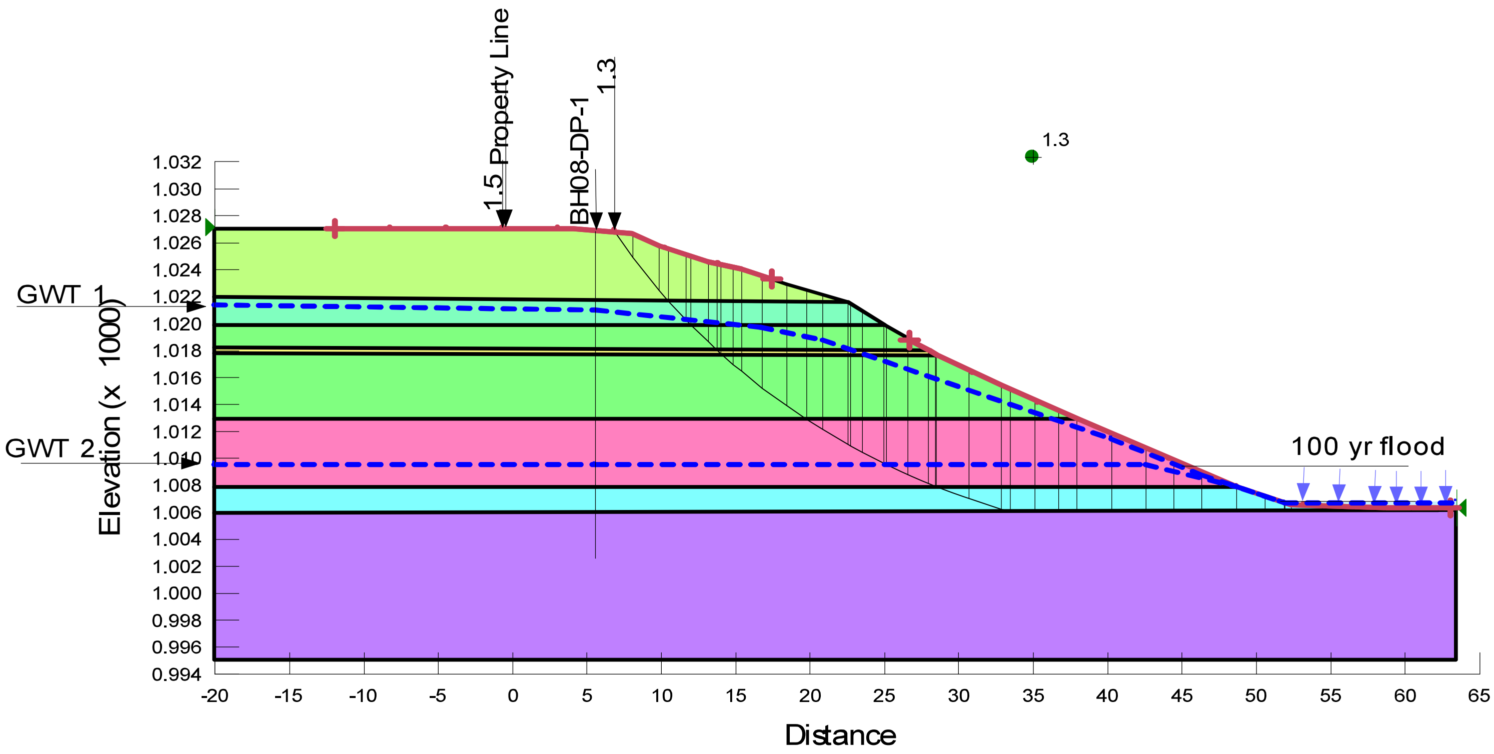
File Name: Section 1 AW2-AE2.gsz

ISC: UNRESTRICTED

Name: Till - Clay   Unit Weight: 19 kN/m³   Cohesion: 0 kPa   Phi: 26 °
Name: Till - Silty Clay or Clayey Silt - Stiff   Unit Weight: 19 kN/m³   Cohesion: 2 kPa   Phi: 28 °
Name: Till - Silty Clay or Clayey Silt - Hard   Unit Weight: 20 kN/m³   Cohesion: 5 kPa   Phi: 30 °
Name: Till - Sandy Silt or Silt - Dense   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 33 °
Name: Weathered Claystone or Mudstone   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 22 °   Piezometric Line: 2
Name: Competent Claystone or Mudstone   Piezometric Line: 2
Name: Sand and Gravel   Unit Weight: 21 kN/m³   Cohesion: 0 kPa   Phi: 38 °   Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 1 - CREST FAILURE - FOS 1.3

Design:	AW	5/8/2015	Project:	11-1321-0003.2200	**Figure: D-2**
Checked:	AE	5/8/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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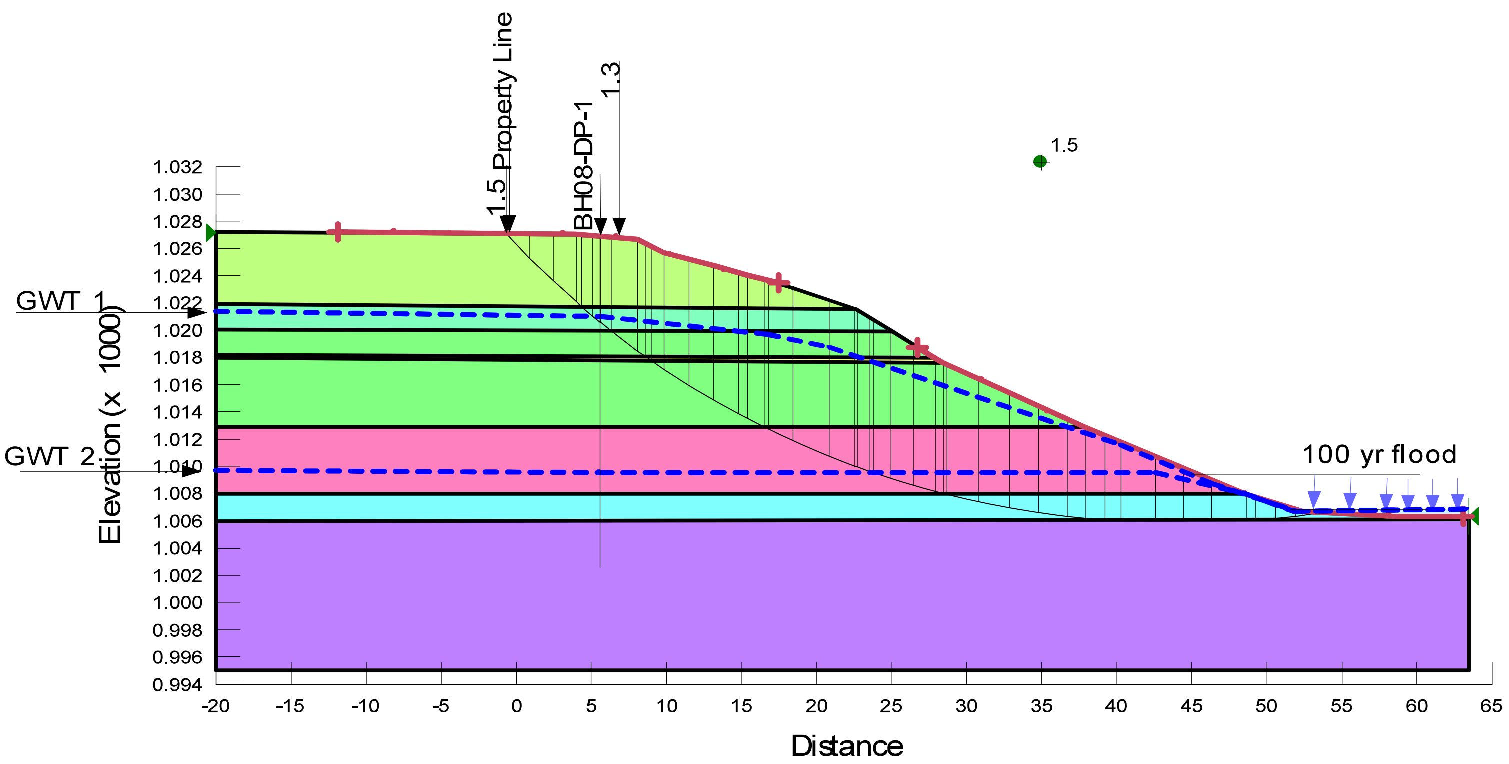
File Name: Section 1 AW2-AE2.gsz

ISC: UNRESTRICTED

Name: Till - Clay   Unit Weight: 19 kN/m³   Cohesion: 0 kPa   Phi: 26 °
Name: Till - Silty Clay or Clayey Silt - Stiff   Unit Weight: 19 kN/m³   Cohesion: 2 kPa   Phi: 28 °
Name: Till - Silty Clay or Clayey Silt - Hard   Unit Weight: 20 kN/m³   Cohesion: 5 kPa   Phi: 30 °
Name: Till - Sandy Silt or Silt - Dense   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 33 °
Name: Weathered Claystone or Mudstone   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 22 °   Piezometric Line: 2
Name: Competent Claystone or Mudstone   Piezometric Line: 2
Name: Sand and Gravel   Unit Weight: 21 kN/m³   Cohesion: 0 kPa   Phi: 38 °   Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 1 - CREST FAILURE - FOS 1.5

Design:	AW	5/8/2015	Project:	11-1321-0003.2200
Checked:	AE	5/8/2015	Rev:	0
Reviewed:	DEB	7/31/2015		

Figure: D-3

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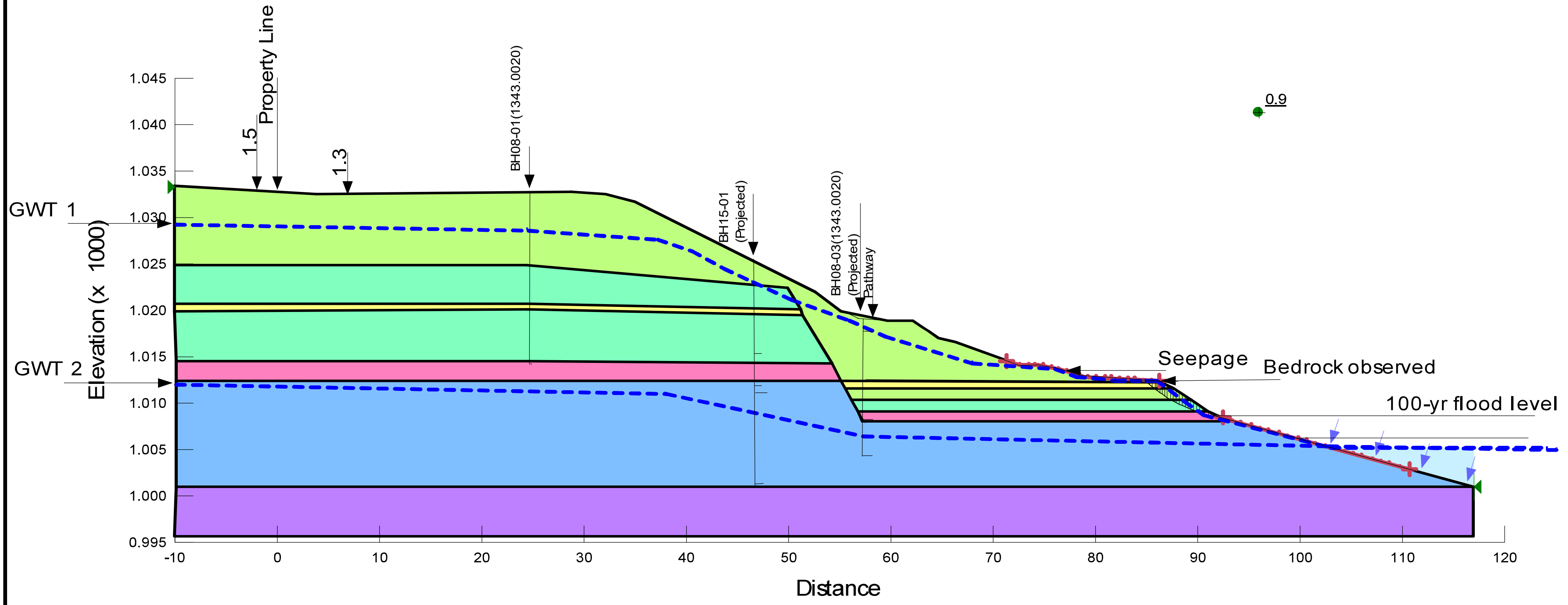
File Name: Section 2 1.0-AE-AW.gsz

ISC: UNRESTRICTED

Name: Till - Clay Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 26 ° Piezometric Line: 1
Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 1
Name: Till - Silt or Sandy Silt - Dense Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 33 ° Piezometric Line: 1
Name: Weathered Siltstone or Sandstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 2
Name: Competent Claystone or Mudstone Piezometric Line: 2
Name: Sand and Gravel Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 2 - TOE FAILURE

Design:	AW	5/4/2015	Project:	11-1321-0003.2200
Checked:	AE	5/5/2015	Rev:	0
Reviewed:	DEB	7/31/2015		

Figure: D-4

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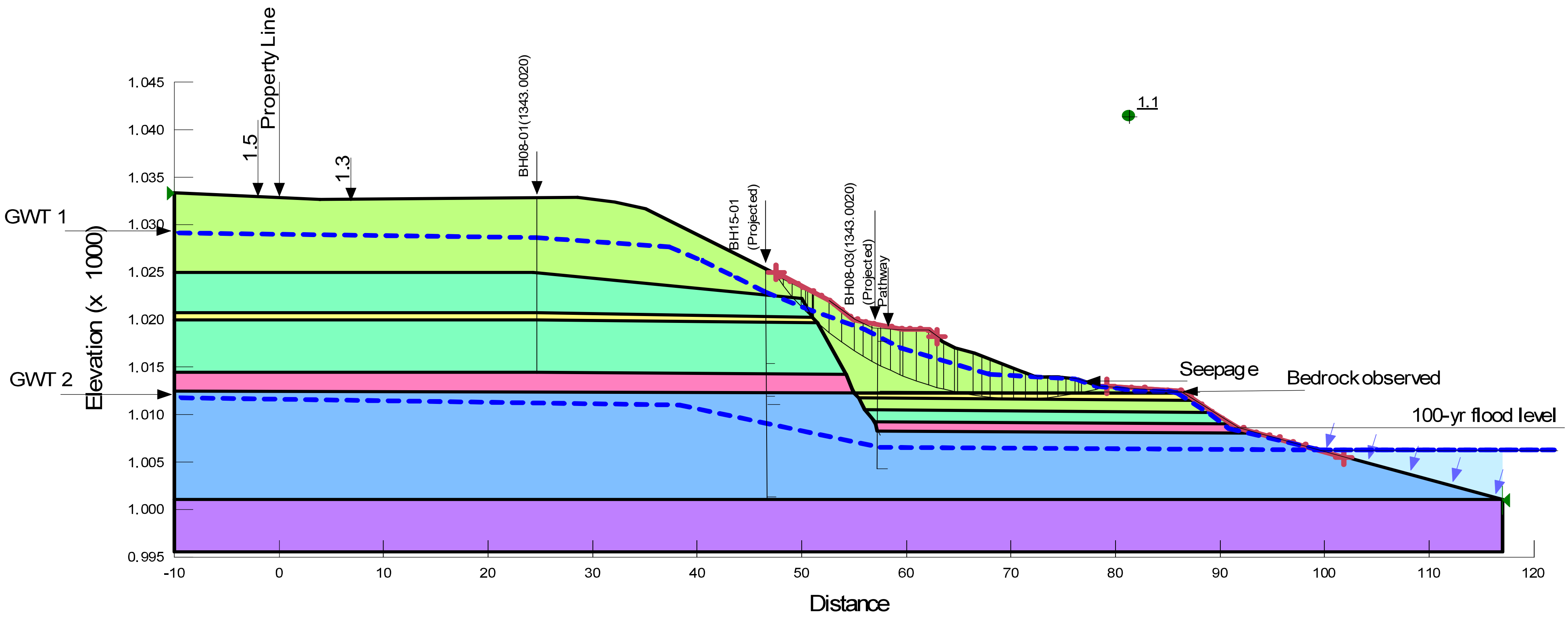
File Name: Section 2 1.0-AE-AW.gsz

ISC: UNRESTRICTED

Name: Till - Clay Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 26 ° Piezometric Line: 1
Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 1
Name: Till - Silt or Sandy Silt - Dense Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 33 ° Piezometric Line: 1
Name: Weathered Siltstone or Sandstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 1
Name: Competent Claystone or Mudstone Piezometric Line: 2
Name: Sand and Gravel Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 1



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 2 - MID SLOPE FAILURE

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-5**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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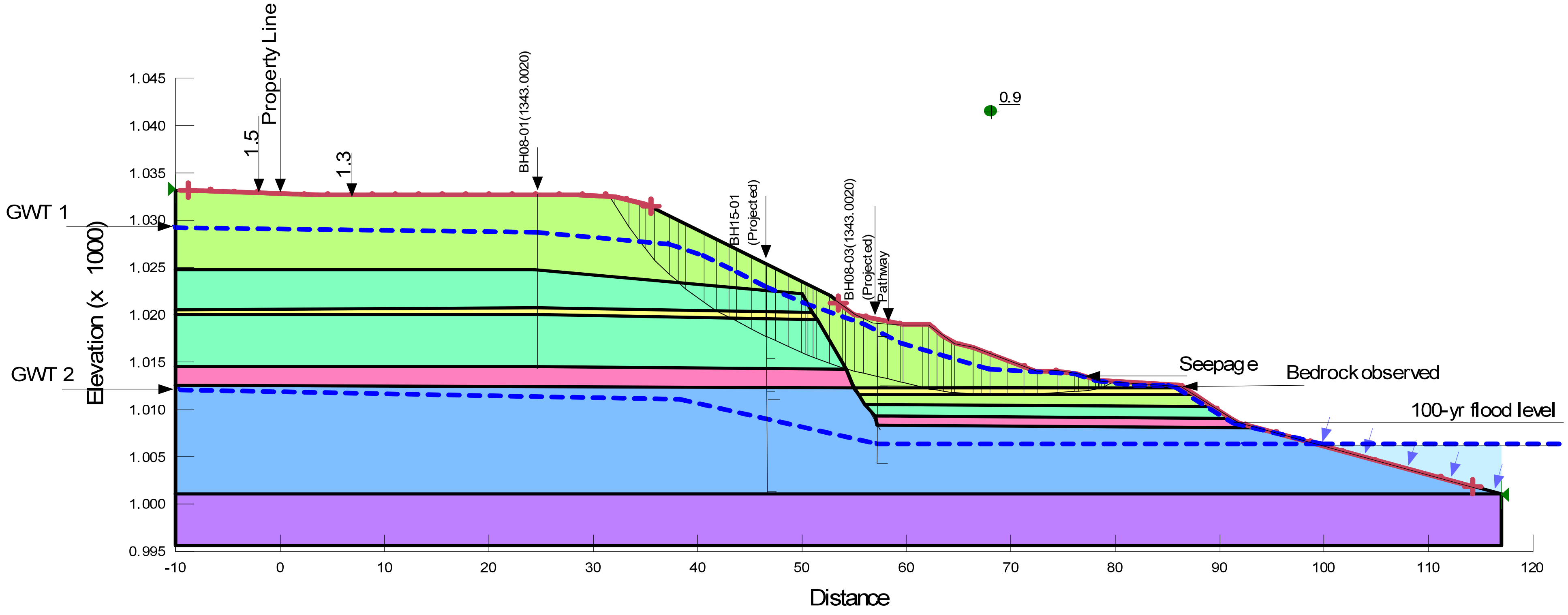
File Name: Section 2 1.0-AE-AW.gsz

ISC: UNRESTRICTED

Name: Till - Clay Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 26 ° Piezometric Line: 1
Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 1
Name: Till - Silt or Sandy Silt - Dense Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 33 ° Piezometric Line: 1
Name: Weathered Siltstone or Sandstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 2
Name: Competent Claystone or Mudstone Piezometric Line: 2
Name: Sand and Gravel Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 1



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 2 - CONTROLLING CREST FAILURE

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-6**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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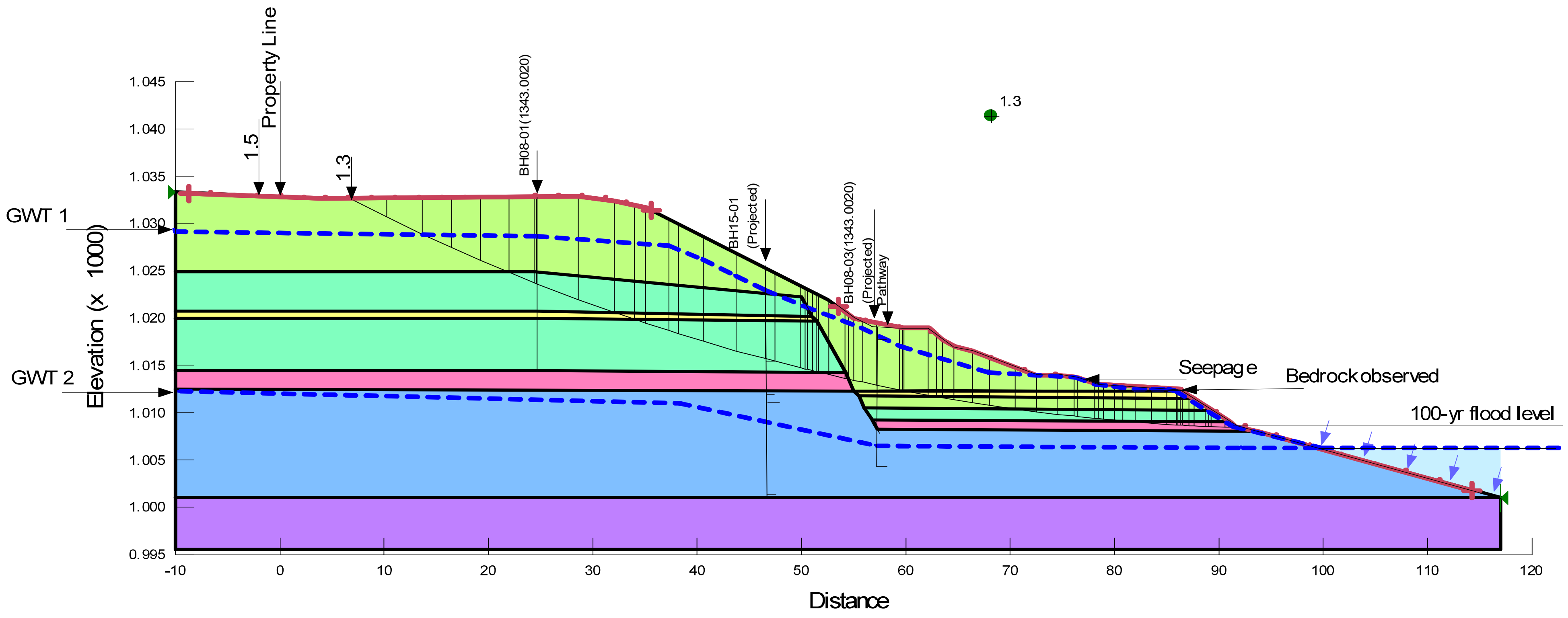
File Name: Section 2 1.0-AE-AW.gsz

ISC: UNRESTRICTED

Name: Till - Clay Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 26 ° Piezometric Line: 1
Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 1
Name: Till - Silt or Sandy Silt - Dense Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 33 ° Piezometric Line: 1
Name: Weathered Siltstone or Sandstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 2
Name: Competent Claystone or Mudstone Piezometric Line: 2
Name: Sand and Gravel Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 1



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟪	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 2 - CREST FAILURE - FOS 1.3

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-7**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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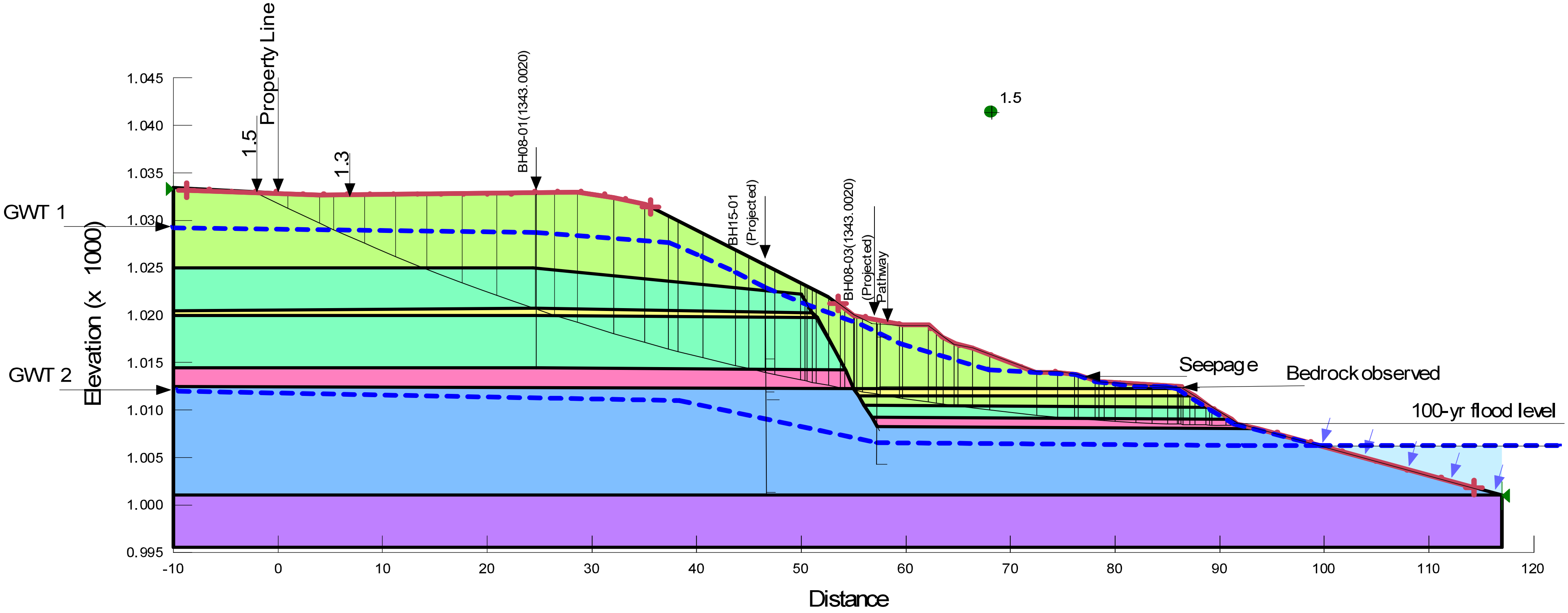
File Name: Section 2 1.0-AE-AW.gsz

ISC: UNRESTRICTED

Name: Till - Clay Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 26 ° Piezometric Line: 1
Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 1
Name: Till - Silt or Sandy Silt - Dense Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 33 ° Piezometric Line: 1
Name: Weathered Siltstone or Sandstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 2
Name: Competent Claystone or Mudstone Piezometric Line: 2
Name: Sand and Gravel Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 1



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 2 - CREST FAILURE - FOS 1.5

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-8**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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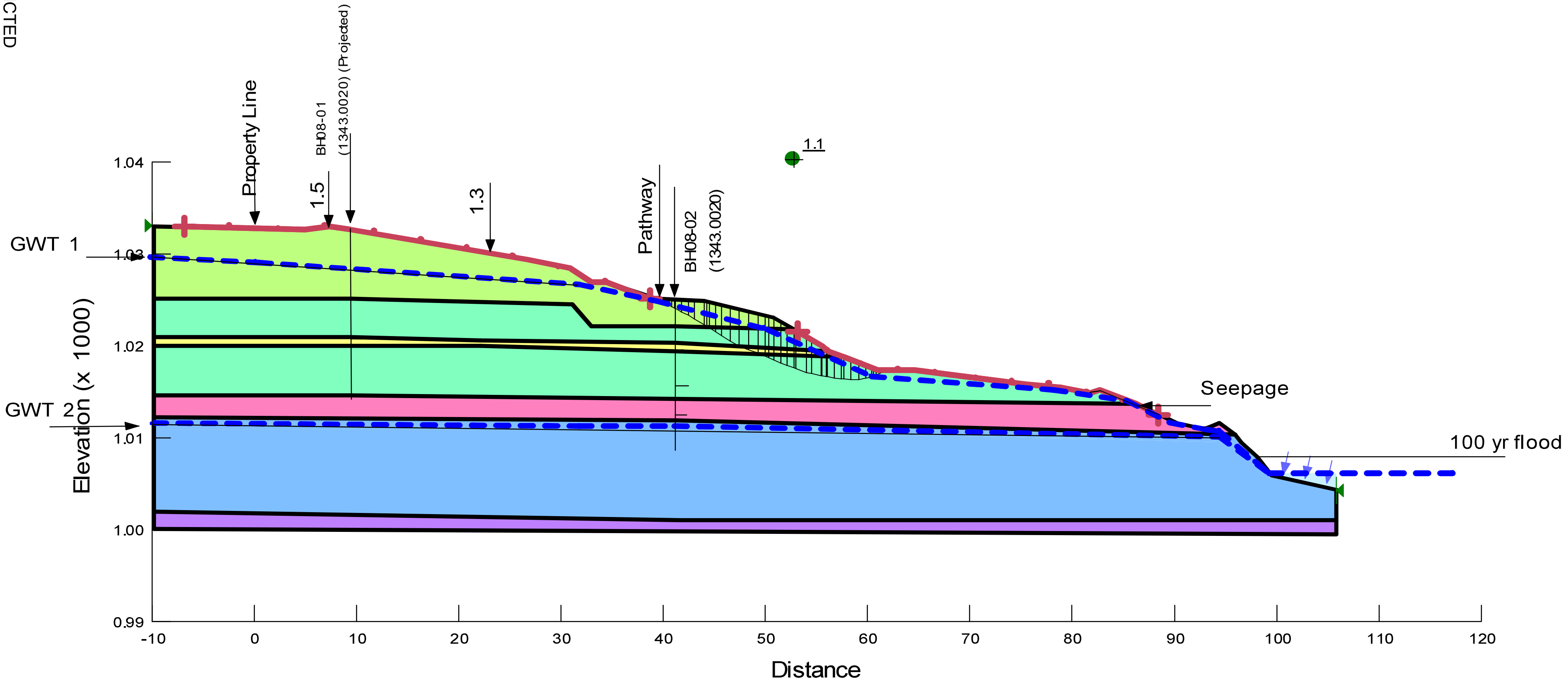
File Name: Section 3 1.0-AE-AW.gsz

ISC: UNRESTRICTED

Name: Till - Clay Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 26 ° Piezometric Line: 1
Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 1
Name: Till - Silt or Sandy Silt - Dense Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 33 ° Piezometric Line: 1
Name: Weathered Siltstone or Sandstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 2
Name: Competent Claystone or Mudstone Piezometric Line: 2
Name: Sand and Gravel Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 1



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 3 - CONTROLLING CREST FAILURE

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-9**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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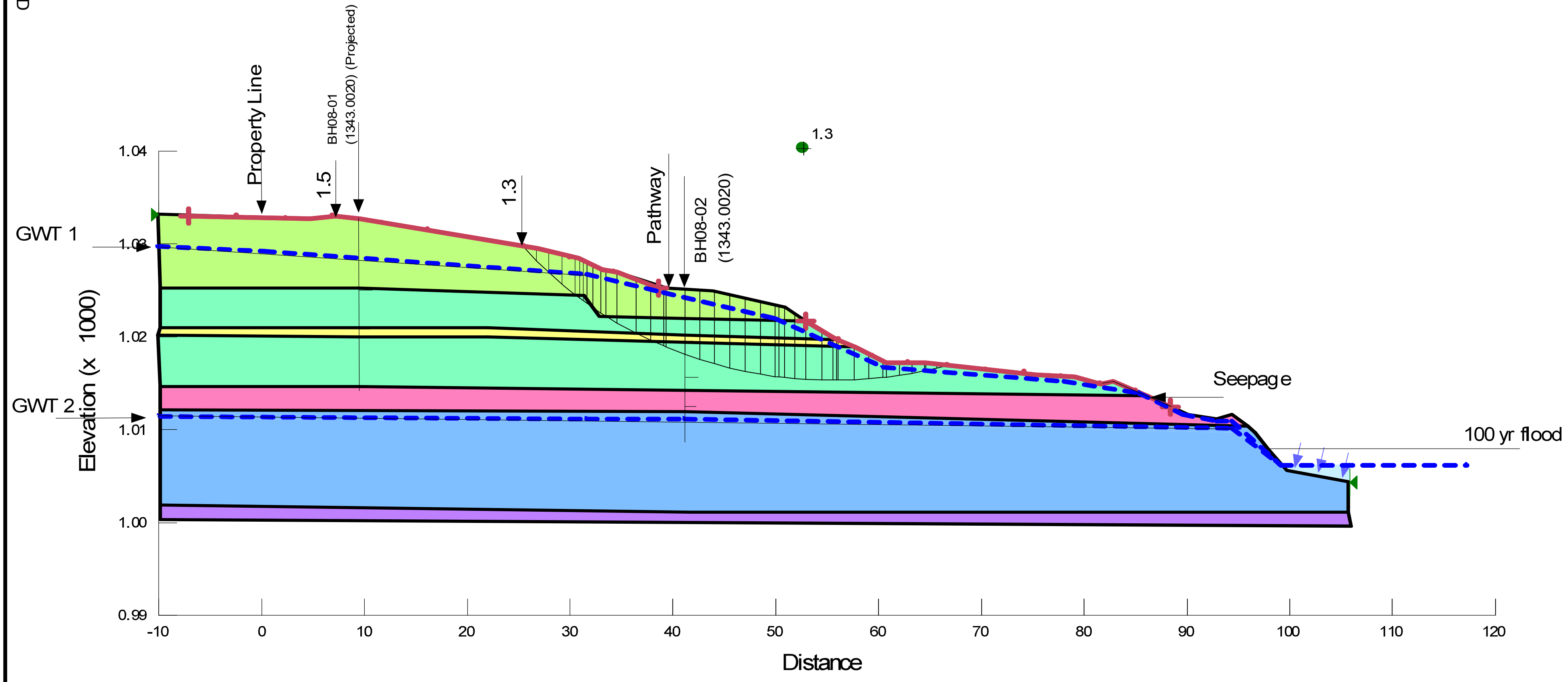
File Name: Section 3 1.0-AE-AW.gsz

ISC: UNRESTRICTED

Name: Till - Clay Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 26 ° Piezometric Line: 1
Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 1
Name: Till - Silt or Sandy Silt - Dense Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 33 ° Piezometric Line: 1
Name: Weathered Siltstone or Sandstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 2
Name: Competent Claystone or Mudstone Piezometric Line: 2
Name: Sand and Gravel Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 1



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 3 - CREST FAILURE - FOS 1.3

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-10**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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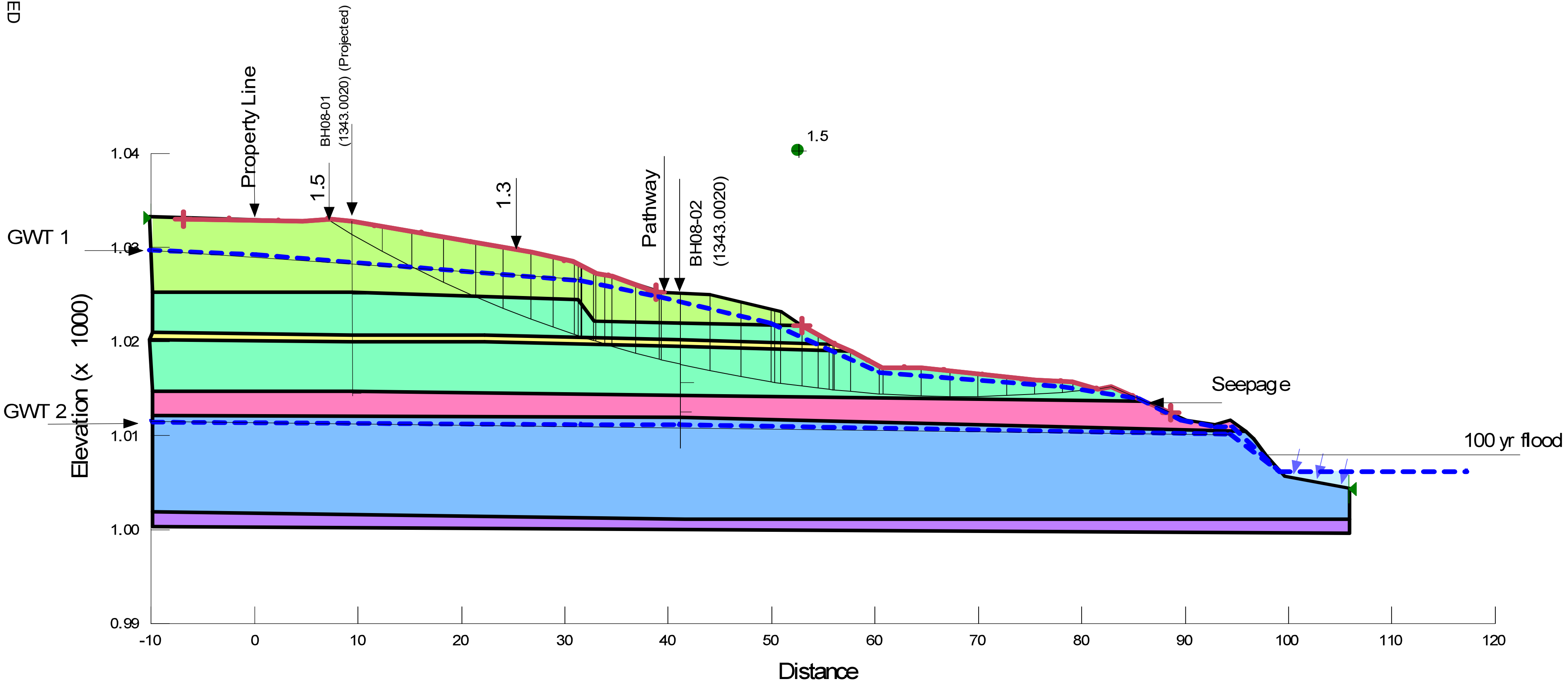
File Name: Section 3 1.0-AE-AW.gsz

ISC: UNRESTRICTED

Name: Till - Clay   Unit Weight: 19 kN/m³   Cohesion: 0 kPa   Phi: 26 °   Piezometric Line: 1
Name: Till - Silty Clay or Clayey Silt - Stiff   Unit Weight: 19 kN/m³   Cohesion: 2 kPa   Phi: 28 °   Piezometric Line: 1
Name: Till - Silt or Sandy Silt - Dense   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 33 °   Piezometric Line: 1
Name: Weathered Siltstone or Sandstone   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 38 °   Piezometric Line: 2
Name: Competent Claystone or Mudstone   Piezometric Line: 2
Name: Sand and Gravel   Unit Weight: 21 kN/m³   Cohesion: 0 kPa   Phi: 38 °   Piezometric Line: 1



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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CITY OF CALGARY
DOUGLASDALE FEASIBILITY STUDY

SECTION 3 - CREST FAILURE - FOS 1.5

Design:	AW	5/4/2015	Project:	11-1321-0003.2200
Checked:	AE	5/5/2015	Rev:	0
Reviewed:	DEB	7/31/2015		

Figure: D-11

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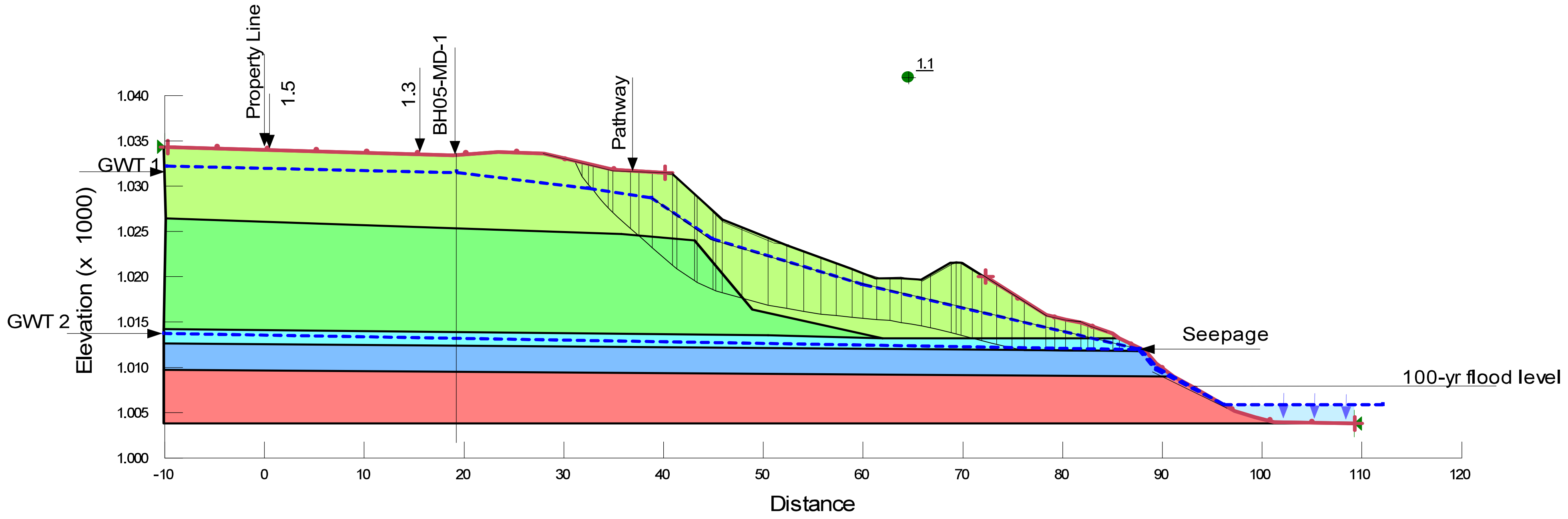
File Name: Section 4 1.0-AE-AW.gsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 1
Name: Till - Silty Clay or Clayey Silt - Hard Unit Weight: 20 kN/m³ Cohesion: 5 kPa Phi: 30 ° Piezometric Line: 1
Name: Weathered Claystone or Mudstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 22 ° Piezometric Line: 2
Name: Weathered Siltstone or Sandstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 2
Name: Competent Siltstone or Sandstone Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟪	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 4 - CONTROLLING CREST FAILURE

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-12**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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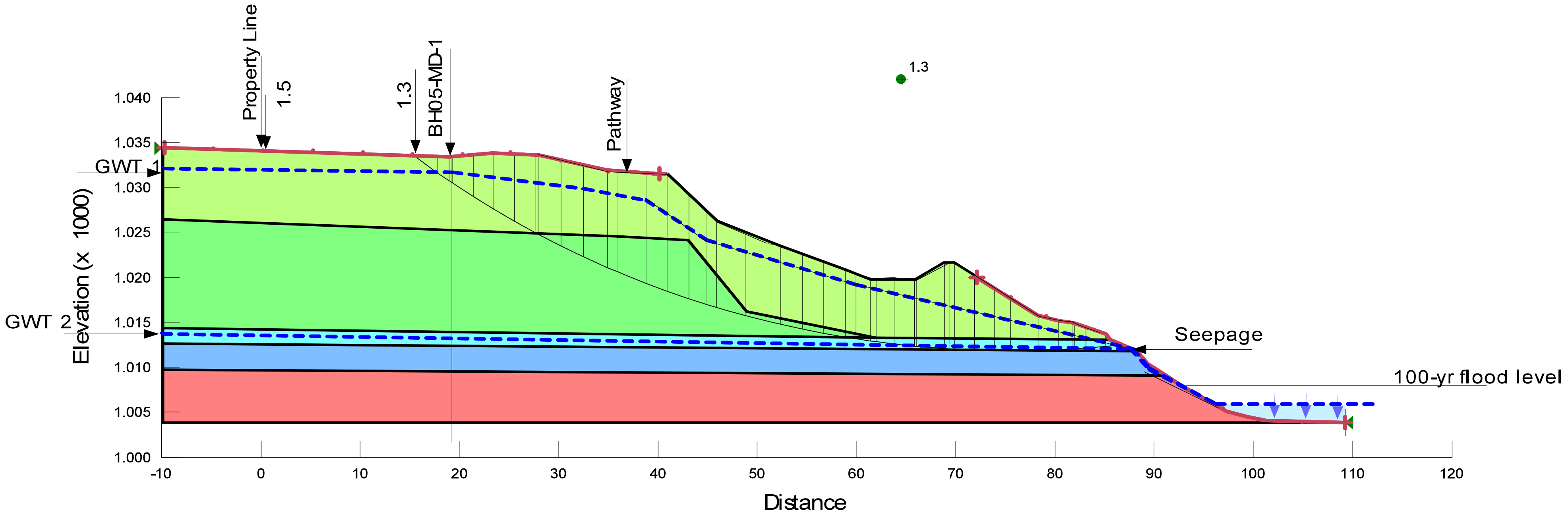
Directory: R:\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\01_Geotechnical\Slope Stability Analysis\Section 4\
File Name: Section 4 1.0-AE-AW.gsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 1
Name: Till - Silty Clay or Clayey Silt - Hard Unit Weight: 20 kN/m³ Cohesion: 5 kPa Phi: 30 ° Piezometric Line: 1
Name: Weathered Claystone or Mudstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 22 ° Piezometric Line: 2
Name: Weathered Siltstone or Sandstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 2
Name: Competent Siltstone or Sandstone Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟪	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 4 - CREST FAILURE - FOS 1.3

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-13**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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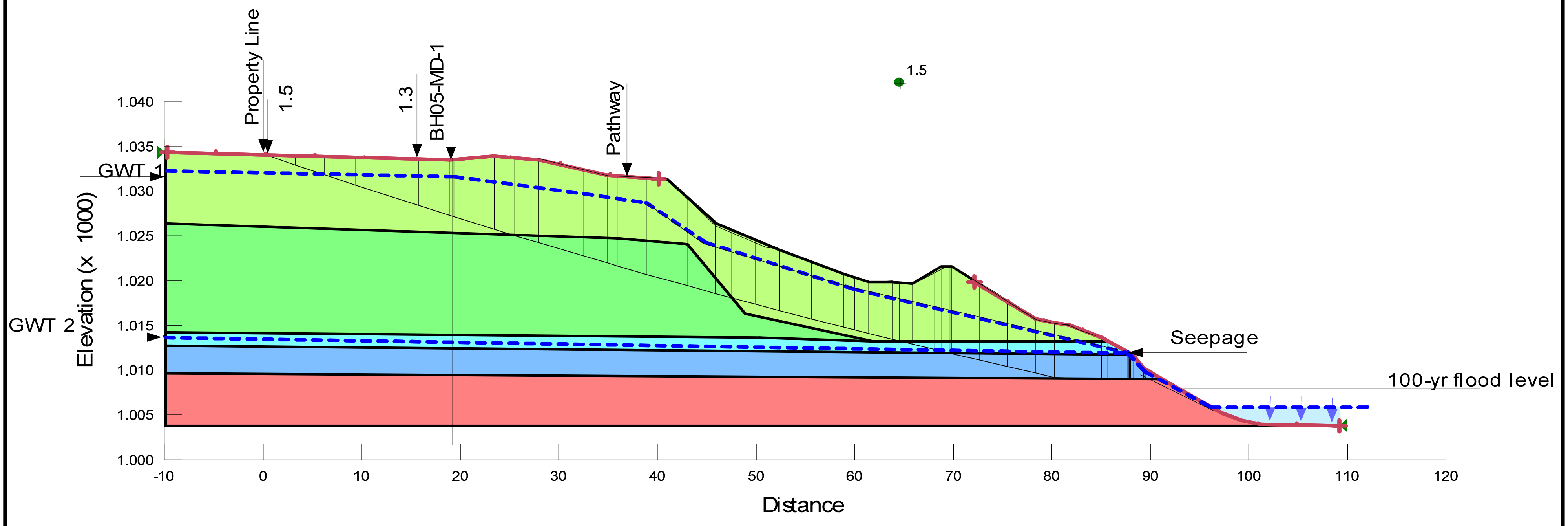
Directory: R:\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\01_Geotechnical\Slope Stability Analysis\Section 4\
File Name: Section 4 1.0-AE-AW.gsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 1
Name: Till - Silty Clay or Clayey Silt - Hard Unit Weight: 20 kN/m³ Cohesion: 5 kPa Phi: 30 ° Piezometric Line: 1
Name: Weathered Claystone or Mudstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 22 ° Piezometric Line: 2
Name: Weathered Siltstone or Sandstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 2
Name: Competent Siltstone or Sandstone Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟪	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 4 - CREST FAILURE - FOS 1.5

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-14**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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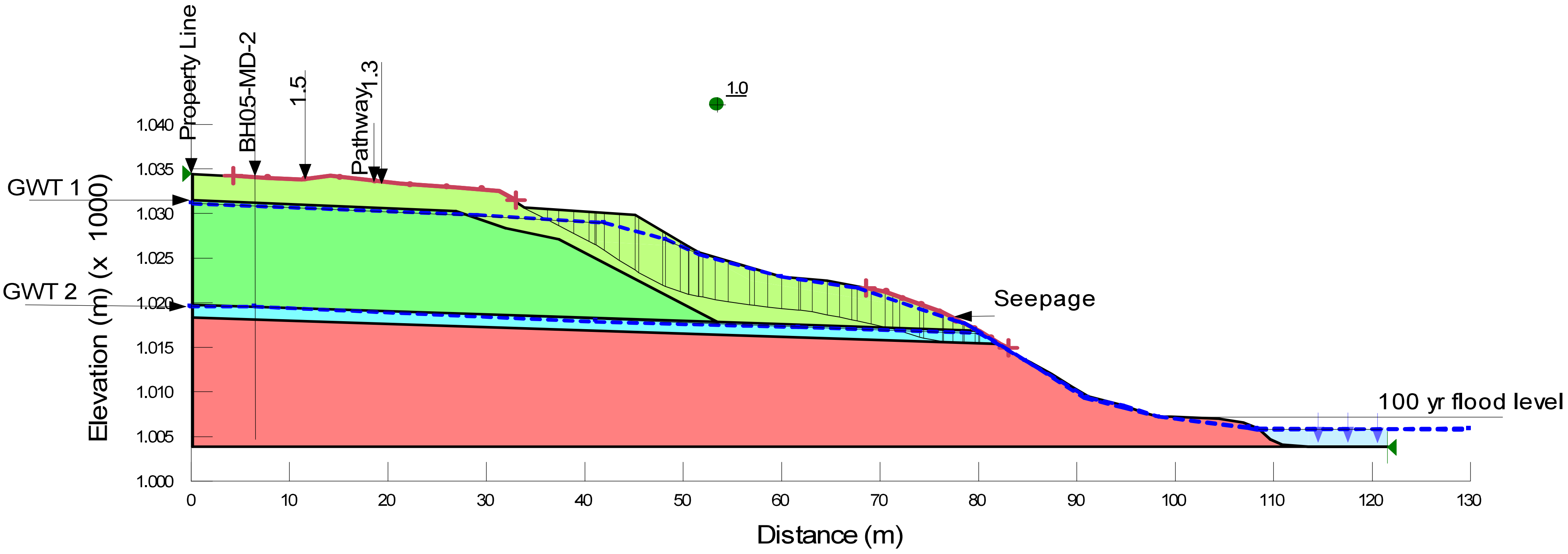
Directory: R:\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\01_Geotechnical\Slope Stability Analysis\Section 5\
File Name: Section 5 1.0-Stage 3-AE2-AW-change profile.gsz

ISC: UNRESTRICTED

Name: Tilll - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 1
Name: Till - Silty Clay or Clayey Silt - Hard Unit Weight: 20 kN/m³ Cohesion: 5 kPa Phi: 30 ° Piezometric Line: 1
Name: Weathered Claystone or Mudstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 22 ° Piezometric Line: 2
Name: Competent Siltstone or Sandstone Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟪	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 5 - CONTROLLING CREST FAILURE

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-15**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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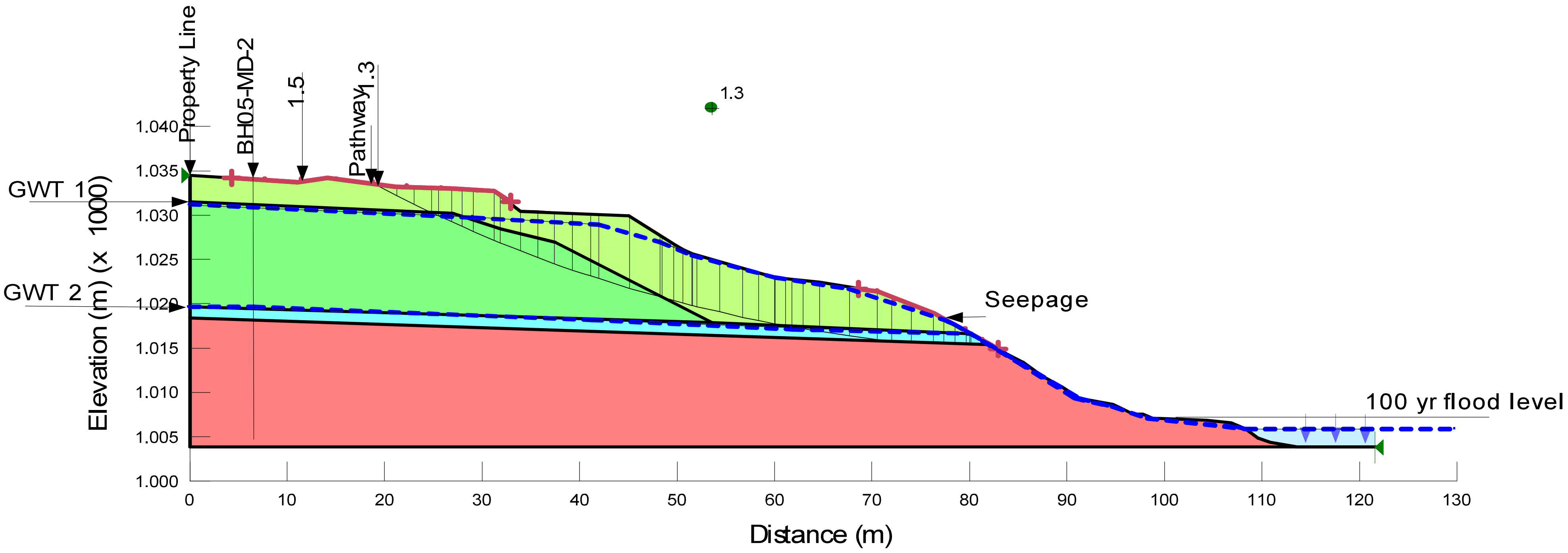
File Name: Section 5 1.0-Stage 3-AE2-AW-change profile.gsz

Name: Tilll - Silty Clay or Clayey Silt - Stiff   Unit Weight: 19 kN/m³   Cohesion: 2 kPa   Phi: 28 °   Piezometric Line: 1
Name: Till - Silty Clay or Clayey Silt - Hard   Unit Weight: 20 kN/m³   Cohesion: 5 kPa   Phi: 30 °   Piezometric Line: 1
Name: Weathered Claystone or Mudstone   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 22 °   Piezometric Line: 2
Name: Competent Siltstone or Sandstone   Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 5 - CREST FAILURE - FOS 1.3

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-16**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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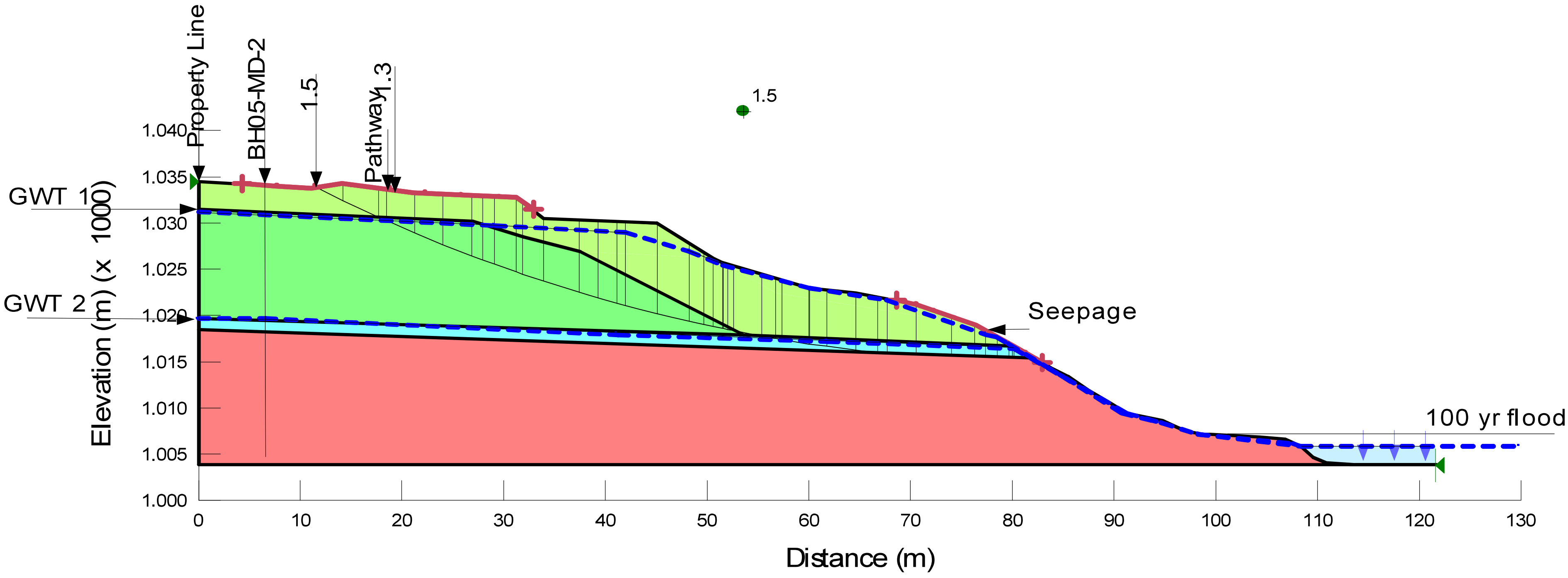
Directory: R:\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\01_Geotechnical\Slope Stability Analysis\Section 5\
File Name: Section 5 1.0-Stage 3-AE2-AW-change profile.gsz

Name: Tilll - Silty Clay or Clayey Silt - Stiff	Unit Weight: 19 kN/m³	Cohesion: 2 kPa	Phi: 28 °	Piezometric Line: 1
Name: Till - Silty Clay or Clayey Silt - Hard	Unit Weight: 20 kN/m³	Cohesion: 5 kPa	Phi: 30 °	Piezometric Line: 1
Name: Weathered Claystone or Mudstone	Unit Weight: 20 kN/m³	Cohesion: 0 kPa	Phi: 22 °	Piezometric Line: 2
Name: Competent Siltstone or Sandstone	Piezometric Line: 2			



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟪	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 5 CREST FAILURE - FOS 1.5

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-17**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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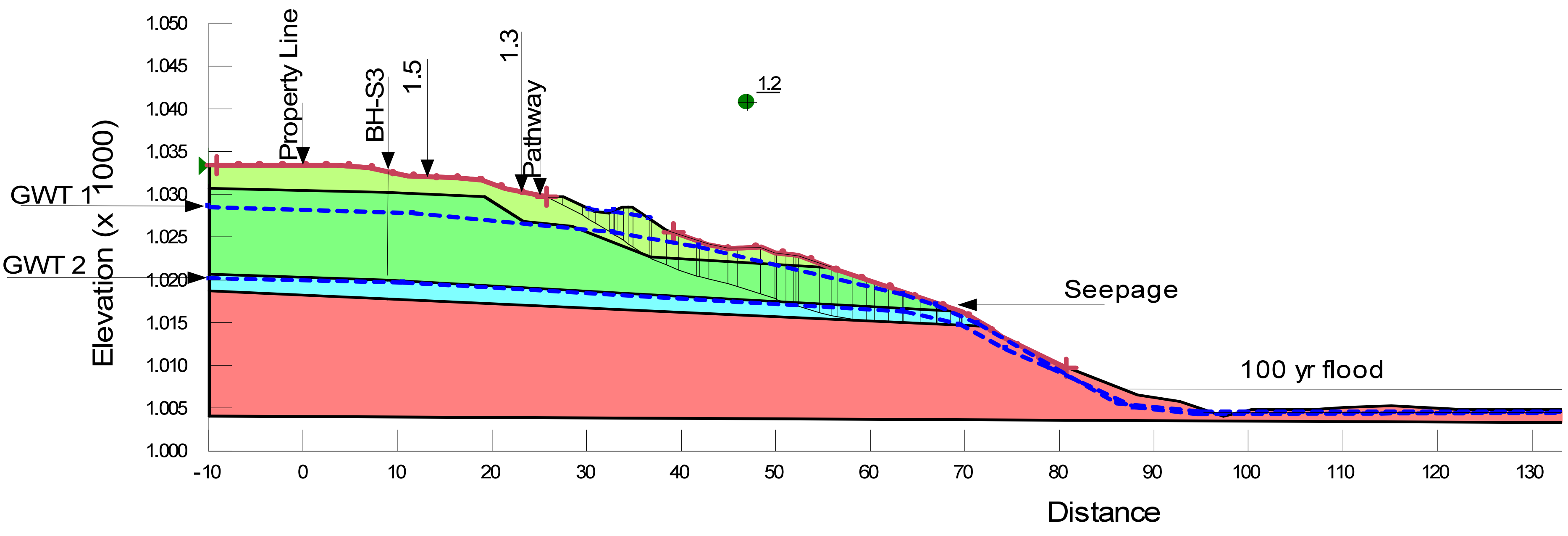
Directory: R:\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\01_Geotechnical\Slope Stability Analysis\Section 6\
File Name: Section 6 1.0-AE2-AW-RC.gsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 3
Name: Till - Silty Clay or Clayey Silt - Hard Unit Weight: 20 kN/m³ Cohesion: 5 kPa Phi: 30 ° Piezometric Line: 1
Name: Weathered Claystone or Mudstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 22 ° Piezometric Line: 2
Name: Competent Siltstone or Sandstone Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 6 - CONTROLLING CREST FAILURE

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-18**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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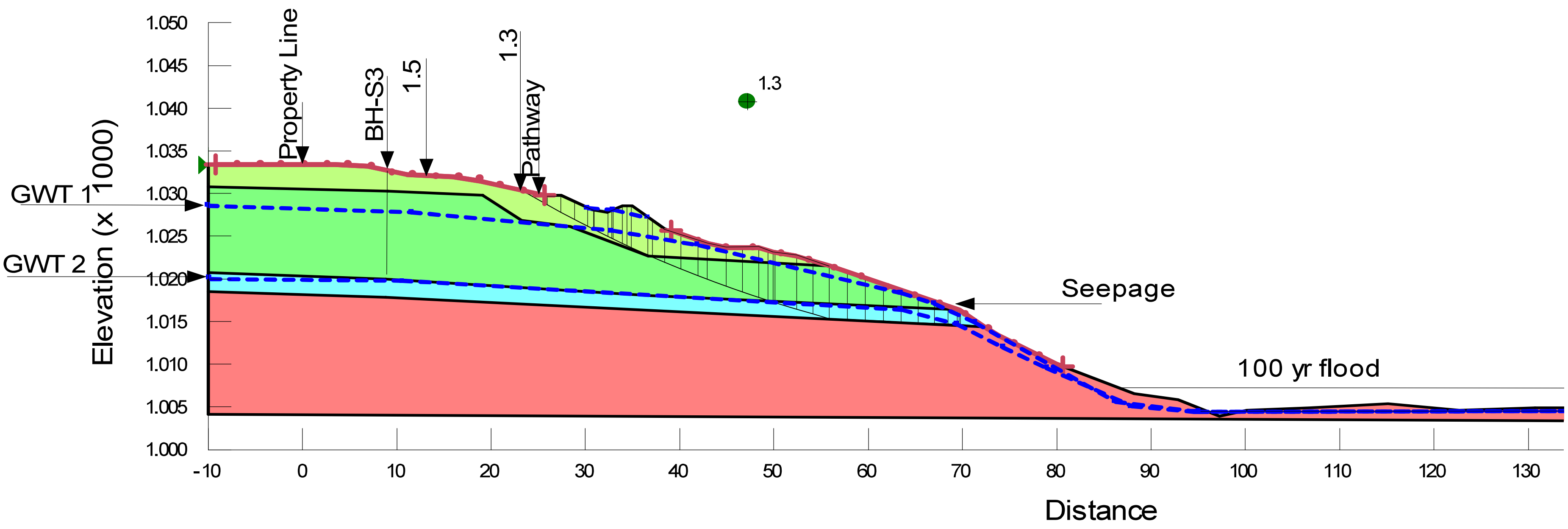
File Name: Section 6 1.0-AE2-AW-RC.gsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 3
Name: Till - Silty Clay or Clayey Silt - Hard Unit Weight: 20 kN/m³ Cohesion: 5 kPa Phi: 30 ° Piezometric Line: 1
Name: Weathered Claystone or Mudstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 22 ° Piezometric Line: 2
Name: Competent Siltstone or Sandstone Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 6 - CREST FAILURE - FOS 1.3

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-19**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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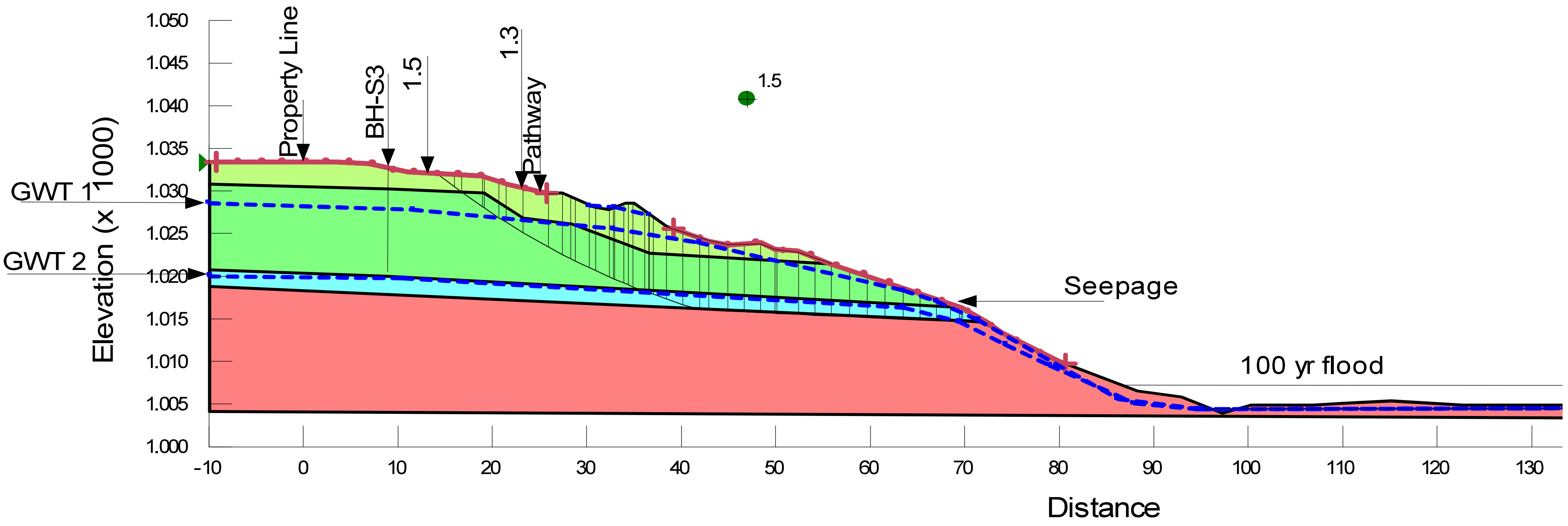
File Name: Section 6 1.0-AE2-AW-RC.gsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Stiff	Unit Weight: 19 kN/m³	Cohesion: 2 kPa	Phi: 28 °	Piezometric Line: 3
Name: Till - Silty Clay or Clayey Silt - Hard	Unit Weight: 20 kN/m³	Cohesion: 5 kPa	Phi: 30 °	Piezometric Line: 1
Name: Weathered Claystone or Mudstone	Unit Weight: 20 kN/m³	Cohesion: 0 kPa	Phi: 22 °	Piezometric Line: 2
Name: Competent Siltstone or Sandstone	Piezometric Line: 2			



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟪	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 6 - CREST FAILURE - FOS 1.5

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-20**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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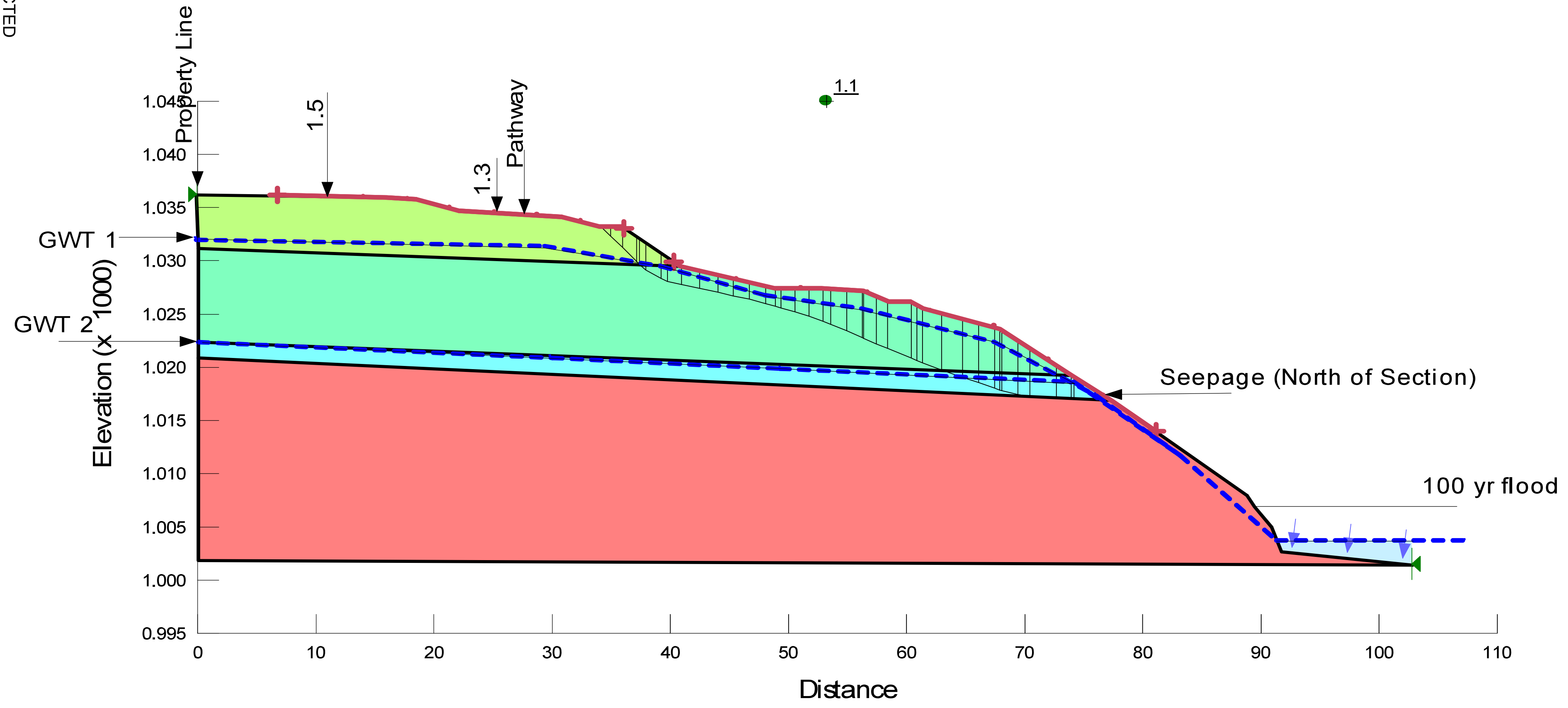
Directory: R:\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\01_Geotechnical\Slope Stability Analysis\Section 7\
File Name: Section 7 1.0-AE-AW claystone.gsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Stiff   Unit Weight: 19 kN/m³   Cohesion: 2 kPa   Phi: 28 °   Piezometric Line: 1
Name: Till - Silt or Sandy Silt - Dense   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 33 °   Piezometric Line: 1
Name: Weathered Claystone or Mudstone   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 22 °   Piezometric Line: 2
Name: Competent Siltstone or Sandstone   Piezometric Line: 2



Symbol	Soil
	Till - Clay
🟨	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 7 - CONTROLLING CREST FAILURE

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-21**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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ISC: UNRESTRICTED

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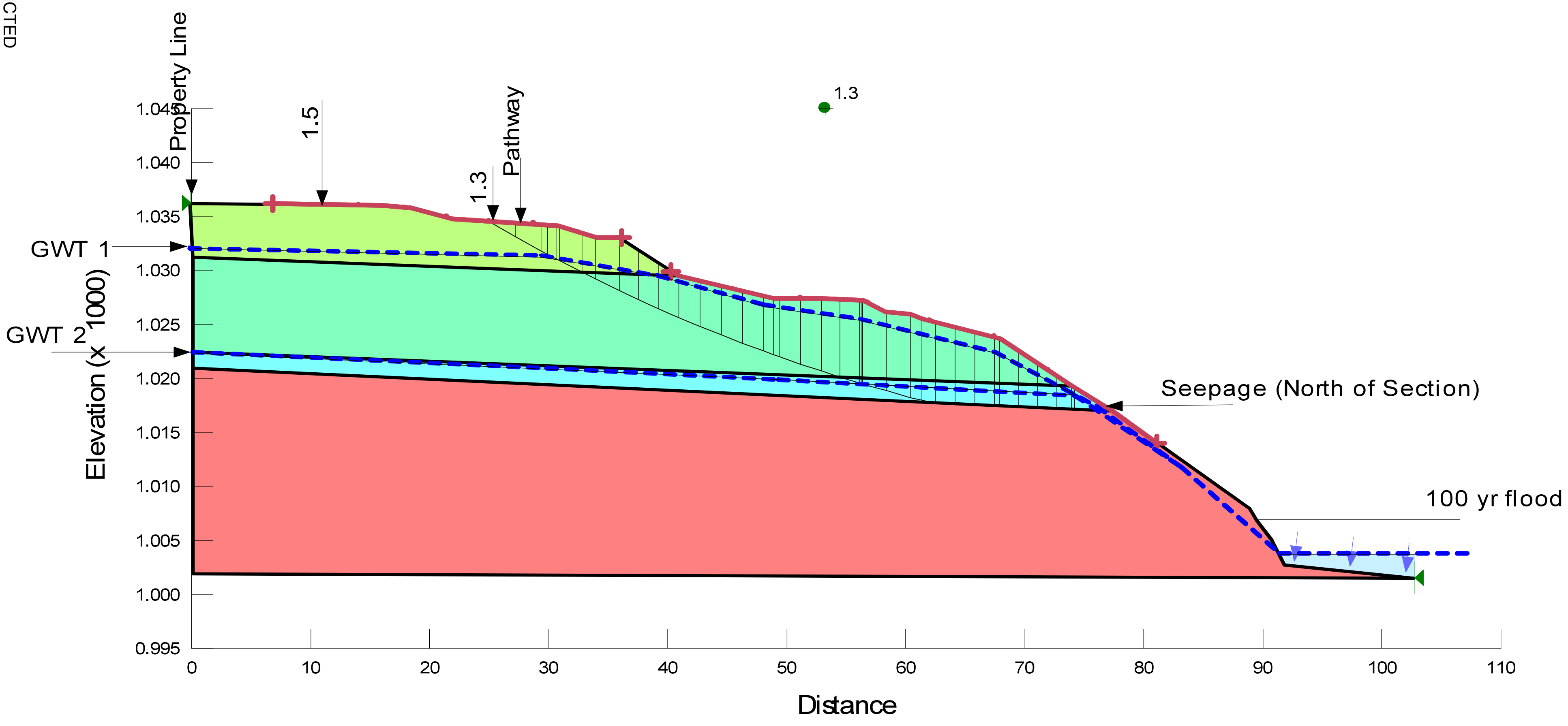
File Name: Section 7 1.0-AE-AW claystone.gsz

Name: Till - Silty Clay or Clayey Silt - Stiff   Unit Weight: 19 kN/m³   Cohesion: 2 kPa   Phi: 28 °   Piezometric Line: 1
Name: Till - Silt or Sandy Silt - Dense   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 33 °   Piezometric Line: 1
Name: Weathered Claystone or Mudstone   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 22 °   Piezometric Line: 2
Name: Competent Siltstone or Sandstone   Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 7 CREST FAILURE - FOS 1.3

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-22**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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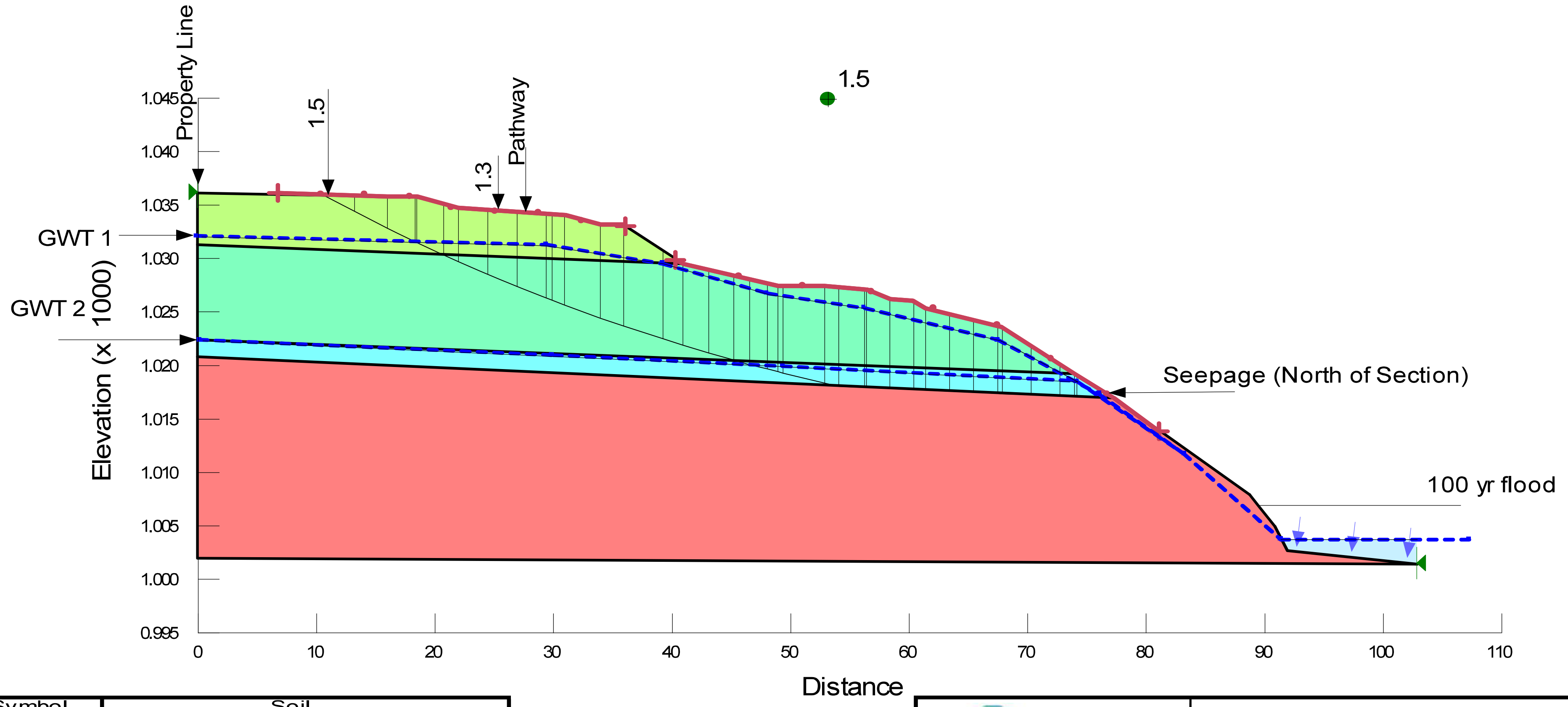
File Name: Section 7 1.0-AE-AW claystone.gsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 1
Name: Till - Silt or Sandy Silt - Dense Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 33 ° Piezometric Line: 1
Name: Weathered Claystone or Mudstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 22 ° Piezometric Line: 2
Name: Competent Siltstone or Sandstone Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟪	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 7 CREST FAILURE - FOS 1.5

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-23**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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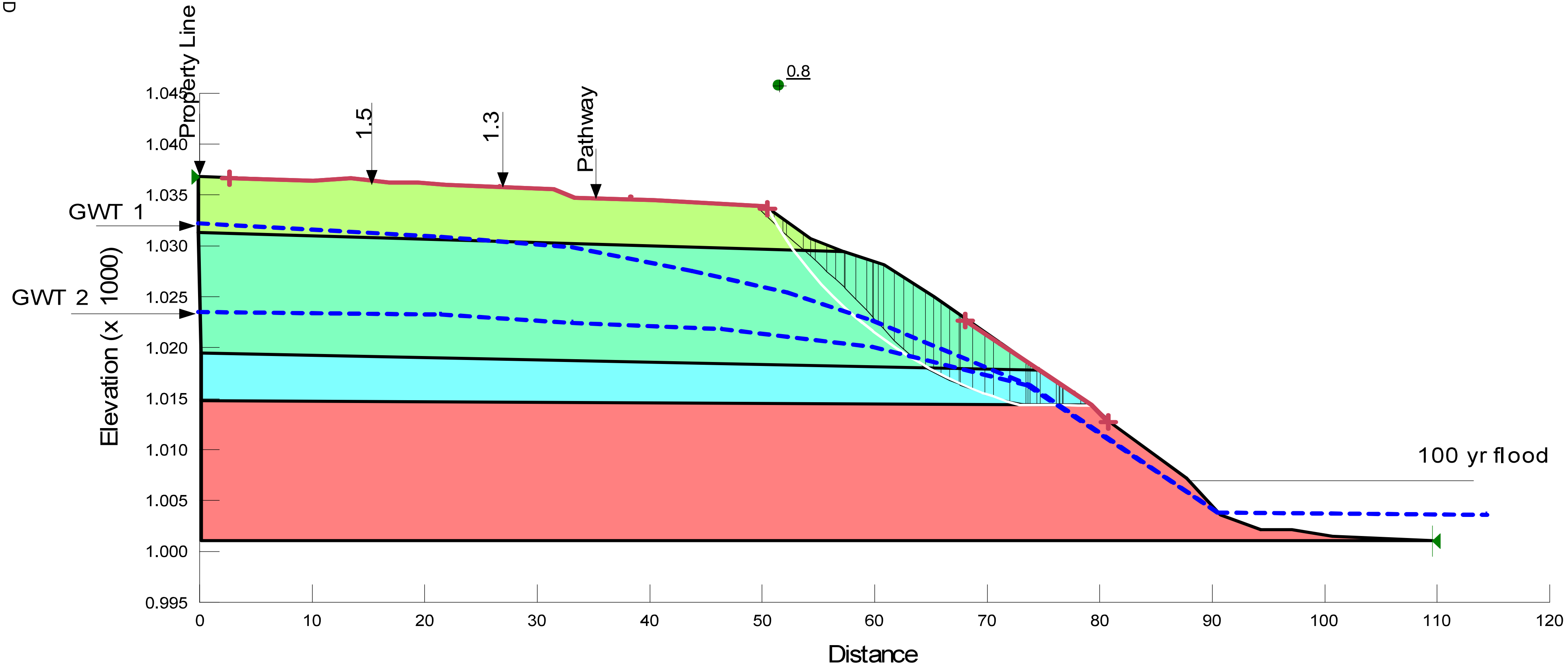
File Name: Section 8 1.0-AE-AW Claystone.gsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 1
Name: Till - Silt or Sandy Silt - Dense Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 33 ° Piezometric Line: 1
Name: Weathered Claystone or Mudstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 22 ° Piezometric Line: 2
Name: Competent Siltstone or Sandstone Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟪	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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CITY OF CALGARY
DOUGLASDALE FEASIBILITY STUDY

SECTION 8 - CONTROLLING CREST FAILURE

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-24**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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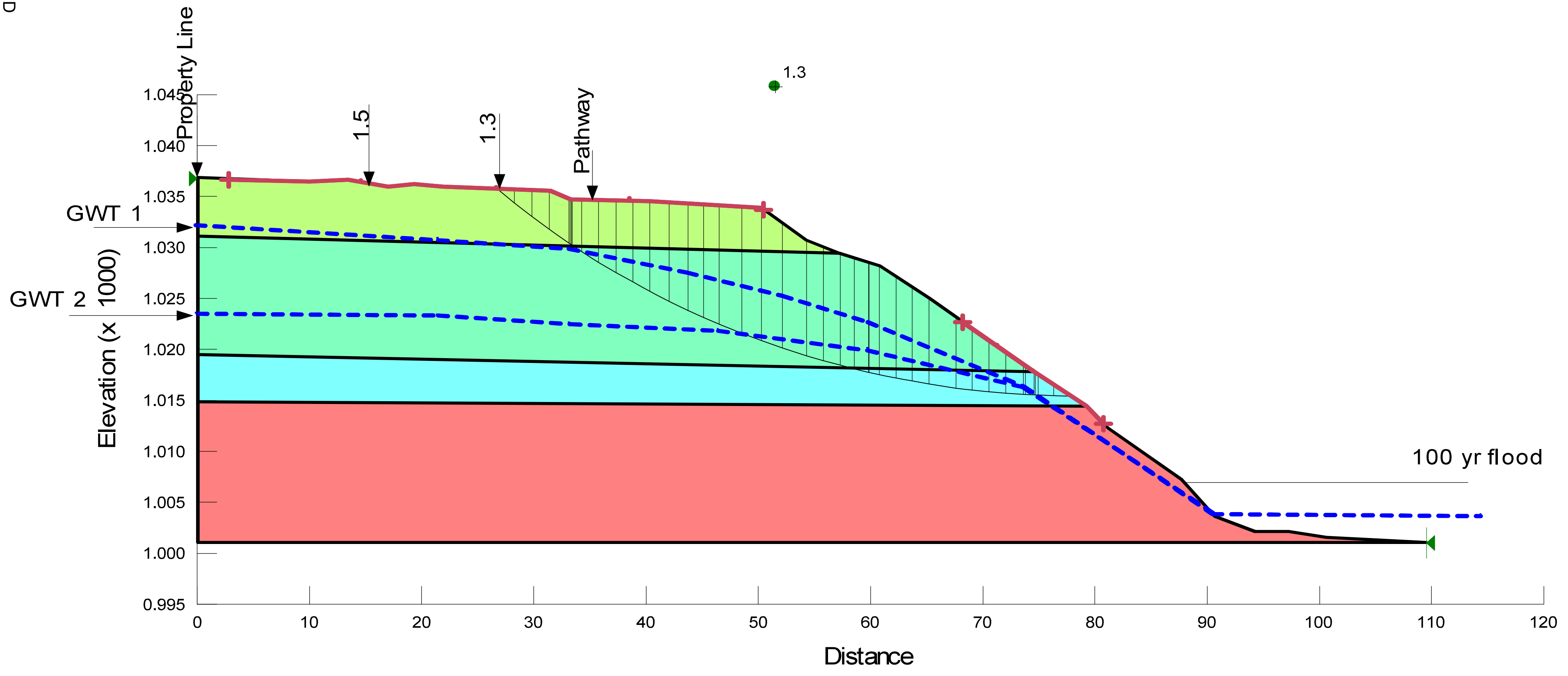
Directory: R:\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\01_Geotechnical\Slope Stability Analysis\Section 8
File Name: Section 8 1.0-AE-AW Claystone.gsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 1
Name: Till - Silt or Sandy Silt - Dense Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 33 ° Piezometric Line: 1
Name: Weathered Claystone or Mudstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 22 ° Piezometric Line: 2
Name: Competent Siltstone or Sandstone Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟪	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 8 - CREST FAILURE - FOS 1.3

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-25**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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ATTACHMENT 2

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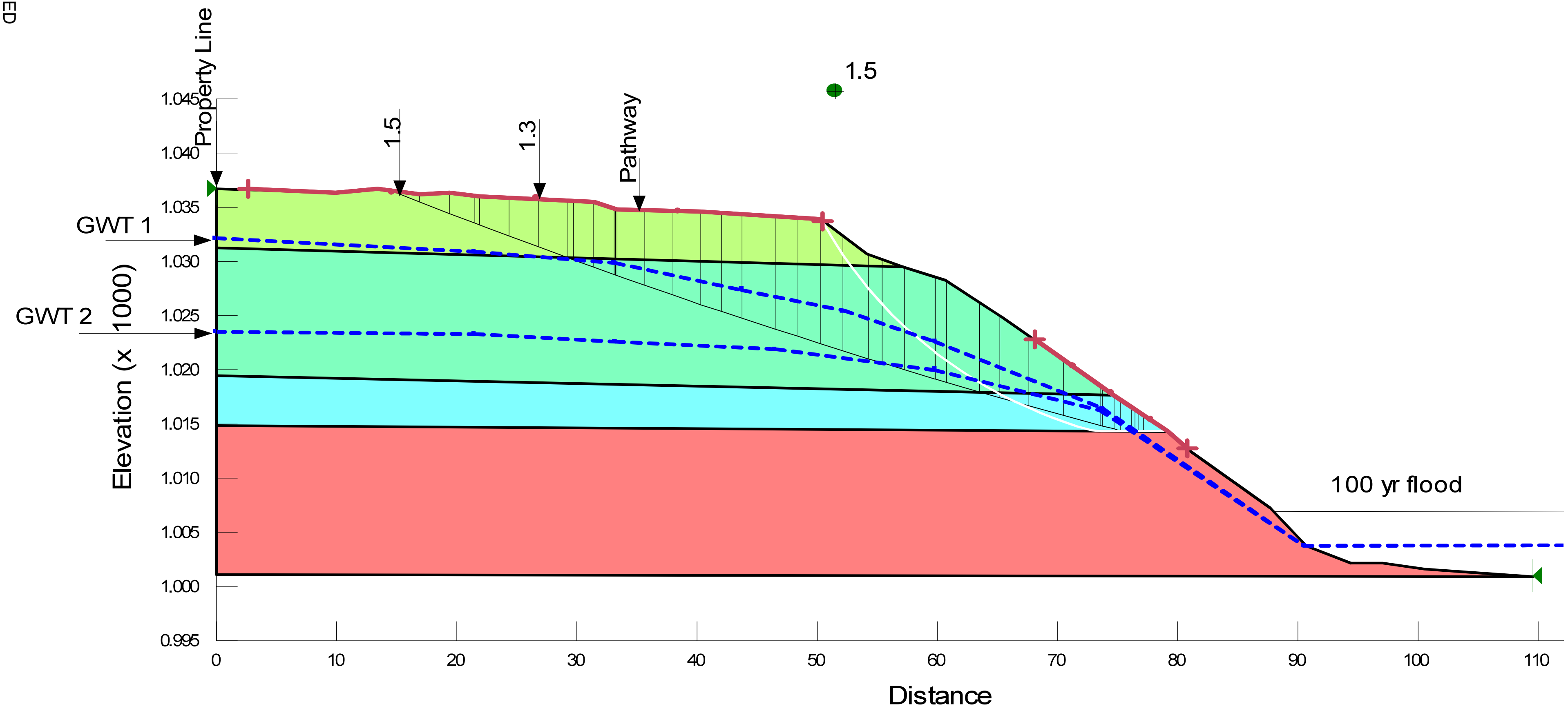
Directory: R:\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\01_Geotechnical\Slope Stability Analysis\Section 8\
File Name: Section 8 1.0-AE-AW Claystone.gsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 1
Name: Till - Silt or Sandy Silt - Dense Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 33 ° Piezometric Line: 1
Name: Weathered Claystone or Mudstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 22 ° Piezometric Line: 2
Name: Competent Siltstone or Sandstone Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟪	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 8 - CREST FAILURE - FOS 1.5

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-26**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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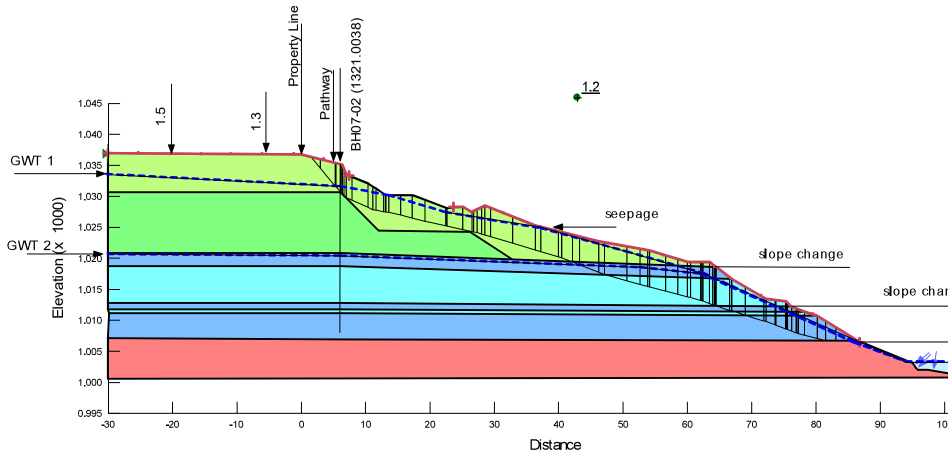
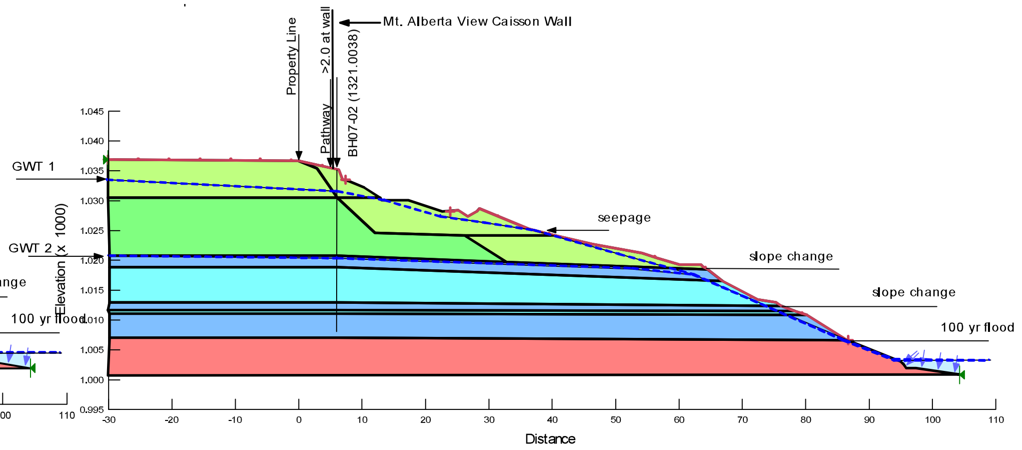
Directory: R:\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\01_Geotechnical\Slope Stability Analysis\Section 9\
File Name: Section 9 1.0-AE2-AW.gsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 1
Name: Till - Silty Clay or Clayey Silt - Hard Unit Weight: 20 kN/m³ Cohesion: 5 kPa Phi: 30 ° Piezometric Line: 1
Name: Weathered Claystone or Mudstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 22 ° Piezometric Line: 2
Name: Weathered Siltstone or Sandstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 2
Name: Competent Siltstone or Sandstone Piezometric Line: 2



Calculated factor of safety for slope areas north and south of the Mt. Alberta View wall.



The calculated factor of safety for the overall slope at the Mt. Alberta View wall has been designed to be greater than 2.0.

Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟪	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 9 - CONTROLLING CREST FAILURE

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-27**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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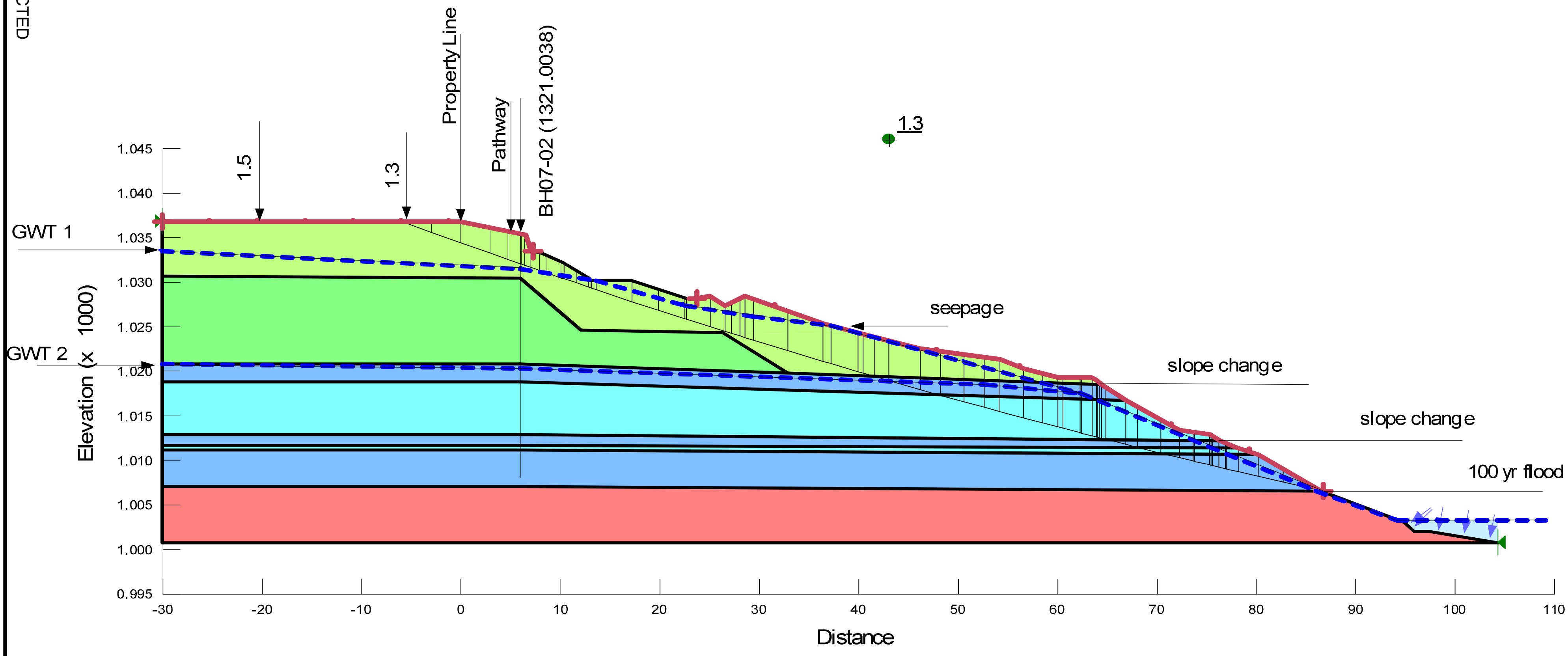
Directory: R:\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\01_Geotechnical\Slope Stability Analysis\Section 9\
File Name: Section 9 1.0-AE2-AW.gsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 1
Name: Till - Silty Clay or Clayey Silt - Hard Unit Weight: 20 kN/m³ Cohesion: 5 kPa Phi: 30 ° Piezometric Line: 1
Name: Weathered Claystone or Mudstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 22 ° Piezometric Line: 2
Name: Weathered Siltstone or Sandstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 2
Name: Competent Siltstone or Sandstone Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟪	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 9 - CREST FAILURE - FOS 1.3

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-28**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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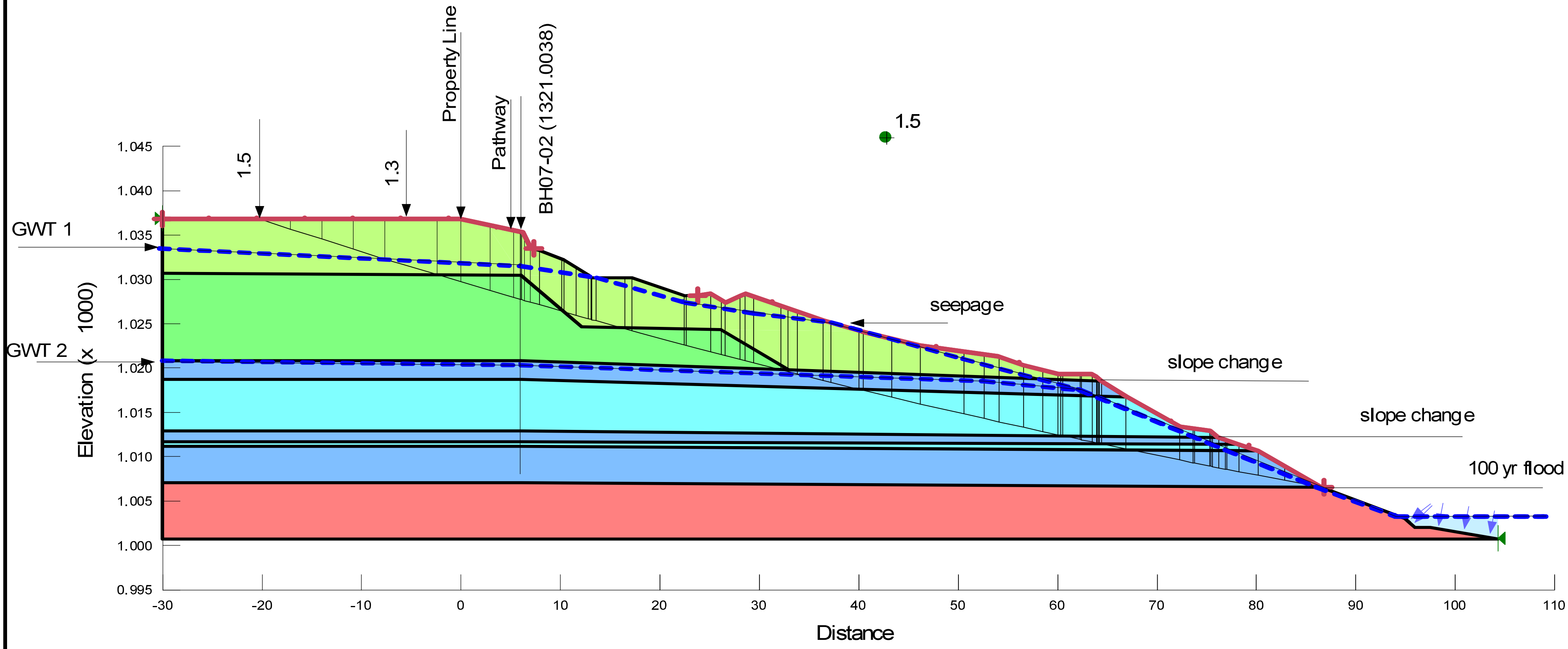
Directory: R:\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\01_Geotechnical\Slope Stability Analysis\Section 9\
File Name: Section 9 1.0-AE2-AW.gsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 1
Name: Till - Silty Clay or Clayey Silt - Hard Unit Weight: 20 kN/m³ Cohesion: 5 kPa Phi: 30 ° Piezometric Line: 1
Name: Weathered Claystone or Mudstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 22 ° Piezometric Line: 2
Name: Weathered Siltstone or Sandstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 2
Name: Competent Siltstone or Sandstone Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 9 - CREST FAILURE - FOS 1.5

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-29**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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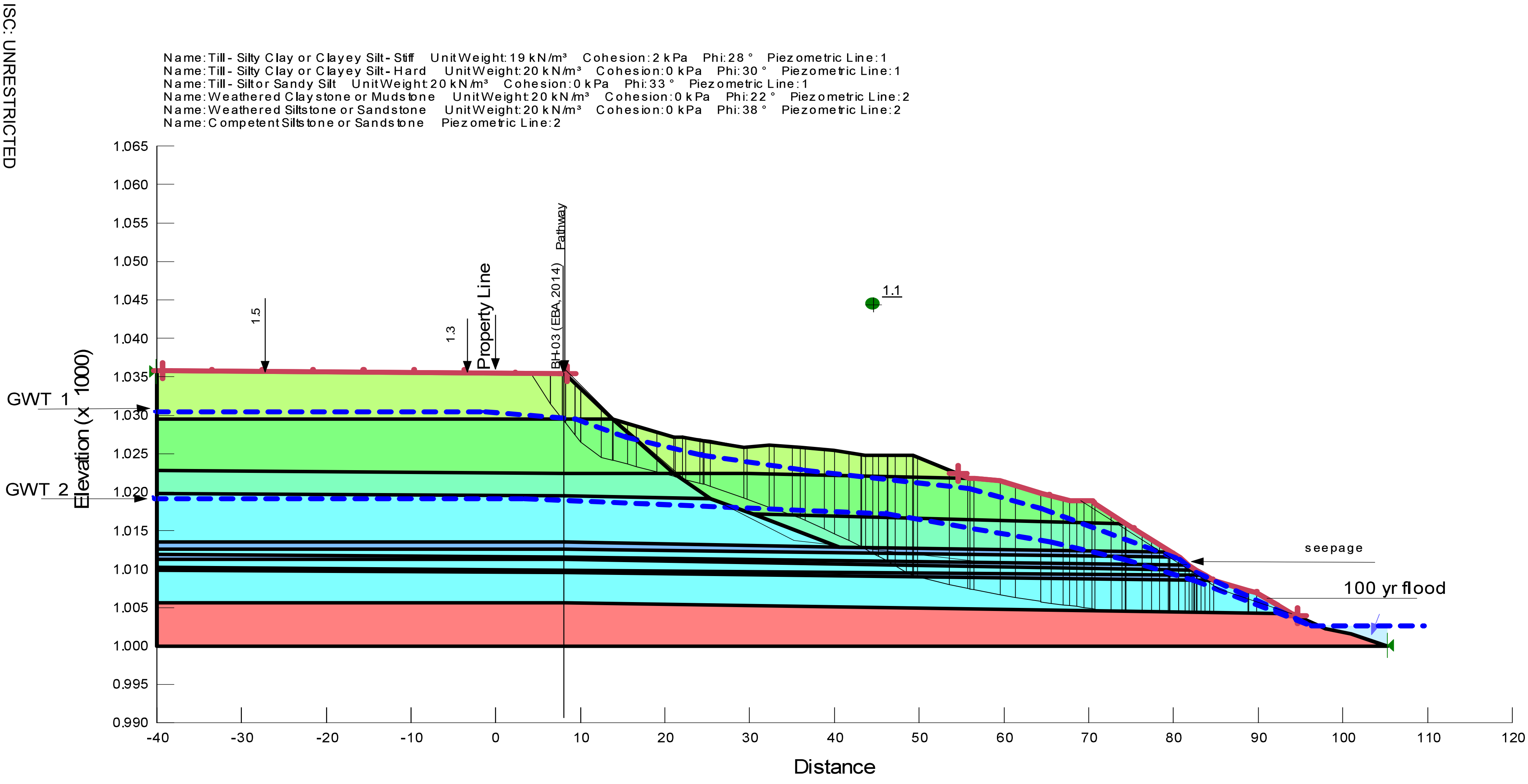
Directory: R:\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\01_Geotechnical\Slope Stability Analysis\Section 10\
File Name: 10_RC-AEgsz

ISC: UNRESTRICTED



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 10 - CONTROLLING CREST FAILURE

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-30**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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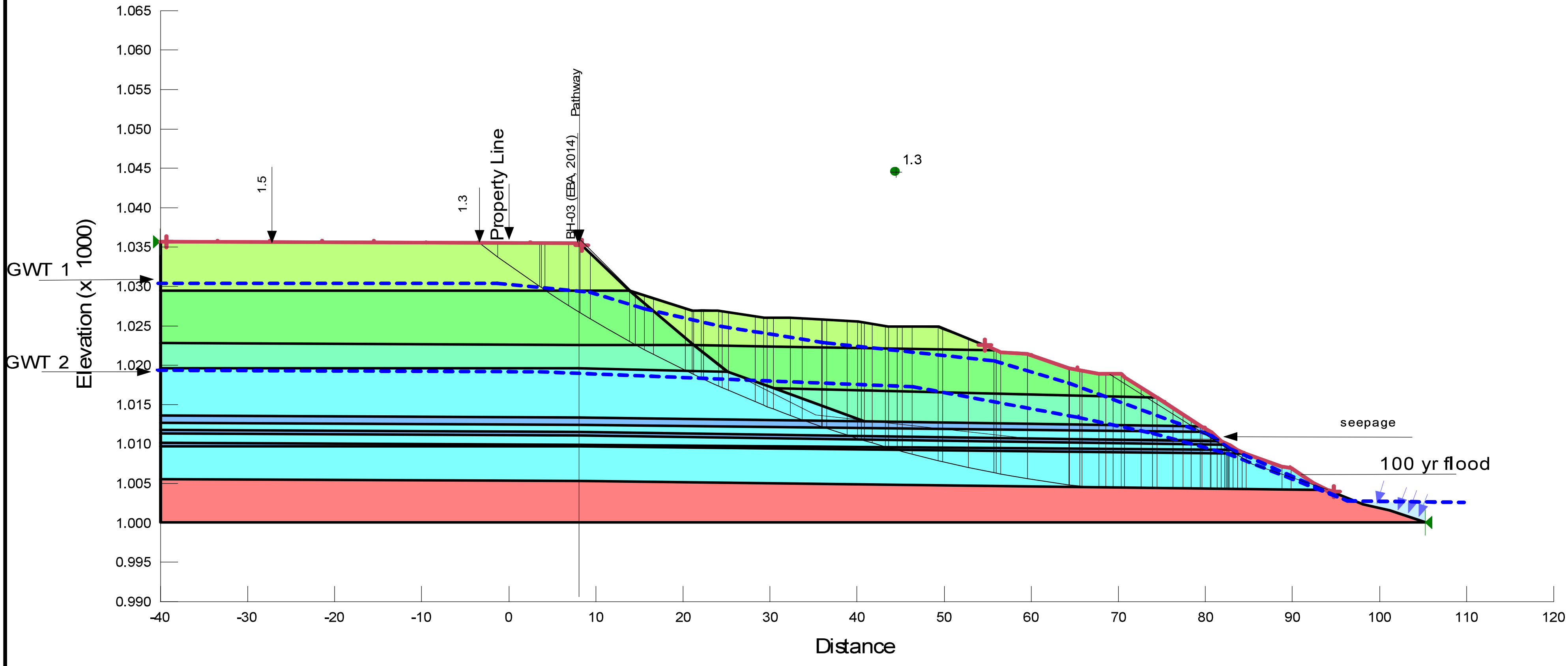
Directory: R:\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\01_Geotechnical\Slope Stability Analysis\Section 10\
File Name: 10_RC-AEgsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 1
Name: Till - Silty Clay or Clayey Silt - Hard Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 30 ° Piezometric Line: 1
Name: Till - Silt or Sandy Silt Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 33 ° Piezometric Line: 1
Name: Weathered Claystone or Mudstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 22 ° Piezometric Line: 2
Name: Weathered Siltstone or Sandstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 2
Name: Competent Siltstone or Sandstone Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 10 - CREST FAILURE - FOS 1.3

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-31**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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File Name: 10_RC-AE.gsz

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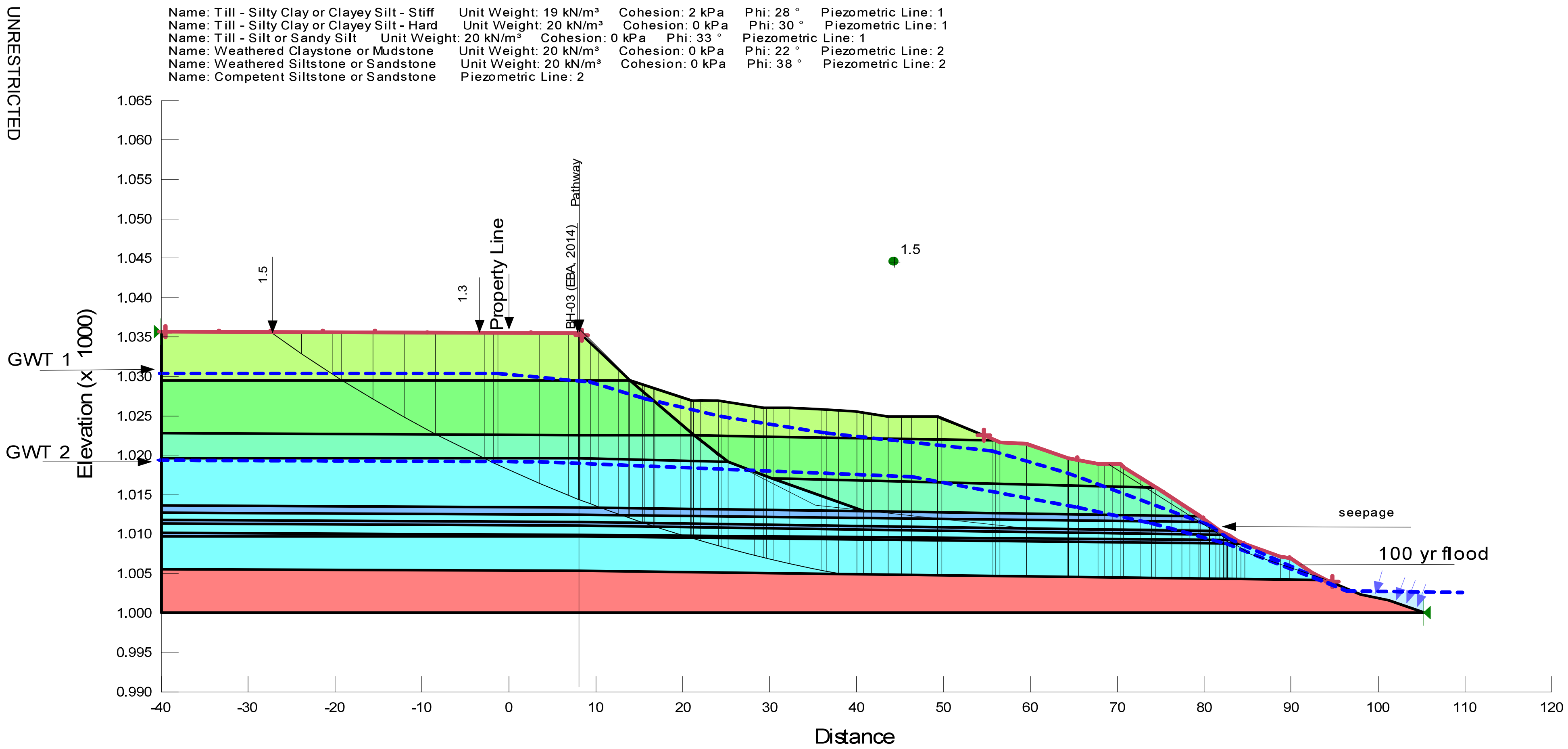

Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟪	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 10 - CREST FAILURE - FOS 1.5

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-32**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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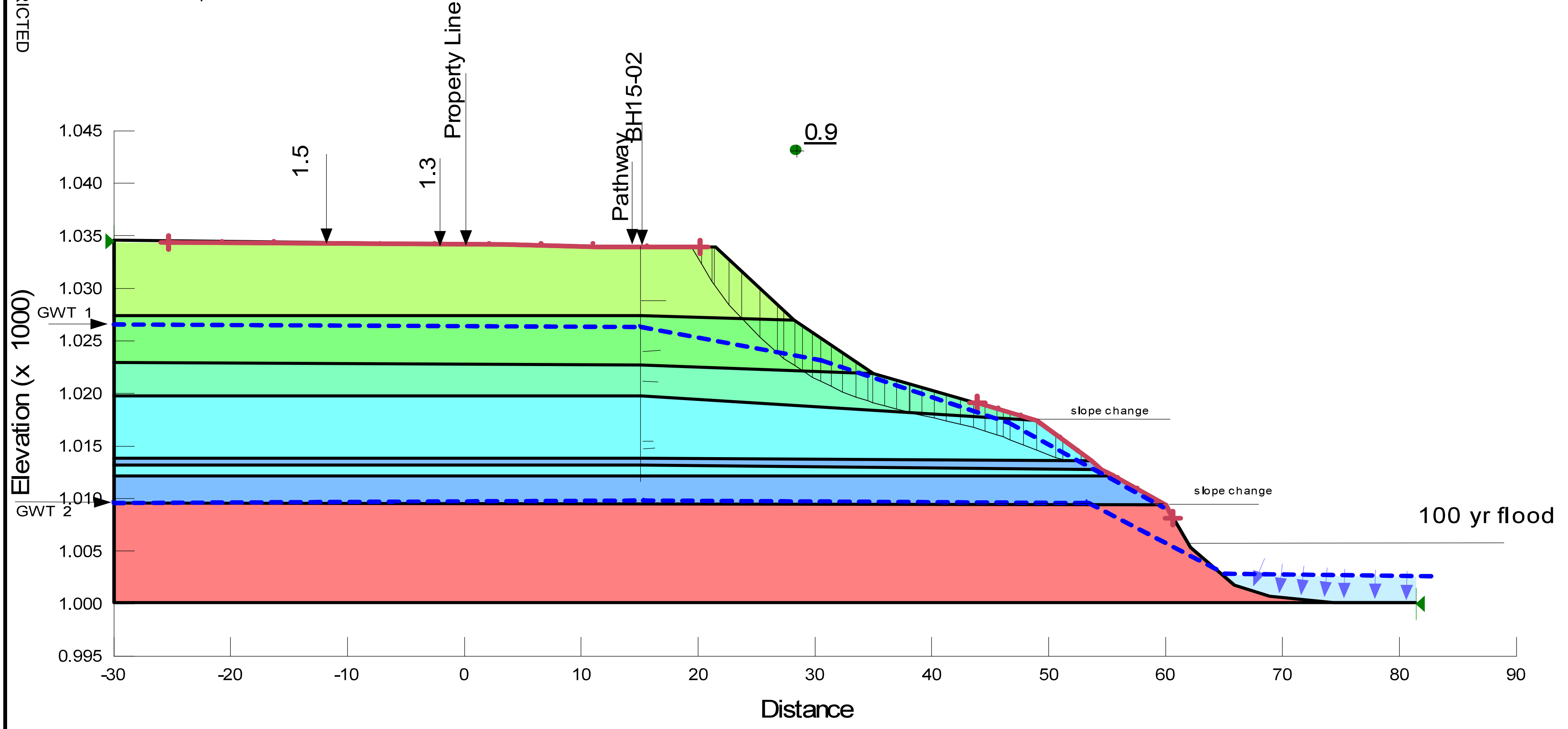
Directory: R:\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\01_Geotechnical\Slope Stability Analysis\Section 11\
File Name: Section 11 1.0-AE-AW.gsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Stiff   Unit Weight: 19 kN/m³   Cohesion: 2 kPa   Phi: 28 °   Piezometric Line: 1
Name: Till - Silty Clay or Clayey Silt - Hard   Unit Weight: 20 kN/m³   Cohesion: 5 kPa   Phi: 30 °   Piezometric Line: 1
Name: Till - Silt or Sandy Silt - Dense   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 33 °   Piezometric Line: 1
Name: Weathered Claystone or Mudstone   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 22 °   Piezometric Line: 2
Name: Weathered Siltstone or Sandstone   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 38 °   Piezometric Line: 2
Name: Competent Siltstone or Sandstone   Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 11 - CONTROLLING CREST FAILURE

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-33**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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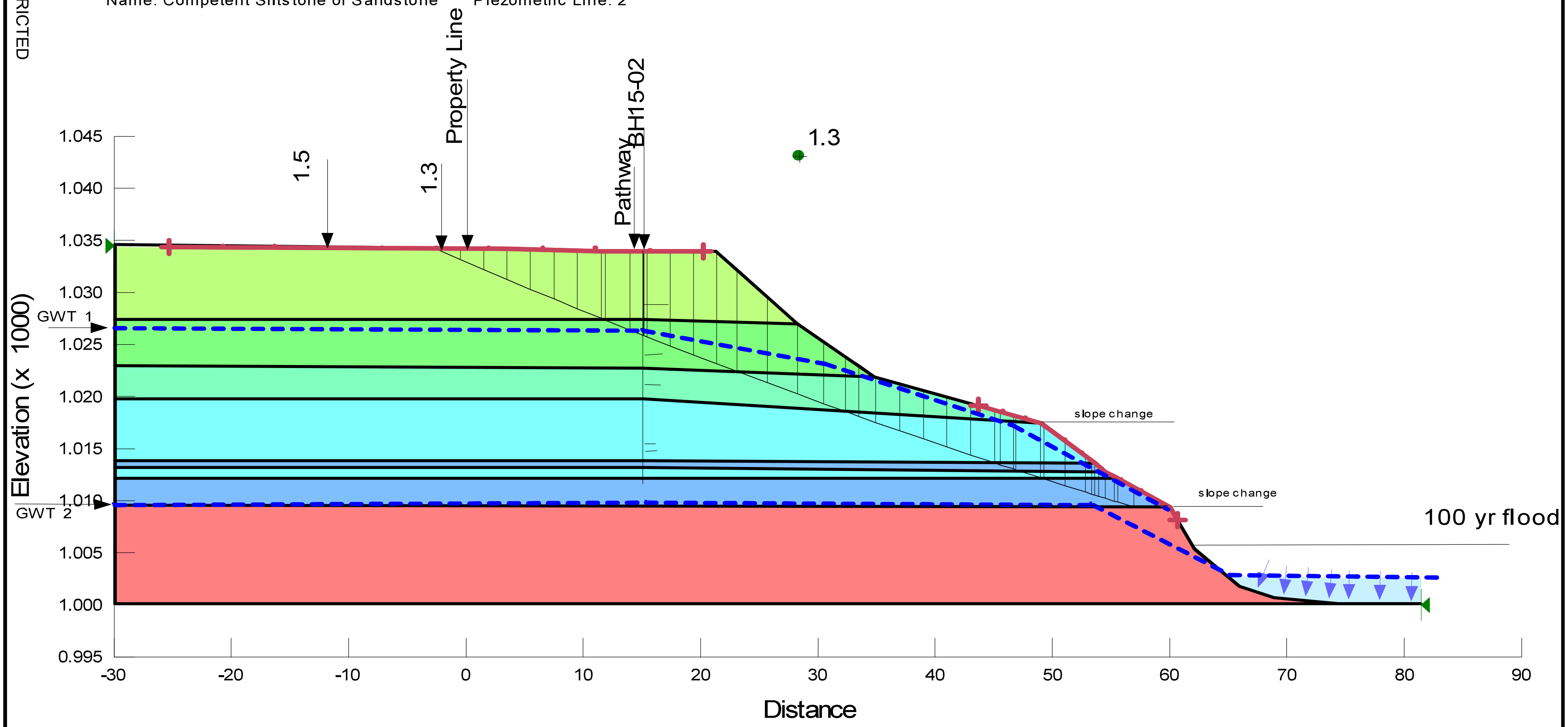
Directory: R:\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\01_Geotechnical\Slope Stability Analysis\Section 11\
File Name: Section 11 1.0-AE-AW.gsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 1
Name: Till - Silty Clay or Clayey Silt - Hard Unit Weight: 20 kN/m³ Cohesion: 5 kPa Phi: 30 ° Piezometric Line: 1
Name: Till - Silt or Sandy Silt - Dense Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 33 ° Piezometric Line: 1
Name: Weathered Claystone or Mudstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 22 ° Piezometric Line: 2
Name: Weathered Siltstone or Sandstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 2
Name: Competent Siltstone or Sandstone Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 11 - CREST FAILURE - FOS 1.3

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-34**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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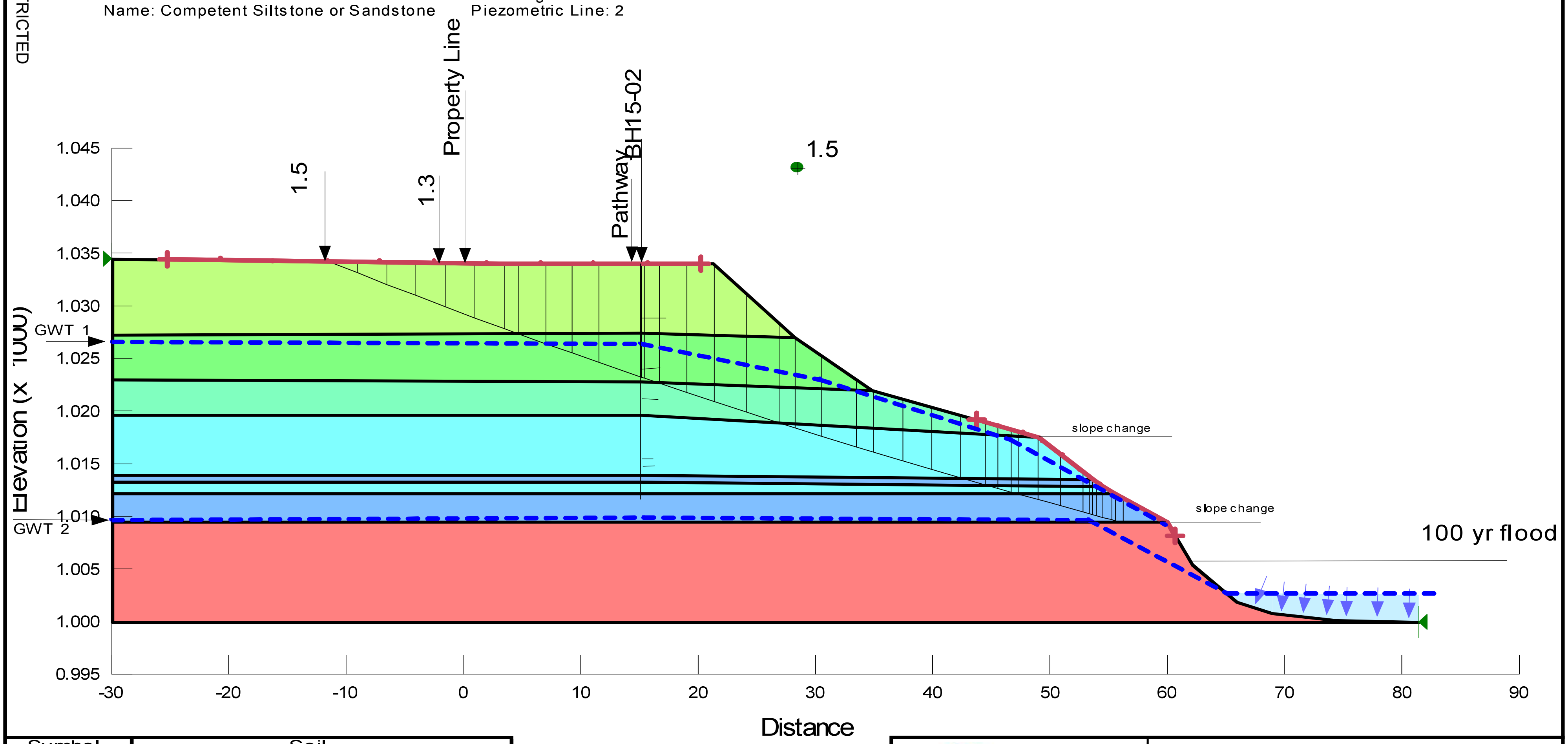
Directory: R:\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\01_Geotechnical\Slope Stability Analysis\Section 11\
File Name: Section 11 1.0-AE-AW.gsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Stiff Unit Weight: 19 kN/m³ Cohesion: 2 kPa Phi: 28 ° Piezometric Line: 1
Name: Till - Silty Clay or Clayey Silt - Hard Unit Weight: 20 kN/m³ Cohesion: 5 kPa Phi: 30 ° Piezometric Line: 1
Name: Till - Silt or Sandy Silt - Dense Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 33 ° Piezometric Line: 1
Name: Weathered Claystone or Mudstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 22 ° Piezometric Line: 2
Name: Weathered Siltstone or Sandstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 2
Name: Competent Siltstone or Sandstone Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

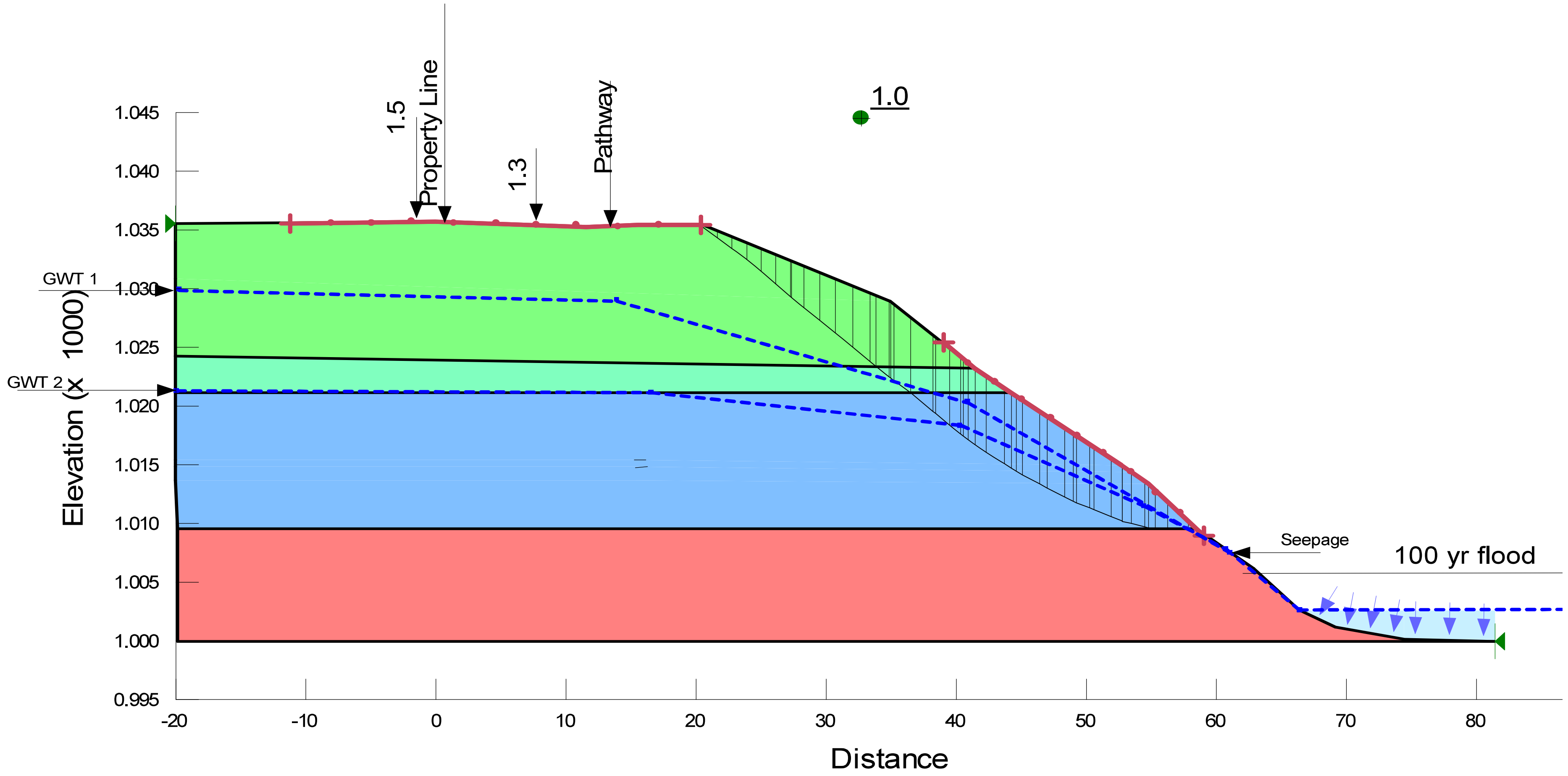
SECTION 11 - CREST FAILURE - FOS 1.5

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-35**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

Directory: R:\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\01_Geotechnical\Slope Stability Analysis\Section 12\
File Name: Section 12 1.0-AE2-AW.gsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Hard   Unit Weight: 20 kN/m³   Cohesion: 5 kPa   Phi: 30 °   Piezometric Line: 1
Name: Till - Silt or Sandy Silt - Dense   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 33 °   Piezometric Line: 1
Name: Weathered Siltstone or Sandstone   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 38 °   Piezometric Line: 2
Name: Competent Siltstone or Sandstone   Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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CITY OF CALGARY
DOUGLASDALE FEASIBILITY STUDY

SECTION 12 - CONTROLLING CREST FAILURE

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-36**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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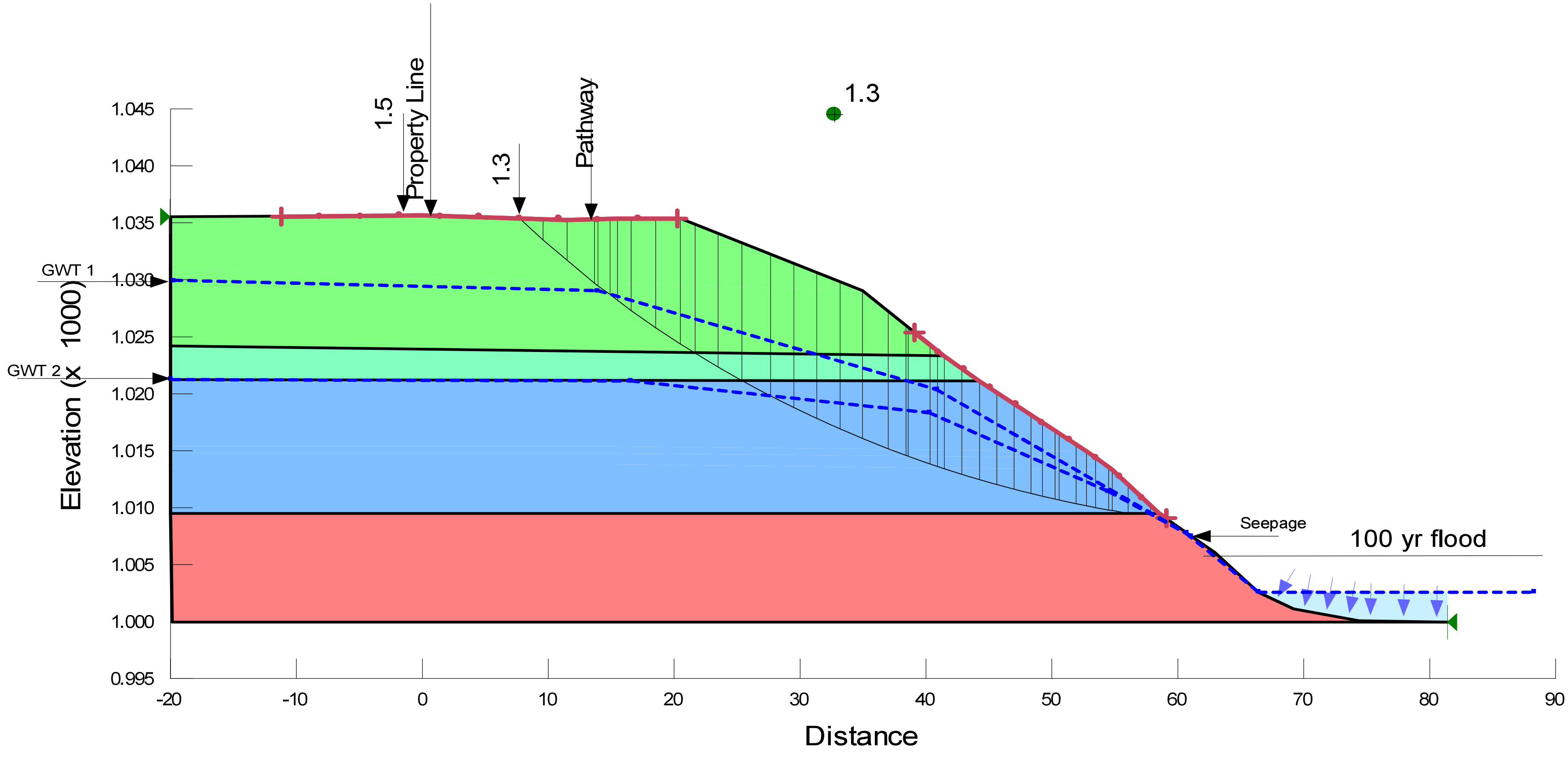
Directory: R:\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\01_Geotechnical\Slope Stability Analysis\Section 12\
File Name: Section 12 1.0-AE2-AW.gsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Hard Unit Weight: 20 kN/m³ Cohesion: 5 kPa Phi: 30 ° Piezometric Line: 1
Name: Till - Silt or Sandy Silt - Dense Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 33 ° Piezometric Line: 1
Name: Weathered Siltstone or Sandstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 2
Name: Competent Siltstone or Sandstone Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟪	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 12 - CREST FAILURE - FOS 1.3

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-37**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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ATTACHMENT 2

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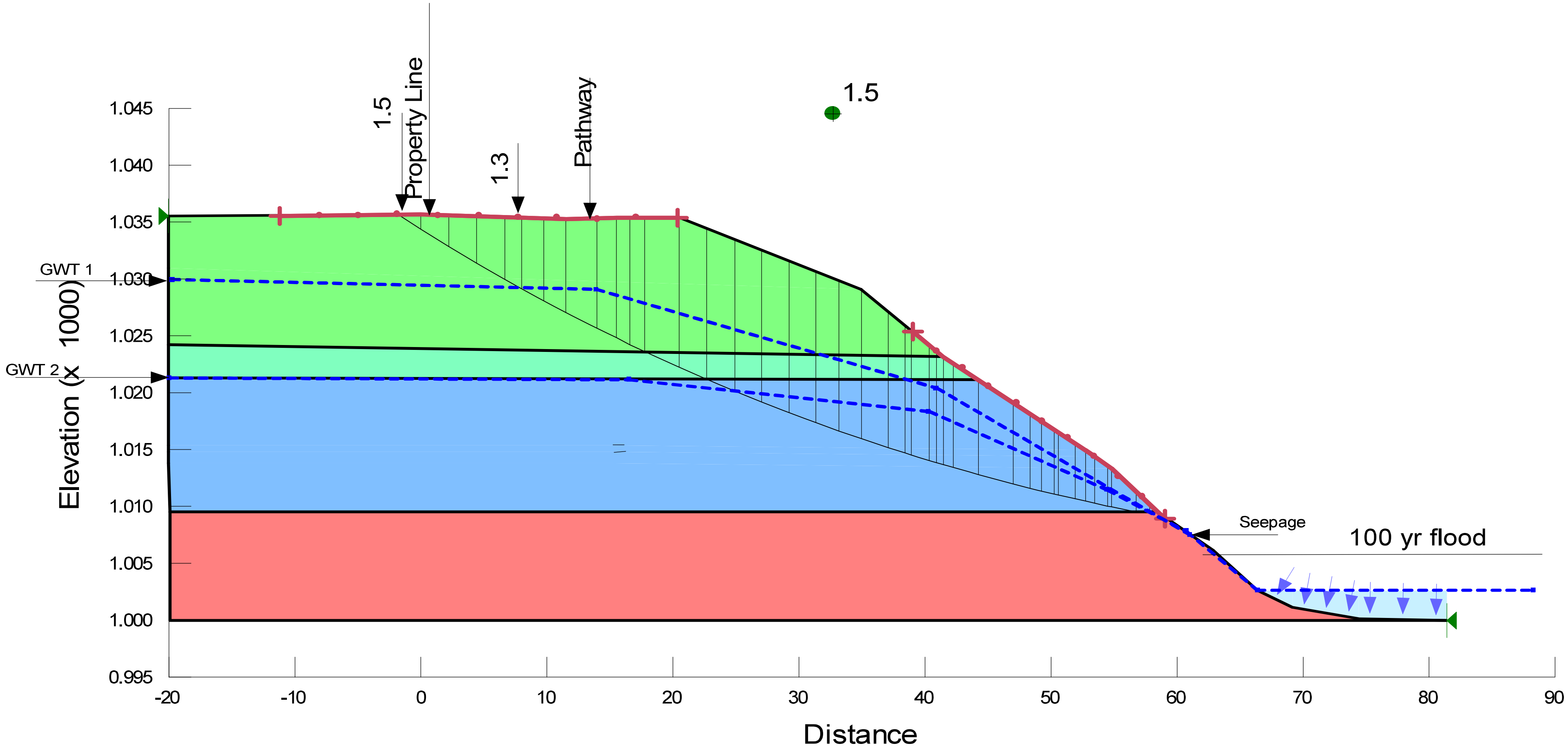
Directory: R:\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\01_Geotechnical\Slope Stability Analysis\Section 12\
File Name: Section 12 1.0-AE2-AW.gsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Hard   Unit Weight: 20 kN/m³   Cohesion: 5 kPa   Phi: 30 °   Piezometric Line: 1
Name: Till - Silt or Sandy Silt - Dense   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 33 °   Piezometric Line: 1
Name: Weathered Siltstone or Sandstone   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 38 °   Piezometric Line: 2
Name: Competent Siltstone or Sandstone   Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟪	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 12 - CREST FAILURE - FOS 1.5

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-38**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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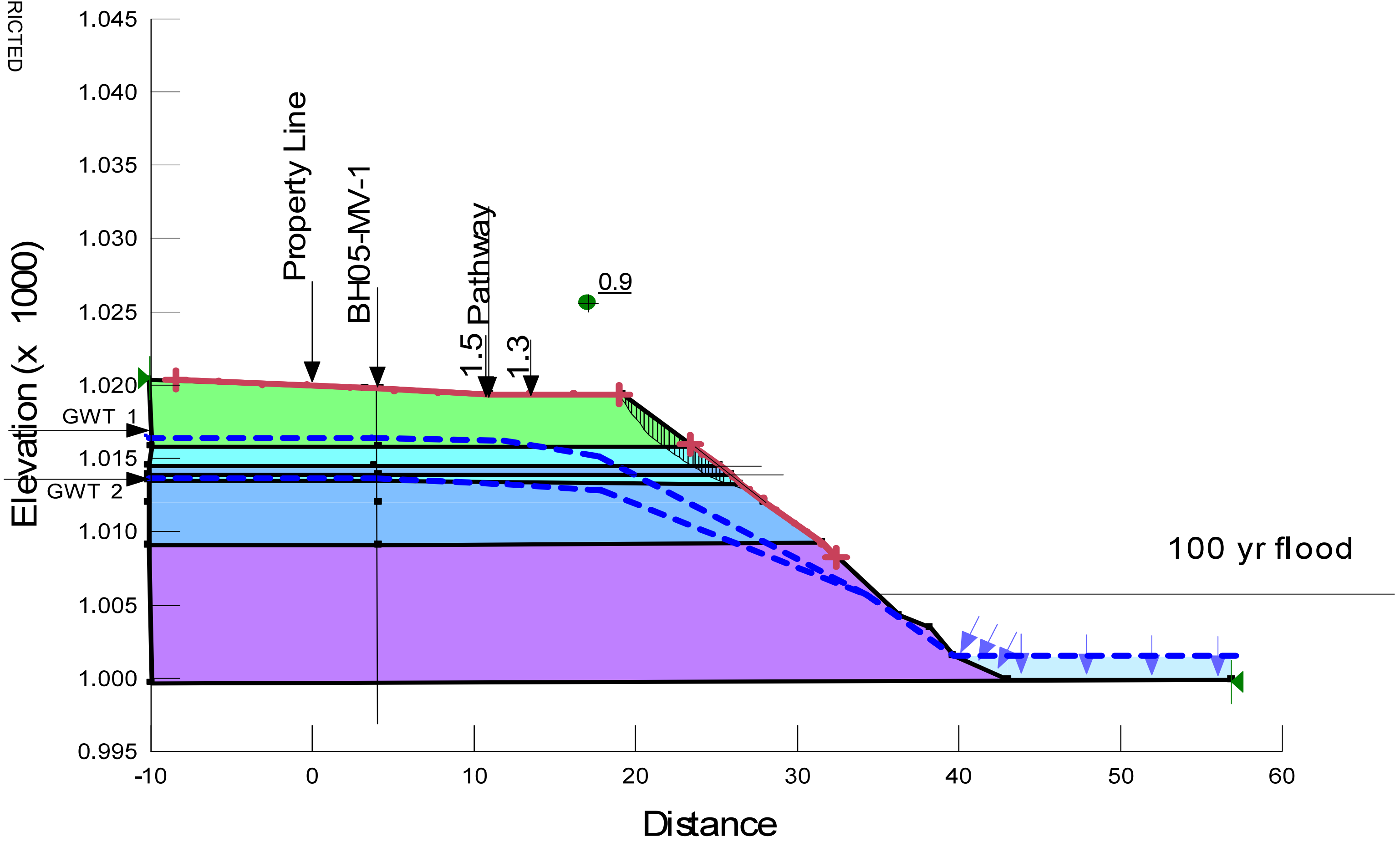
Directory: R:\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\01_Geotechnical\Slope Stability Analysis\Section 13\
File Name: Section 13 1.0-AE-2-AW.gsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Hard   Unit Weight: 20 kN/m³   Cohesion: 5 kPa   Phi: 30 °   Piezometric Line: 1
Name: Weathered Claystone or Mudstone   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 22 °   Piezometric Line: 2
Name: Weathered Siltstone or Sandstone   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 38 °   Piezometric Line: 2
Name: Competent Claystone or Mudstone   Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 13 - CONTROLLING CREST FAILURE

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-39**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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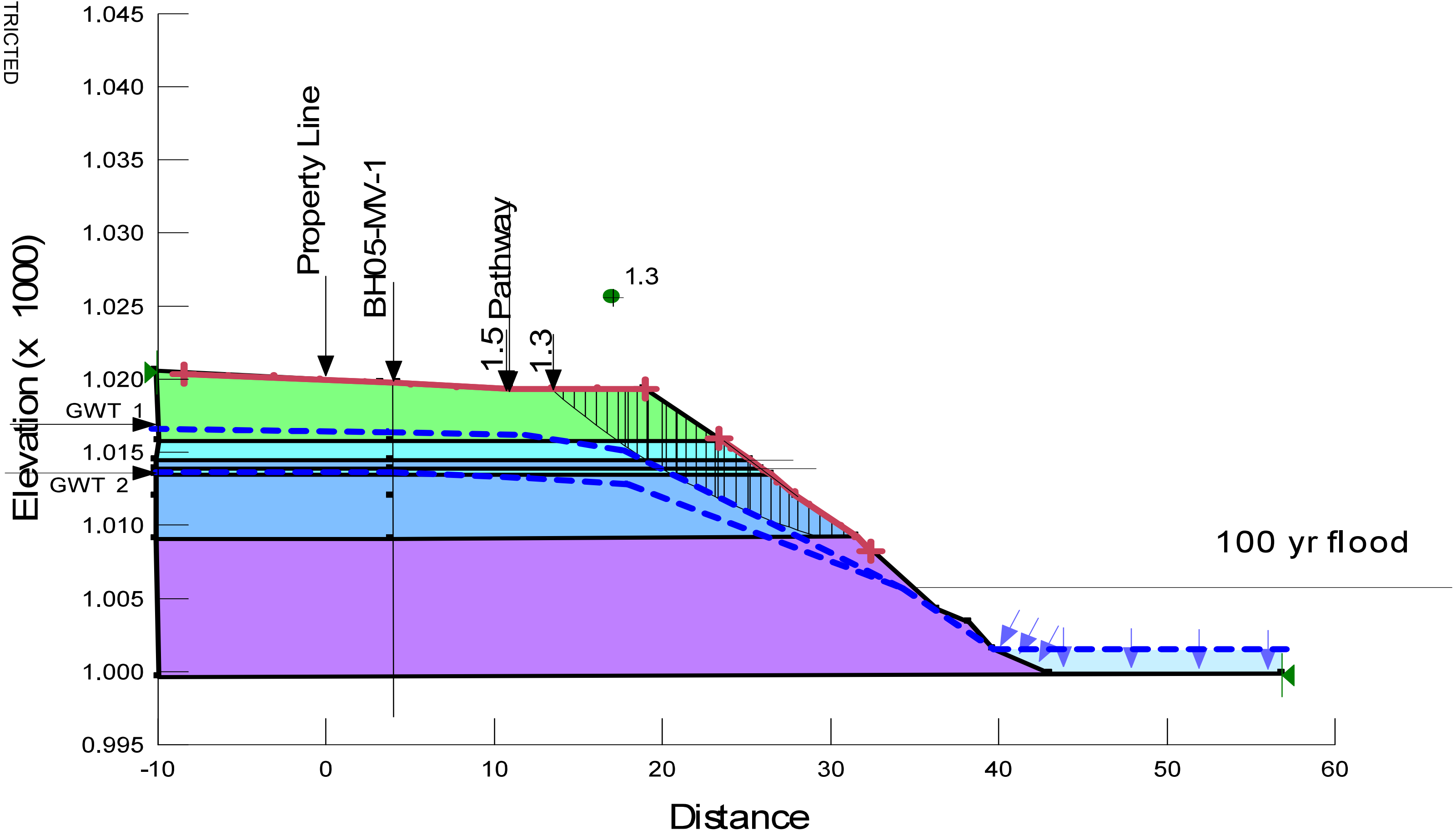
Directory: R:\Active_2011\1321\11-1321-0003 - City - Slope Stability Program\Phase 2200 - Douglasdale Feasibility 2015\06_Technical\01_Geotechnical\Slope Stability Analysis\Section 13\
File Name: Section 13 1.0-AE-2-AW.gsz

Name: Till - Silty Clay or Clayey Silt - Hard   Unit Weight: 20 kN/m³   Cohesion: 5 kPa   Phi: 30 °   Piezometric Line: 1
Name: Weathered Claystone or Mudstone   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 22 °   Piezometric Line: 2
Name: Weathered Siltstone or Sandstone   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 38 °   Piezometric Line: 2
Name: Competent Claystone or Mudstone   Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
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🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 13 - CREST FAILURE - FOS 1.3

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-40**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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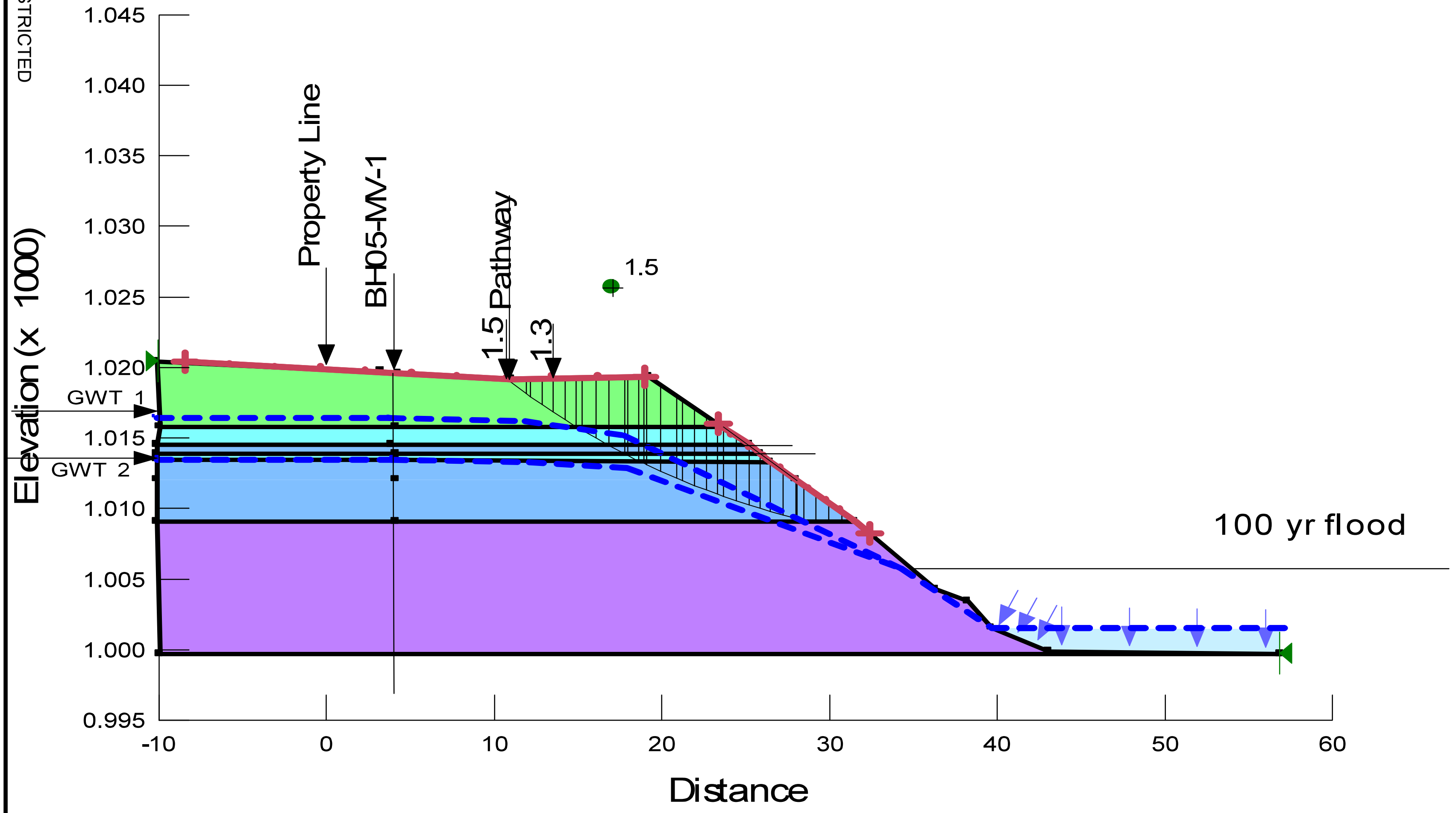
File Name: Section 13 1.0-AE-2-AW.gsz

ISC: UNRESTRICTED

Name: Till - Silty Clay or Clayey Silt - Hard Unit Weight: 20 kN/m³ Cohesion: 5 kPa Phi: 30 ° Piezometric Line: 1
Name: Weathered Claystone or Mudstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 22 ° Piezometric Line: 2
Name: Weathered Siltstone or Sandstone Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 38 ° Piezometric Line: 2
Name: Competent Claystone or Mudstone Piezometric Line: 2



Symbol	Soil
🟨	Till - Clay
🟩	Till - Silty Clay or Clayey Silt - Stiff
🟩	Till - Silty Clay or Clayey Silt - Hard
🟩	Till - Silt or Sandy Silt - Dense
🟥	Sand and Gravel
🟦	Weathered Claystone or Mudstone
🟦	Weathered Siltstone or Sandstone
🟪	Competent Claystone or Mudstone
🟥	Competent Siltstone or Sandstone

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DOUGLASDALE FEASIBILITY STUDY

SECTION 13 - CREST FAILURE - FOS 1.5

Design:	AW	5/4/2015	Project:	11-1321-0003.2200	**Figure: D-41**
Checked:	AE	5/5/2015	Rev:	0	
Reviewed:	DEB	7/31/2015			

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