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PERPETUAL SLIDE
SUMMERLAND, BRITISH COLUMBIA

Geotechnical and Hydrogeological Study

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REPORT

Golder Associates

Executive Summary

This report presents the results of a geotechnical and hydrogeological study conducted by Golder Associates Ltd. (Golder) for a large slide mass commonly known as the “Perpetual Slide” that is located along the north side of the steep canyon overlooking Trout Creek, along the southern boundary inside the District of Summerland (DoS). The slide area is located along the southern boundary of the District of Summerland on the north side of the steep canyon overlooking Trout Creek within the general area is locally known as Paradise Flats. Land use in the area mainly consists of large residential lots with small scale agriculture. The Summerland Golf and Country Club is located immediately west of the slide.

The scope of work was specific to the review of potential risks that the Perpetual Slide might impose upon nearby private and public properties, public utilities and roadways along Canyon View Road, Paradise Road, and also upon the northern portion of the Summerland Golf and Country Club golf course, as well as the potential impact if a slide occurs blocking Trout Creek and is subsequently breached. The work was limited to a non-intrusive assessment, which consisted of:

- the collection and review of historical information from studies completed by Golder and others;
- a geotechnical and hydrogeological site reconnaissance of the slide to assess slide activity, to verify the slide scarp limits, and to review roadway conditions and distress features along portions of Canyon View Road, Paradise Road and the golf course maintenance access lane;
- the development of a Resident Questionnaire that may be distributed to residents in subsequent phases of work, if required; and,
- preparation of a report documenting the factual results of the study based on our interpretation of the slide condition observed at the time of the reconnaissance together with our review of available information.

To our knowledge, a borehole intrusive investigation within the slide area has never been conducted. Slide research studies have been based on assumed and inferred subsurface conditions, estimated slide failure zone depth(s) and groundwater conditions together with the collection of some shallow soil and rock samples taken from slope exposures. Golder provides a summary of previous work, which outlines the inferred slide mechanism and associated controlling factors. Others have concluded that the slide failure surface was founded with Tertiary sediments, primarily within claystone gouge material that exhibited cohesive properties and a weaker residual shear strength in comparison to other slide material types resulting in a massive retrogressive rotational failure causing a backward tilt in the direction of the head scarp. The gouge is clay rich, has a low permeability, and swells in contact with water. The slide gouge confines upward discharge from underlying bedrock and allows high porewater pressures to form at the base of the slide, which contribute directly to the slide mechanism. Groundwater flow is implicated as a significant factor in the failure of the slide.

Results of previous monitoring assessments, historical air photographs and topographic mapping were compared to results of the Site reconnaissance to assess apparent changes in the slide features together with an estimation of the magnitude of slide displacements and rate of material loss. In general, between 1970 and 2012 the slide surface across the middle and lower portions have dropped by about 5 to 10 m and moved laterally by about 5 to 20 m with the graben features showing the greater amount of displacement, especially approaching towards the crest of the canyon side slopes.

Based on the results of the slide reconnaissance together with comments provided by DoS and the golf course, Golder identified slide zones based on the level of observed slide activity together with the magnitude of ground surface displacements. Based on the slide angle and activity information Golder recommended that a preliminary setback zone be established along the crest of the existing head scarp that extends back for a distance of at least 50 m. The preliminary setback distance should be reviewed pending the results of a proposed monitoring program and detailed field investigation that is discussed in detail within the report.

Results of the hydrogeological review show the presence of several data gaps, including the lack of subsurface borehole records within and up-gradient of the slide area, no recent groundwater level monitoring data, and no detailed information regarding wastewater disposal systems. Based on groundwater level data collected over the period between 1979 and 1982, an apparent trend for piezometers P1 and P5 showed that the peak groundwater levels occurred in the late fall and early winter months. This correlates with the observations made in a previous study by others that greater seepage discharge at springs was noted during the fall and winter months, which also corresponded with an increase in the slide displacement rates.

Based on our interpretation of the reviewed information it is Golder's opinion that ongoing slide activity will continue above the head scarp that will impact existing public infrastructure and private properties. It is not possible to predict if or when a significant slide may occur at this site. If one did occur, there is potential for the slide material to block off streamflow in Trout Creek. Depending on the size of the slide and volume of material plugging the canyon, a natural dam would form and it would begin impounding streamflow. The resulting scenario could lead to a dam breach failure and there could be an extreme hazard to downstream people, infrastructure, environmental values, and cultural values. To quantify or delineate the potential flood inundation impacts, further study is required along the lower floodplain of Trout Creek. If a slide dammed Trout Creek there could be a significant safety hazard to equipment and people working to remove deposited material, and as such the emergency response and recovery aspects need to be considered.

Based on Golder's interpretation of the potential hazard that the slide imposes to neighbouring properties and nearby public infrastructure, recommendations related to the following topics are provided for consideration:

- Land Use and Planning Measures (setback zone, minimizing impact to infrastructure above slide zone, education and outreach)
- Survey Monitoring Program
- Intrusive Field Investigation
- Flood Mitigation Options (monitoring streamflow, education and signage, emergency response, flood protection works)
- Collection of Water Use Information
- Bylaw Measures

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1.0 INTRODUCTION

This report presents the results of a geotechnical and hydrogeological study conducted by Golder Associates Ltd. (Golder) for a large slide mass commonly known as the *"Perpetual Slide"* (hereafter referred to as the "slide") that is located along the north side of the steep canyon overlooking Trout Creek, along the southern boundary inside the District of Summerland (DoS).

It should be noted that the scope of this report is limited to the geotechnical and hydrogeological study and does not include any investigations, analytical testing or other assessments associated with possible soil and groundwater contamination, archaeological or biological considerations or sediment control measures.

This report should be read in conjunction with "***Important Information and Limitations of This Report***" provided in Appendix A. The reader's attention is specifically drawn to this information, as it is essential for the proper use and interpretation of this report.

Authorization to proceed was provided by Mr. Don Darling, Director of Works and Utilities with DoS on December 17, 2014 through an e-mail notification to Gerald Imada. The scope of work presented in Golder's proposal was specific to the review of potential risks that the Perpetual Slide might impose upon nearby private and public properties, public utilities and roadways along Canyon View Road, Paradise Road, and also upon the northern portion of the Summerland Golf and Country Club golf course. The scope of work was later expanded to include a general discussion of the potential impact if a slide occurs blocking Trout Creek and is subsequently breached, based on discussions held a meeting between DoS and Golder on August 12, 2015 to review the Draft report issued on May 15, 2015.

1.1 Scope of Work

The scope of work for this study was described in Golder's proposal titled *Proposal and Cost Estimate to Provide Geotechnical and Hydrogeological Assessment of the Perpetual Slide, Canyon View Road, Summerland, British Columbia,* dated November 26, 2014 (Reference Number P1417553). The terms and conditions included in the noted proposal are also applicable to this report.

For this study, the scope of work was limited to a non-intrusive assessment, which consisted of the following described tasks.

Task 1 – Desktop Review

This task included the collection and review of historical information from studies completed by others including Golder projects, together with other pertinent information provided by DoS, such as water usage records for properties adjacent to the slide including the golf course, history of infrastructure repairs along Canyon View and Paradise Roads, and 2005 and 2012 electronic topographic drawings with corresponding digital ortho-photographs.

- A review of recent and historical aerial photographs was also undertaken to determine progression and changes to the slide's spatial extents and features. The aerial photographs reviewed are listed in the following table (Table 1).

Table 1: Aerial Photographs

Year	Flight Number	Photograph Number(s)
2012	Ortho-photograph	-
2007	BCD07035	039, 040
2005	Ortho-photograph	-
2001	BCC01032	143, 144
1996	-	-
1992	BCB9005	172,173, 174
1985	BCC372	175, 176, 177
1980	BC80046	045, 046, 047, 048
1980	BC80046	036, 037, 038
1976	BC7602	145, 146
1969	BC5330	024, 025
1963	BC4192	169, 170
1951	BC1647	89, 90
1938	BC106	49, 50
1938	BC106	95

- Review of groundwater level information that was recorded by DoS until about mid-1982, after which semi-annual readings were taken to 1987, with the last known reading taken on July 1, 1988. It is not known if DoS continued the monitoring program beyond the 1988 reading.
- A preliminary review of surface, irrigation and groundwater information from sources within and above the slide area in order to assess the potential groundwater recharge condition within the slide area.
- The development of a Resident Questionnaire with the help of DoS to identify private water supply well locations, septic disposal field areas and other infrastructure that may provide information regarding the subsurface, and irrigation information (such as crop type, irrigation schedules, peak periods and estimated water consumption volumes). The Resident Questionnaire will only be distributed to residents in subsequent phases of work if required.

Task 2 – Site Reconnaissance

The second task of the study was to conduct a geotechnical and hydrogeological site reconnaissance of the slide to assess the magnitude of recent slide activity from observations of displacement features, and to verify the slide scarp limits in comparison to historical and recent aerial photographs together with other possible slide movement encroaching towards and/or onto nearby adjacent properties. This included a review of the roadway distress features along a portion of Canyon View Road, a review of the roadway conditions along Paradise Road and also along the golf course maintenance access lane along the east side of the golf course.

Golder attempted to locate six (6) monitoring piezometers that were installed in 1979 together with seven (7) survey monuments that were used to measure potential lateral movements along the slide head scarp. To our knowledge, survey coordinates do not exist for these installations as their locations were simply identified on a site plan at the time of the initial golf course construction.

Areas of possible shallow groundwater seepage and seepage discharge areas within the slide were also identified and located using a handheld GPS receiver.

Measurements using a total station survey instrument were taken for a remaining old monument and piezometer installation that was found near the north end of the golf course. Spot elevations were also taken along the Canyon View Road distress area to determine the magnitude of vertical displacement together with the setup of several temporary benchmarks that were established outside of the distress area that subsequently can be used and incorporated into a future field monitoring program.

Task 3 – Report Preparation

The final task of the study was the preparation of a report documenting the factual results of the study based on our interpretation of the slide condition observed at the time of the reconnaissance together with our review of available information. The following aspects are presented and discussed in the report.

- Comments regarding the magnitude of slide activity, progression of the slide scarp, and apparent changes to seepage zones within the slide. This includes a plan showing the current slide scarp limits together with establishing preliminary hazard zones above the slide scarp based on different level of risks for potential for property damage, damage to public infrastructure, and general public safety. The risk rating system is based on our interpretation of the current slide activity, the slide scarp progression, and the potential hydrogeological impacts.
- Estimation of the volume of slide material that flows into Trout Creek based on a review of topographic information.
- Comments regarding the potential consequences on the Trout Creek area should a slide occur damming Trout Creek and the subsequent breach of the dammed creek.
- Comments pertaining to the probable mechanism that caused distress to the infrastructure along a portion of Canyon View Road and to the northern portion of the golf course. This also includes geotechnical recommendations for the reconstruction of the affected portion of Canyon View Road.
- A review of available domestic and irrigation water use data was conducted. Best practice guidelines regarding irrigation are provided to reduce potential impacts that irrigation may have on the slide area and its progression, specifically by using better controls and/or implementing reasonable water usage guidelines.
- Comments and recommendations pertaining to an intrusive field investigation program with suggested borehole locations and depths, a survey monitoring program, and estimated costs.
- Considerations for Education and Outreach, Land Use Planning and Bylaw measures, which DoS may wish to implement.

2.0 SITE SETTING

The slide area is located along the southern boundary of the District of Summerland on the north side of the steep canyon overlooking Trout Creek. The elevation change between the creek and the top of the slide scarp is approximately 125 m. Above the scarp is a relatively flat bench between elevations of approximately 625 m above sea level (masl) and 590 masl, which slopes gently to the southeast, towards Trout Creek. Mount Conkle is located to the northwest of the slide, and rises to a peak of 935 masl.

Land use in the area mainly consists of large residential lots with small scale agriculture (horse pasture, forage crops, orchards and vineyards). The Summerland Golf and Country Club is located immediately west of the slide. There is also a cemetery located to the north of the slide, on Canyon View Road. The general area is locally known as Paradise Flats.

3.0 HISTORY OF THE PERPETUAL SLIDE

The most comprehensive known study conducted on the slide to date is the Riglin (1977) thesis. Based on this, it is understood that slide features were first noted by local settlers between 1914 and 1917 where the slide scarp had developed through to about 1925. Most of the large slide movements had occurred prior to 1938 based on a comparison between 1938 and 1970 topographic map where the main head scarp had progressed to about its present-day location.

To our knowledge, a borehole intrusive investigation within the slide area has never been conducted to date in order to determine actual subsurface conditions, the depth of the slide failure surface(s), and to acquire soil strength properties. Slide research studies have been based on assumed and inferred subsurface conditions, estimated slide failure zone depth(s) and groundwater conditions together with the collection of some shallow soil and rock samples taken from slope exposures.

3.1 Slide Mechanism

Riglin (1977) concluded that the slide failure surface was founded with Tertiary sediments, primarily within claystone gouge material that exhibited cohesive properties and a weaker residual shear strength in comparison to other slide material types resulting in a massive retrogressive rotational failure causing a backward tilt in the direction of the head scarp. The failure also caused large translational blocks to develop at different elevations across the middle and lower slide benches resulting in depressed features located near the toe of these slide benches, which are commonly referred to as grabens.

The claystone gouge material also may be acting as an impermeable layer whereby the underlying groundwater flow is constrained resulting in the development of higher hydraulic gradients in excess of hydrostatic between different soil units resulting in a decrease in the effective soil stress and thereby causing even lower shear strengths along the slide failure surface(s). Local perched groundwater conditions could also occur because of impermeable layers across the slide mass.

Shear testing results from the Riglin study on a sample of the gouge material reported a residual friction angle of 18.5 degrees. This is equivalent to a slope angle of about 3 horizontal to 1 vertical.

3.2 Slide Monitoring

Slide monitoring using a stadia survey technique was conducted between 1975 and 1976 where a series of surface monuments and stakes were surveyed to determine seasonal and spatial fluctuations across the slide area. The monitoring results indicated a significant range of movement existed across the slide's longitudinal profile suggesting complex rotational slide geometry. Movements were calculated at about 0.08 m/year along the toe of the head scarp and increased to about 0.13 m/year for the flatter middle portions of the slide. Going further downslope across the longitudinal slide profile, the magnitude of lateral displacement increased from about 0.51 m/year to 1.49 m/year and up to 15.69 m/year along the crest of the steep Trout Creek canyon. The monitoring results also indicated a seasonal increase in the displacement rates during the fall and winter months, which correlated closely with an increase in groundwater seepage discharge at the localized springs located across the crest of the steep slide slopes above Trout Creek canyon.

Riglin estimated that the total slide mass loss amounted to about 11,500 m^3 per year for the portion of the slide mass located between the head scarp and the crest of the steep canyon slopes.

In 1979, Golder installed seven monument control points along the east side of the golf course overlooking Trout Creek with a reference base station located along the west side of the golf course along Mountain Avenue for the purpose of determining if lateral movements were occurring near the crest of the slide scarp as part of the golf course groundwater monitoring program that is discussed in the proceeding Subsection 2.3. Only one complete set of readings were taken by Golder at each monument control point on July 16, 1979 for use as a comparison baseline for future monitoring purposes, which to our knowledge was never carried out.

3.3 Surface Hydrology

Historical records indicate that irrigation was initially introduced into the Paradise Flats farming area around 1903 to 1906 that preceded the initial slide event(s) between 1914 and 1917. Prior to that time, no irrigation and domestic water existed within the slide drainage catchment area across Paradise Flats and below Conkle Mountain. Unlined earth ditches were initially constructed, and then gradually replaced by wooden flumes, which were then subsequently replaced by metal flumes in the 1930's through 1950's. Since the 1950's through to 1970's, the metal flumes were gradually replaced by concrete flumes, except for about a 0.5 km length of overflow line, which remained as an unlined earth ditch. Golder was not able to verify whether this unlined ditch still exists.

Past hydrology studies undertaken in the 1970's concluded that it is possible that changes to the groundwater regime caused by the introduction of irrigation into the Paradise Flats contributed to instability of the steep slopes above Trout Creek and consequently caused the initial slide failure event(s) from about 1914 to 1917.

Furthermore, it is also understood that "silty" water quality downstream of the slide in Trout Creek occurs on a regular basis as the slide material continues to be washed and scoured into the creek channel.

3.4 Groundwater Monitoring

A monitoring program commenced in 1979 for DoS, where Golder installed six (6) piezometers and seven (7) survey control points along the crest of the slope overlooking Trout Creek canyon. The purpose of the monitoring program was to assess if changes to the groundwater level were related to irrigation of the golf course as well as to determine if lateral movements were occurring along the slope crest that could be associated with increased groundwater levels and adversely impact slide movement.

The piezometers were installed through the upper sand and gravel deposits and into the underlying bedrock or glacial till deposits. Monthly groundwater levels were initially recorded by DoS to about mid-1982, after which time semi-annual readings were taken until 1987 with the last reading taken on July 1, 1988. It is not known if DoS continued the monitoring program beyond the 1988 reading. The locations of the monitoring piezometers and soil descriptions are included in Appendix B together with a summary of the groundwater levels to 1988 and the average monthly precipitation for 1979 to 1982.

Based on the results for the 1979 to 1980 groundwater monitoring period, it was determined that piezometers located closer to the Trout Creek slope crest along the east side of the golf course tended to have lower groundwater levels, and that groundwater levels tended to increase to the north possibly in response to adjacent agricultural irrigation practices.

Higher monthly precipitation amounts were recorded during May and December based on average values between 1979 and 1982. For the 1979 to 1988 period, higher precipitation was recorded for the months of May, June and December. Based on the limited piezometer monitoring data, an apparent trend for piezometers P1 and P5 showed that the peak groundwater levels occurred in the late fall and early winter months. The groundwater levels at these locations began to increase shortly after the high May-June precipitation. In general, there was a five to six month lag between the high May-June precipitation amounts and the late fall high groundwater levels. The higher fall groundwater levels correlates well with the observations made in the Riglin (1977) study where greater seepage discharge at springs was noted during the fall and winter months, which also corresponded with an increase in the slide displacement rates.

3.5 Trout Creek Impact

A hydrological risk assessment report for Trout Creek was prepared by Grainger and Associates Consulting Ltd., dated April, 2009 and submitted to the BC Ministry of Environment. The Perpetual Slide was noted as being *"a chronic source of sediment"*. It was stated *"Toe erosion along the base of the steep slopes may undermine and reactivate existing failures and/or initiate new failures. The result will be increased coarse and fine sediment loads downstream on the fan."* Aggradation of the diked portions of the channel downstream of the Perpetual Slide has been documented following past flood events. Consequently, the Trout Creek fan area was assigned as having a *"very high"* hydrologic hazard rating. The results of the assessment also noted that the Highway 97 bridge structure and the upstream flood protection dikes were rated as having a *"Low"* vulnerability since the completion of the dike and bridge improvements that were carried out following the 1972 flood event.

Another hazard and risk assessment prepared by EmergeX Planning Inc. was submitted to DoS in February 2006. The results of that study identified the Perpetual Slide as not posing any risks to major structures, however it was stated that "*this could have a negative impact on the golf course itself*". The substantial sediment release into Trout Creek was also identified as contributing to the loss of downstream fish habitat. That study rated the level of risk for a landslide occurrence as *"moderate"* defined as having a likelihood of *"occasional/slight chance"* for an event to occur with a corresponding impact/severity rating of *(8-14)* on a scale of (1-7) being *Low* and (22-28) being *High*.

4.0 DISCUSSION

The following provides a summary of our geotechnical and hydrogeological discussion after reviewing available information provided by DoS, the results of the site reconnaissance, review of historical air photographs, resident questionnaire, and estimated slide activity based on displacements derived by comparing topographical features using 1970, 2005, and 2012 base contour maps.

4.1 Site Reconnaissance

A site reconnaissance was conducted on February 13, 2015 along the slide head scarp, portions of Canyon View Road, Paradise Road, the northern portion of the golf course, and within the slide extents. The site reconnaissance was scheduled several weeks after the snow cover had melted in order to allow for easier identification of "fresh" tell-tale evidence of recent slide activity, particularly in areas where prominent slide features exist. Digital photographs were taken of pertinent slide features as well as GPS waypoints for future reference purposes. The pertinent GPS waypoint locations are shown on Figure 1.

4.1.1 Previous Piezometers/Monuments

At the time of the reconnaissance, Golder also attempted to locate the old 1979 piezometers and survey monuments using the old site location plan (Figure 1 in Appendix B) that was overlaid onto the 2012 Google Earth image coverage for the particular area of interest. Only piezometer/monument P1 was successfully located together with the base reference station that is located along the west side of the golf course. Piezometer/monument P1 was still intact within its protective box cover, as well as the base reference station that was set in a concrete pad. We were not able to locate the remaining piezometers and monuments as they appear to have been buried within raised features that border the east side of the golf course.

Piezometer/monument P1 was sounded to a depth of about 2.8 m where the probe unexpectedly stopped without the detection of any groundwater. A review of the last reading taken in July 1988 measured the groundwater at a depth of 14.87 m below ground surface. It is not known if the 2.8 m stoppage is caused by an obstruction inside the PVC pipe or if the pipe has been sheared by lateral ground movement as this piezometer is located within 10 m of the slide head scarp.

On February 20, 2015, a measurement was taken between the base station and P1 using a Nikon DTM-520 total station in order to compare it to the July 16, 1979 reading. The result of the measurement shows an increase in distance of about 6.27 m between the base station and monument P1. This difference was also checked and verified using a differential GPS receiver. The additional displacement measured since the 1979 reading does not seem reasonable as there is no other site evidence to suggest that magnitude of lateral movement, except that this area is within a localized lower lying area *(Photograph 3864 in Appendix C)*. Therefore, it is our opinion that the difference is probably related to the use of different instruments and their level of accuracy between the 1970s era and current electronic distance measuring technology. However, considering that the piezometer is now plugged at a depth of about 2.8 m, this does suggest that there has possibly been sufficient lateral movement to cause the obstruction or shearing of the PVC pipe at the 2.8 m depth, as unusual movement has also been reported at the golf green located to the north of this location for the past several years.

4.1.2 Canyon View Road

It is understood that recurring breaks have occurred within the water main pipe that is located along the south side of Canyon View Road. It is further understood that the water main consists of a 250 mm diameter AC pipe and that deflections were observed at every pipe joint indicating differential movements between the pipe sections.

An elevation and distance survey using a total station instrument was also carried out on a portion of the roadway where a distinct depression (dip) is located opposite 10920 Canyon View Road where limits of two large crescent shaped pavement cracks were measured and tied into several temporary benchmarks for future monitoring comparison purposes *(Photograph 3801 in Appendix C).* A series of repeating diagonal pavement cracks were also observed along the south outer 1.5 m roadway width (south wheel path) that extend further east up to the driveway at 10818 Canyon View Road *(Photograph 3818 in Appendix C)*. Currently, it is not known if these cracks are associated with settlement of the roadway as a direct result of water line breaks with wetting of the roadway fill embankment and subgrade soil. It should be noted that these cracks are also located along a portion of the roadway that is constructed as a fill embankment that is about 1.7 m high.

Other observations did not reveal any unusual features for the remaining portions of Canyon View Road between Simpson Road and Paradise Road, except for localized pavement patches. However, a slight broad dip does exist near the west end of Canyon View Road that was previously noted at the time of a 2003 investigation for a proposed RV park. It is understood that this dip is probably associated with a former drainage swale that was in-filled years ago.

4.1.3 Paradise Road and McGee Street

It is understood that other water main breaks have also occurred in the last several years near the corner of Paradise Road at McGee Street across from an abandoned mobile home structure and across from the No. 3 Green and the 4th -tee box at the north end of the Summerland Golf and Country Club (Figure 4). It is understood that DoS did not keep track of the dates and details of these breaks.

4.1.4 Golf Course

In discussion with the Summerland Golf and Country Club course supervisor, it is understood that the No. 3 Green has experienced differential movement over the past several years and that the magnitude of movement appears to have increased in the last year or so that has resulted in the development of small tiered subsidence benches across the east portion of the green that now amounts to an overall drop of about 30 cm thus making the green practically unplayable. To date, breakage of irrigation pipes on the golf course has not occurred that would be associated with potential slide movement, especially at the north end of the golf course in the vicinity of the No.3 Green.

Suspicious movement has also been identified along the north end of the material storage yard. No other movements have been noticed at the work shop or other areas of the golf course.

The larger pond feature at the north end of the golf course is understood to be lined. Actual monitoring of the pond for potential water storage loss has never been carried out. It is understood that the pond was accidentally overfilled about seven years ago that resulted in the overnight flow of excess water that created a washout over the crest of the slide scarp.

4.1.5 Slide Features

The following table (Table 2) provides a summary of features that were noted at the time of the site reconnaissance. The locations of the GPS references listed in the table are also shown Figure 1 for reference purposes. References to site photographs that were taken on February 13, 2015 are also included in the following table with photographs and general comments found in Appendix C.

Table 2: Slide Features

GPS Reference Locations	General Description of Site Features
TC1, TC2	Localized roadway depression (dip) with patched pavement cracks at the east and west ends of Canyon View Road over a distance of about 95 m along the south edge of pavement *(Photograph 3801)*. Water line breaks occurred in the 250 mm diameter pipe at each end of the road dip in 2012. A survey shows subsidence of up to about 52 cm has occurred along the outside south lane relative to its estimated original profile. A second crescent shaped crack has developed inside (south) of the larger outer crack within the last year or so *(Photograph 3809)*. It is not known if this feature is associated with gradual post-break subsidence within the water line trench as a result of earlier water line breaks. The overall area of subsidence extends to a distance of about 5 m inside the property at 10920 Canyon View Road.
TC3, TC4	Fresh tension crack development along slide head scarp where vertical and horizontal displacements extend up to about 10 to 15 cm within predominantly sand deposits *(Photograph 3837)*.

GPS Reference Locations	General Description of Site Features
TC5	Multiple fresh tension cracks along old cut trail about 1.2 m apart with ~1 cm wide gap separations. This area is located immediately above a graben feature along the toe of the head scarp where deciduous tree growth was observed. It should be noted that a review of the old groundwater level records at piezometer/monument P1 shows the highest groundwater level was measured on December 30, 1983 at an elevation of about 579.9 m, which potentially puts the groundwater to within several metres above the toe of the steep scarp slope.
TC6	Fresh tension crack about 1-2 mm wide in asphalt pathway near piezometer/monument P1, crack is parallel to the head scarp *(Photograph 3863).*
TC7	Along crest of steep canyon side slope at far south end of golf course near old P4 piezometer that was not found *(see Figure 1 in Appendix B for P4 location).*
TC8	Outside of the south slide limits where no evidence of movement was observed.
TC9	South flank of the slide limits overlooking the middle slide bench and graben area.
TC10	Multiple tension cracks each having up to 15 cm vertical drop along ridge located immediately downslope of a graben feature.
TC11	Fresh tension crack that is partially covered by slope ravelling is located about midway up a steep sand and gravel slope overlooking the lower slide bench *(Photograph 3882)*.
GPS12	Large bend in 70 cm diameter tree located within a graben feature showing about 7 m of displacement between its trunk and the upright top portion of the tree trunk that is indicative of significant slide movement. Most trees in this area are leaning backwards and upslope in a northwest direction.
GPS13	Area where significant landslide rotational movement resulting in the backwards leaning of mature trees that vary between angles of about 25 to 35 degrees from vertical *(stitched Photographs 3963-3965 and 3998).*
GPS14	Large seepage discharge area about 15 m wide within shallow graben with very loose wet soil conditions consisting of a mixture of sand and silty sand with pockets of cohesive clayey sand. Multiple tension cracks throughout the area that are spaced about 1.2 to 1.5 m apart with tension cracks widths of about 5 cm and up to 50 cm vertical displacements at the cracks *(Photograph 3991).*
GPS15	East side of large area of significant slide activity (~120 m wide) where recent backward rotational displacements/sloughs have occurred resulting in the development of fresh back scarps extending to about 3 to 5 m in height. Groundwater seepage discharge noted along the toe of the fresh back scarps. Slide material consists of intermixed sand with clayey silt and large blocks of highly fractured dark grey/black bedrock *(stitched Photographs 3940, 3942).*
GPS16	Top of groundwater seepage located within a narrow drainage gully starting at the treeline about 15 m upslope from the active slide back scarp.
GPS17	West flank of active slide limits along east-west ridge that consists predominantly of sand and gravel with fines.
GPS18	Wet area above the crest of the steep canyon near east side of the slide limits.
GPS19	Near toe of the east slide flank where a steep sided slope exists that predominantly consists of silty sand and gravel.

4.1.6 Springs and Seepage

Based on the Site reconnaissance, the groundwater seepage discharge is limited to the lower slide bench that extends for about the full width of the slide at an elevation of about 525 m.

4.2 Review of Historical Air Photographs

The following table (Table 3) provides a brief summary of the historical air photograph review conducted by Golder.

Table 3: Air Photograph Review

Year	Comments
1938	Current golf course not developed. Areas north of slide not developed. Local areas at toe of Mt. Conkle developed with small orchards. Slide area consists of three hummocky benches (upper, middle and lower) incised by two major gullies, one at the east and one at the west sides of the slide. Appears to be a localized pond of water within the graben between Paradise Flats and the upper bench. Slope below lower bench subject to active sloughing.
1951	Appears to be very little noticeable change from the 1938 photographs.
1963	More orchards noted above the slide area. Slope between upper and middle benches appears to be subject to active sloughing.
1969	Same as 1963
1974	More orchard development. Lower bench width is narrower.
1980	Golf course has been developed. Extraction of sand and gravel occurring within upper bench during an ARDA project. Lower bench appears narrower and lower in elevation. Active sloughing occurring on slope below lower bench. Auto-wrecker occupying corner lot Paradise and Canyonview Roads.
1985	Middle and lower benches lower in elevation.
1992	Auto-wrecker gone. Lower bench no longer distinguishable.
1996	Small pond feature noted on golf course. Middle bench noted to be at about the same elevation of lower bench.
2001	Pond on golf course larger.
2005	Ortho-photograph, not a stereo pair.
2007	Active sloughing of slope below lower bench.
2012	Ortho-photograph, not a stereo pair.

4.3 Review of Slide Movements Using Topographic Maps

The following table (Table 4) provides a summary of our review regarding apparent changes in the slide features together with an estimation of the magnitude of slide displacements based on a comparison between 1970 and 2012 topographical mapping. The slide feature areas discussed in the following table are also shown on Figure 2.

Table 4: Comparison of Slide Features

Slide Reference Label	General Description of Slide Feature Location	Feature Comparison Comments
A	Along the west slide head scarp alongside Paradise Road and the north end of the golf course.	Little change in the upslope extents and elevation along the crest above the slide head scarp, i.e., the head scarp has not progressed further upslope.
B	Along the north slide head scarp along the south side of Canyon View Road.	1970 elevations are about 1 to 2 m higher than the 2012 elevations. There appears to have been some progression of the 1970 slide scarp by about 3 to 5 m further upslope (north) towards Canyon View Road, especially where the 1970 slide scarp is nearer to the road. This apparent progression may be related to previous gravel extraction operation carried out in that area of the old pit.
C	East slide flank along relatively flat bench.	1970 elevation is about 1 m higher than the 2012 elevation. The crest of this feature has progressed further upslope (easterly direction) by about 4 m.
D	Lower slide bench overlooking Trout Creek canyon.	Distinct graben features that existed at an elevation of about 522 m no longer exist on the 2012 plan as these areas have been replaced by steep slide scarps at elevations of about 525 to 530 m. This suggests significant lateral creep movement towards the canyon side slopes. The overall width of the lower slide bench has generally remained the same, but the elevation along the crest of the canyon side slope has dropped by about 5 to 8 m in elevation.
E	Southwest slide flank below the golf course maintenance yard.	Little change has occurred along the portion of the slide limits.
F	Distinct area along steep slope between upper and middle slide benches.	Distinct depression with steep side slopes in 2012 that did not exist in 1970. This feature is probably related to the previous gravel extraction operation as there are remnants of an old screening structure that is located to the south across an abandoned trail.
G	Toe along main/upper head scarp.	Depression areas (shallow graben feature) along the toe of the main slide scarp appears to have increased in depth as these depressions appear to be more pronounced.
H	Crest of upper slide bench where sand and gravel deposits are exposed.	The crest of the steep slope along the south side of the upper bench does not appear to have shifted further downslope as little change has occurred in its overall elevation.
I	Graben features along toe of steep sand and gravel slope.	The elevation at the 1970 graben was at 550 m. The 2012 graben elevation is lower at an elevation of 542 m with the centre of the graben feature now located about 18 m further downslope.

Slide Reference Label	General Description of Slide Feature Location	Feature Comparison Comments
J	Isolated ridge along broad base gully feature along the east side of the slide.	The 1970 high point of the ridge was at an elevation of about 544 m. In 2012, this ridge no longer exists as it has disappeared and become part of the broad base gully at an elevation of about 535 m for the same gully location.

In general, the slide surface across the middle and lower portions have dropped by about 5 to 10 m and moved laterally by about 5 to 20 m with the graben features showing the greater amount of displacement, especially approaching towards the crest of the canyon side slopes.

4.3.1 Estimated Slide Material Volume Loss

The Perpetual Slide movement has resulted in the net loss of material into the Trout Creek channel that is continually being flushed downstream with finer sediments being washed into Okanagan Lake. The Riglin (1977) study estimated that the material loss amounted to an annual volume of about 11,500 m^3. The material loss is directly caused by the gradual downslope movement of large rotational blocks that results in backward (upslope) tilting of mature trees within graben areas, *(Photograph 3998 in Appendix C)* as the reworked slide material gradually sloughs upon getting wet by the groundwater seepage causing it to "flow" further downslope along the steep canyon side slopes and into Trout Creek. The repeated action is gradually eroding the crystalline bedrock surface above Trout Creek whereby the steep side slope has regressed further upslope by about 5 to 8 m, as illustrated on Figure 3 that shows the comparison of the 1938, 1970, 2005 and 2012 sectional profiles relative to Riglin's 1938 and 1970 slide profile comparison.

Using the 2005 and 2015 topography provided by DoS, slide profiles were also prepared from 3D surface models and compared using the same sections that were presented in Riglin's Figure 1-2c. Calculations using average end areas for these sections indicate that the volume loss between 1970 and 2012 is very similar at about 15,700 m^3 per year. It should be noted that this volume was calculated using the same profile length that extends between the head scarp down to the crest of the Trout Creek canyon and does not take into account for different levels of accuracy in the preparation of the topographic plans between the earlier and later years. The difference in the slide surfaces between each comparison year is shown by the shaded areas for each section on Figure 3.

A volume comparison between the 2005 and 2012 was also carried out as the level of accuracy is expected to be better than the earlier plans. Based on a comparison between the 3D surfaces for 2005 and 2012, it is interesting that the net volume loss was also calculated to be similar at about 11,600 m^3. However, this volume lost was generally limited to the lower slide bench below an elevation of 525 m with little volume change between the topography for the upper part of the slide between the head scarp and elevation 525 m.

4.4 Slide Zone Activity Rating

Based on the results of the slide reconnaissance together with comments provided by DoS and the golf course, different slide zones have been identified based on the level of observed slide activity together with the magnitude of ground surface displacements. The estimated zone boundaries are shown on Figure 4 and their degree of activity is discussed in the following table (Table 5).

Table 5: Slide Zone Activity Rating

Rating Designation	General Description
Very High (VH)	Lower bench area that extends up to an elevation of about 525 m where groundwater seepage discharge generally extends across the full width of the slide above the crest of the Trout Creek canyon. This area has little or no tree cover with fresh soil exposure throughout. Currently, the greater amount of activity is occurring across the west half of the bench.
High (H)	This area is located above an elevation of 525 m and extends upslope up to the crest of the steep middle slope. Graben features are typical along the toe of the steep sand and gravel slope where trees tilt backwards because of rotational slide movement.
Moderate to Low (M-L)	Upper slide bench and head scarp slope where most of the former gravel extraction was carried out. Shallower graben features exist along the toe of the head scarp with potential shallow groundwater along the graben areas.
IA – Increased Activity	Two areas of increased slide activity has developed since the last several years that did not exist at the time of the 2012 DoS aerial photography. These areas are located at the north end of the golf course near the intersection of McGee Street and Paradise Road and also along Canyon View Road about midway between Paradise and Simpson Roads that have resulted in several water line breaks as well as causing significant roadway subsidence. These areas of activity extend further up from the crest of the existing head scarp by a distance of approximately 30 to 50 m.

4.5 Hydrogeological Review

4.5.1 Contributing Watershed

Based on topographic data provided by the District of Summerland, Golder has inferred the watershed area of Trout Creek contributing recharge to the slide (the “contributing watershed”) to be as shown on Figure 5. The following provides a summary of area estimates based on topography and ortho-imagery.

- Total watershed area contributing to slide: 1,541,210 m^2 (approximately 154 hectares)
- Agricultural area within watershed: 381,525 m^2 (approximately 38 hectares)
- Total area of golf course: 488,015 m^2 (approximately 49 hectares)
- Area of golf course turf inside watershed: 38,586 m^2 (approximately 4 hectares)
- Area of golf course pond: 11,184 m^2 (approximately 1 hectare)

In comparison, Riglin (1977) estimated the catchment basin of the slide to be approximately 1,790,000 m^2 (179 hectares), 373,000 m^2 (37.3 hectares) of which was cultivated. As the catchment areas are very similar, the difference is inferred to be related to increased accuracy of estimating areas using current digital mapping methods.

4.5.2 Bedrock and Surficial Geology

Riglin (1977) provides a detailed review of bedrock and surficial geology of the slide area. Regional bedrock mapping is described in Okulitch (2011) and a comprehensive review of regional quaternary geology for the Okanagan is Nasmith (1962). To briefly summarize, surficial geology of the slide area consists of glacial outwash terraces, and bedrock in the area of the slide is mainly comprised of older, Jurassic crystalline rocks (granodiorite and a vein and dike complex) enclosing a younger, competent sedimentary limestone-sandstone unit. An unconformity between the older crystalline and younger sedimentary rocks exists, which trends northeast and dips gently northwest. The contact is inferred to be a major fault zone; however, Riglin (1977) states that this unconformity does not generally directly underlie the failure plane of the slide, except at its toe. Instead, Riglin inferred that tertiary sediments form the failure plane of the slide, as discussed in Section 3.1 of this report (Slide Mechanism). Slide gouge at the toe is a mixture of claystone, coal, broken sandstone and till. The gouge is clay rich, has a low permeability, and swells in contact with water. The slide gouge confines upward discharge from underlying bedrock and allows high porewater pressures to form at the base of the slide, which contribute directly to the slide mechanism. Groundwater flow is implicated as a significant factor in the failure of the slide.

4.5.3 Subsurface Conditions in Slide Area

Based on a review of the BC MoE Wells water well database accessed through the Water Resources Atlas, there are no water well records within the contributing watershed area. Thus, the only subsurface information available is that gathered from boreholes drilled during the Golder (1979) investigation (Appendix B). This data was combined with the 2012 elevation survey data to construct two cross sections through the slide area (Figure 6). Cross Section 1 cuts from southwest to northeast across the north end of the golf course and across the face of the slide (Figure 7). The golf course pond is not shown as a basin on the cross section because no bathymetry data were available. Cross Section 2 runs from northwest to southeast across the golf course (Figure 7). It is noted that no boreholes were drilled within the slide area in the 1979 investigation.

The site stratigraphy in the northern portion of the golf course can be described as loose sand and gravel from surface to depths of 3.0 m to 6.7 m overlying a 10 m to 12 m thick unit of compact sand and gravel containing cobbles followed by a 0.5 m to 2.4 m thick layer of glacial till deposited on bedrock. In this area groundwater appears to be perched on the glacial till, with the static water level observed within the compact sand and gravel layer, at depths ranging from 10.3 m to 14.9 m below ground surface (bgs).

Toward the south end of the golf course, where it borders the Trout Creek Canyon, the loose surficial sand and gravel is not present and the compact sand and gravel containing cobbles overlies a thick (14.3 m) unit of glacial till. It is noted that bedrock was not intersected at P4, bordering the canyon.

At the south end of the golf course, the loose sand and gravel at surface is not present and instead the compact sand and gravel unit is present at surface. Below this is a thick unit of glacial till, up to 14.3 m thick at P4, where bedrock was not encountered. It is interesting to note that groundwater level monitoring at P4 over the 1979 to 1988 monitoring period indicated that the water level at P4 continually decreased and was nearly at the bottom of the well screen (installed within the glacial till) by the end of the monitoring program.

Regional groundwater flow is inferred to be generally from northwest to southeast, toward Trout Creek, however in the area of the slide there is a gradient in the direction of the slide graben and seepage areas are at elevations similar to the water table elevation (Figure 6).

4.5.4 Water Use

Available domestic and irrigation water use data for land parcels located within the contributing watershed area was provided by the District of Summerland for the 2014 calendar year, along with the arable area of the parcel in acres (Table 6). The domestic use data was provided in units of cubic metres (m^3) and irrigation data was provided in units of Imperial Gallons. It is noted that some addresses have two entries for domestic water use, which are associated with a secondary building (carriage house or shop). Golder conducted unit conversions and calculated the irrigation rate based on the data provided by the District of Summerland (Table 6).

Table 6: Annual Water Use Data for 2014

Address	Domestic	Irrigation				
	2014 Usage (m^3)	Irrigation 2014 (Imperial Gallons)	Irrigation 2014 (m^3)	Arable Area (acres)	Arable Area (m^2)	Irrigation Rate (mm)
10818 Canyon View Road	109.194	2,010,000	9137.6	4.72	19,101	478
10818 Canyon View Road	237.727					
10920 Canyon View Road	488.785	1,170,000	5318.9	4.72	19,101	278
2405 Mountain Avenue (Golf Course)	No Information	39,095,000	177729.5	52	210,435	845
3616 Mountain Avenue	88.244	0	0.0	4.82	19,506	0
3810 Mountain Avenue	83.289	0	0.0	10.17	41,156	0
4007 Mountain Avenue	185.109	1,276,000	5800.8	4.75	19,222	302
4333 Mountain Avenue	196.545	3,397,000	15443.1	5	20,234	763
4483 Mountain Avenue	213.725	No Irrigation Connection				
3801 Paradise Road	91.794	0	0.0	3.67	14,852	0
3808 Paradise Road	95.91	3,989,000	18134.4	4.75	19,222	943

Address	Domestic	Irrigation					
	2014 Usage (m^3)	Irrigation 2014 (Imperial Gallons)	Irrigation 2014 (m^3)	Arable Area (acres)	Arable Area (m^2)	Irrigation Rate (mm)
4275 Sherk Street – House	146.27	3,977,000	18079.8	6.88	27,842	649
4208 Sherk Street	129.767	No Information				
4217 Sherk Street	971.048	No Irrigation Connection				
4228 Sherk Street	233.383	1,848,000	8401.2	4	16,187	519
4204 Simpson Road	79.927	574,500	2611.7	4.75	19,222	136
4612 Simpson Road	145.574					
4612 Simpson Road	90.562	2,090,500	9503.6	5.87	23,755	400

The provided domestic water use data shows that water use is variable, ranging from approximately a minimum of 80 m^3/yr to a maximum of 971 m^3/yr. These values appear to be reasonable and bracket the average water use for British Columbia as calculated using the residential per capita water use of 606 L/person/day (Environment Canada 2009) and the average number of persons per household of 2.5 (Statistics Canada 2011), which gives an annual residential water use of 553 m^3/yr per household. One notable data gap is that there is no domestic water use data for the golf course.

The calculated irrigation rates for domestic use range from 136 mm per year to 943 mm per year, while the golf course irrigation rate is calculated to be 845 mm per year. These values are consistent with average water use data calculated for the Okanagan Basin of 660 mm for agriculture and 900 mm for golf courses, parks and domestic irrigation (van der Gulik et al 2010).

4.5.5 Wastewater Disposal

Based on discussion with DoS it is understood that wastewater disposal for all of the parcels comprising the contributing watershed is via individual subsurface effluent disposal fields. No information was available on the locations of, design or condition of the disposal fields.

4.6 Resident Questionnaire

A questionnaire was developed by Golder for future distribution to the residents and businesses in the local area, when required. The questionnaire seeks out information related to water supply wells, septic systems, irrigation associated with the surrounding area. A copy of the questionnaire has been included as Appendix D. The questionnaire was not distributed to the residents as part of this investigation, but is available for future distribution when deemed necessary.

5.0 RECOMMENDATIONS

The following presents our recommendations regarding the activity of the Perpetual Slide based on our interpretation of the information, the potential hazard that it imposes to neighbouring properties and nearby public infrastructure together with our recommendations for short term measures a proposed monitoring program and intrusive geotechnical investigation.

5.1 Land Use and Planning Measures

5.1.1 Preliminary Slide Setback Zone

The overall slide angle starting at the toe of the steep canyon slope along Trout Creek and extending up to the approximate outside area of the noted activity ranges from about 13.5 degrees (4.2 horizontal to 1 vertical) at Section A-B (middle of slide), 15.3 degrees (3.7 horizontal to 1 vertical) at Section C-D and 14.5 degrees (3.9 horizontal to 1 vertical) at Section E-F (Figure 2).

Based on this information, it is recommended that a preliminary setback zone be established along the crest of the existing head scarp that extends back for a distance of at least 50 m (Figure 6). It is expected that this area will probably continue to be affected by retrogressive slide activity as the head scarp gradually continues to advance further upslope through a series of sloughs. It should be noted that the preliminary setback distance should be reviewed pending the results of a monitoring program and following a detailed field investigation that is discussed in the next section.

Consequently, existing infrastructure that is located within the proposed setback zone will likely be subject to unpredictable ground movement. Without specific monitoring data, it is not possible to predict the magnitude of future movements within the proposed setback zone, except that they will likely occur gradually either as slow creeps along the head scarp or suddenly with an abrupt ground subsidence that extends further away from the head scarp similar to the Canyon View Road subsidence.

5.1.2 Potential Impact to Existing Infrastructure above the Perpetual Slide

As discussed above, it is our opinion that ongoing slide activity will continue above the head scarp that will impact existing public infrastructure and private properties. Therefore, for short-term purposes the following items should be considered.

- DoS should implement an emergency response plan for an alternate vehicle route in the event that Canyon View Road becomes temporarily impassable to local traffic because of a sudden collapse of the roadway as well as a plan for the temporary replacement of affected utilities.
- Re-leveling of the settled portion of Canyon View Road can be considered, but it is likely that it will continue to settle and creep with time, which will require ongoing maintenance.
- Emergency shut-off valves should be considered when a sudden pressure drop occurs in the exiting 250 mm water main that will automatically shut the flow of water flow in the event of other breaks in order to

reduce the volume of water that would be discharged directly into the slide mass. The low pressure shut-off valves should be installed beyond the limits of the proposed setback area.

- Alternatively, the existing water main that is currently located within the zone of increased slide activity and also within the proposed setback area should be replaced with a flexible HDPE Sclairpipe that can tolerate significant differential movement with less potential for breakage.
- To date, the overhead hydro/telephone/cable lines and utility poles have not been impacted as a result of the increased slide extents. However, two power poles are currently located within 5 to 10 m from the edge of the north tension crack that extends across the roadway at 10920 Canyon View Road. It is expected that ongoing slide progression will eventually impact these utility poles with the potential loss of services to the noted property.
- The residential structure at 10920 Canyon View Road is not considered to be in imminent danger; however, it appears that the slide has progressed into the property, which could impact underground utilities that services the residence and the property. A review of each service connection to the residence should be conducted to verify their integrity.
- Review the feasibility of establishing a legal utility easement at the rear of the properties that front Canyon View Road in order to accommodate the water main as well as other utilities.

5.1.3 Potential Downstream Consequences to the Trout Creek Area

Flood risks are typically assessed in terms of the hazard (or consequence) of a flood event and the probability of that flood event occurring. It is not possible to predict if or when a significant slide may occur at this site. If one did occur, there is potential for the slide material to block off streamflow in Trout Creek. Depending on the size of the slide and volume of material plugging the canyon, a natural dam would form and it would begin impounding streamflow. The resulting scenario could lead to a dam breach failure and there could be an extreme hazard to downstream people, infrastructure, environmental values, and cultural values.

To quantify or delineate the potential flood inundation impacts, further study is required along the lower floodplain of Trout Creek. Different dam height scenarios could be modelled to assess the potential flood inundation impacts. However, Golder's knowledge of dam breach analysis indicates that the peak flow from a dam breach event would be significantly higher than peak flows from the natural watershed. Further, the hydrograph peak would be over short duration, sending a large flood wave down the river system potentially spilling across the floodplain.

If further study is completed on this potential flood hazard, mitigation options should be assessed. Some mitigation options may include, but are not limited to:

- monitoring downstream streamflow for sudden drops in water level;
- monitoring slope movement on the slide;
- public education and/or erecting signage along the dike system and bridge crossing;
- preparing an emergency response plan;

- additional flood protection works such as higher or set back dikes, or a large debris basin; and,
- modified local by-laws regarding land use on the floodplain.

Lastly, if a slide dammed Trout Creek the emergency response and recovery aspects need to be considered. There could be a significant safety hazard to equipment and people working to remove deposited material. The post-slide material could be unstable and construction access may be difficult. Managing and by-passing water would be an important part of the emergency operations.

5.1.4 Education and Outreach

It is recommended to conduct community outreach for property owners within the contributing watershed area to educate them regarding irrigation best practices such as those described in Appendix E and residential water conservation measures.

5.2 Proposed Survey Monitoring Program

It is recommended that a short-term survey monitoring program be considered for at least three months before a detailed intrusive investigation is started in order to determine the magnitude of slide displacements along the affected portion of Canyon View Road as well as the northern portion of the golf course in the vicinity of the old P1 piezometer. This will enable Golder to better select strategic test hole and in-ground instrumentation locations.

The survey monitoring program should consist of taking monthly coordinate and elevation readings (NEZ) on a series of permanent surface monuments using a total station instrument that can provide a reading accuracy of at least a centimetre. The survey should be tied into local geodetic survey monuments that will not be influenced by future slide activity using the UTM NAD83 spatial reference system. Surface monuments should consist of 20M deformed reinforcement bars installed to a depth of at least 0.8 m below into the ground together with a distinct mark for reading repeatability purposes, and a surface stake marker with an appropriate identification label.

Monthly readings should be taken for a period of at least one year in order to better understand the magnitude of movement relative to seasonal variations, irrigation usage, and groundwater levels. The monitoring frequency can be modified based on the review of monthly readings.

The surface monuments should be installed at 20 m intervals at the following locations:

- Canyon View Road between Sherk Street and Simpson Road for a distance of about 350 m; along the property line on the north side of the road, along the roadway centre line (using temporary surveying nail sets), and at an offset distance of 20 m south from the road centre line.
- Paradise Road starting at Canyon View Road going south to the old Angove Avenue right of way along the west property line and along the east edge of the golf course for a distance of about 350 m.

The survey monitoring program should also include the existing base station along the west side of the golf course and the P1 monument that is located between the existing golf course pond and the slide scarp (Figure 6).

5.3 Proposed Intrusive Field Investigation and Monitoring Program

Based on the results of the survey monitoring program, strategic borehole and inclinometer locations will be selected below and above the slide scarp taking into consideration reasonable site access for drilling equipment in order to reduce field investigation costs. Currently, it is expected that at least four (4) test holes will be required to assess the higher hazard areas, specifically along Canyon View Road where slide progression has apparently occurred over the past several years as well as the north end of the golf course near McGee Street. At each test hole location, slope inclinometers will be installed together with electric vibrating wire piezometers. The inclinometers will provide data that is specific to the depth of the slide surface(s) as well as the displacement rate at the slide surface(s). Data collectors should be included with each vibrating wire in order to record peak groundwater responses (hydraulic pressure response) rather than using conventional open piezometer standpipes that are only capable of recording static water levels. The actual test hole depths will depend on the subsurface conditions encountered, but it is expected that depths will probably extend between 20 to 40 m.

The information collected from the intrusive field program will be used for slope stability modelling purposes that can be used to better define a safe setback distance away from the head scarp.

Depending on the results of the monitoring program and the intrusive field investigation, short-term remediation options can be re-assessed, together with the evaluation of available long-term options.

Results of the monitoring program should be reviewed by qualified professionals.

5.4 Collection of Water Use Information

Water use information should continue to be collected on a monthly basis by the District of Summerland, including non-irrigation (domestic) water use for the golf course operations.

5.5 Bylaw Measures

The District of Summerland may wish to implement the following bylaw measures provided for consideration:

- Update the Official Community Plan bylaw to take into consideration the slide setback zone above the existing head scarp.
- Depending on the results of the monitoring program (geotechnical, hydrogeological and water use); the District of Summerland may wish to initiate the implementation of water application restrictions for domestic and agricultural water users that are located up-gradient of the slide head scarp, especially for properties between the foot of Conkle Mountain and Simpson Road.

6.0 LIMITATIONS

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7.0 CLOSURE

We trust this provides you with the information you require at this time. Should you have any questions or require additional clarification, please feel free to contact the undersigned at your earliest convenience.

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LEGEND

- APPROXIMATE OLD SLIDE LIMITS
- APPROXIMATE AREA OF RECENT MOVEMENT
- PAVEMENT TENSION CRACKS
- GPS REFERENCE LOCATIONS
- MAJOR CONTOUR 5 m INTERVAL (2012)
- MINOR CONTOUR 1 m INTERVAL (2012)
- DEPRESSION CONTOUR (2012)

REFERENCE

CONTOURS AND LEGAL LOT LINES PROVIDED BY THE CLEINT IN DWG FORMAT.

IMAGERY PROVIDED BY THE CLIENT (2012 IMAGERY).

0 50 100

1:2,500 METRES

CLIENT
DISTRICT OF SUMMERLAND

CONSULTANT

Golder Associates

YYYY-MM-DD	2015-03-30
PREPARED	MD
DESIGN	RT
REVIEW	RT
APPROVED	GI

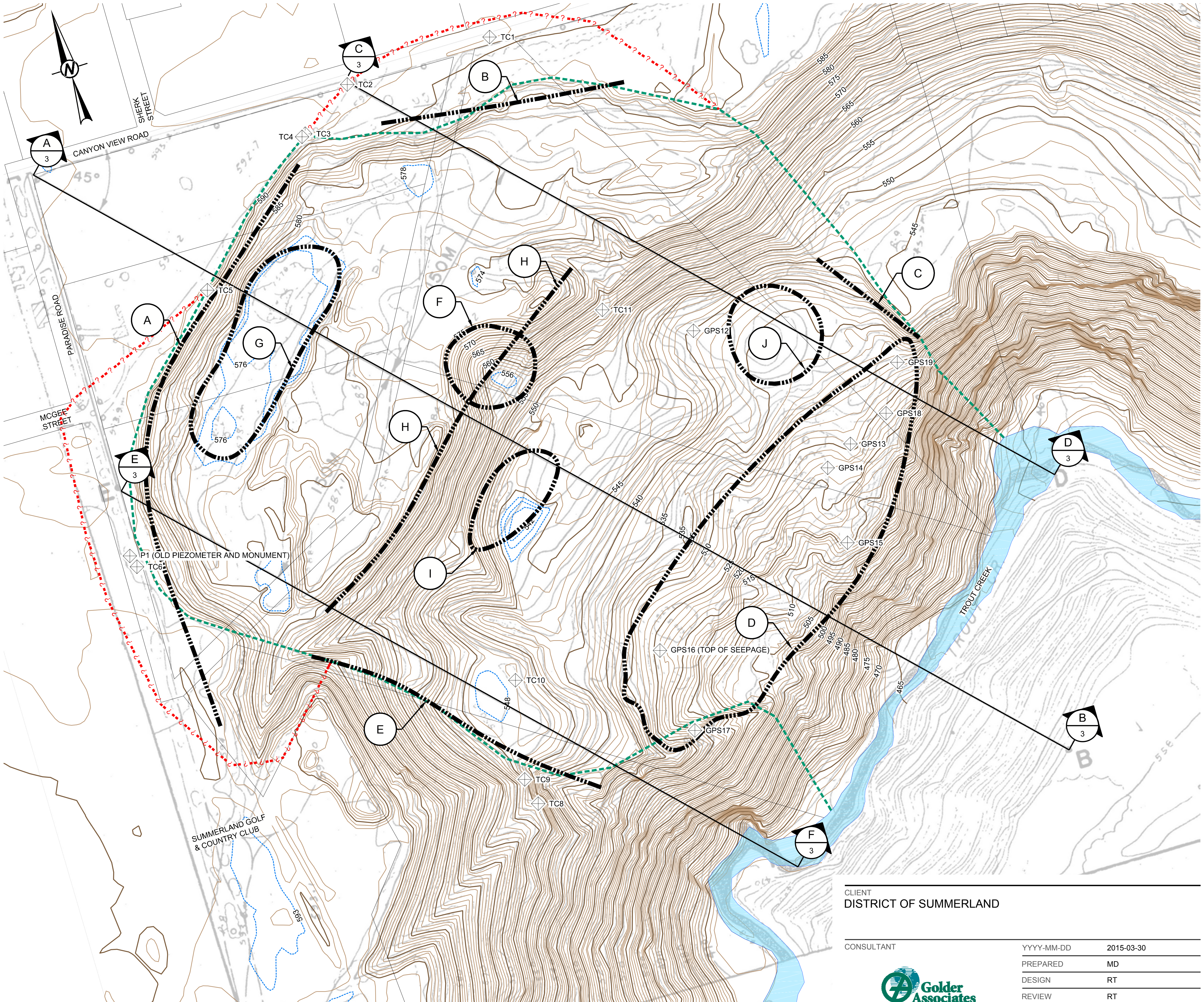
PROJECT
PERPETUAL SLIDE
SUMMERLAND, BC

TITLE
SITE PLAN

PROJECT No.	PHASE	Rev.	FIGURE
1417553	3000	0	1

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

Path: \\golder.gds\gal\Kelowna\Graphics\2014 GLOBAL NUMBERING\1417553\CAD\3000\PRODUCTION\ | File Name: 1417553_3000_01.dwg



LEGEND

- APPROXIMATE OLD SLIDE LIMITS
- APPROXIMATE AREA OF RECENT MOVEMENT
- GPS REFERENCE LOCATIONS
- MAJOR CONTOUR 5 m INTERVAL (2012)
- MINOR CONTOUR 1 m INTERVAL (2012)
- DEPRESSION CONTOUR (2012)
- REFERENCE LINE
- REFERENCE LABEL

REFERENCE

CONTOURS AND LEGAL LOT LINES PROVIDED BY THE CLEINT IN DWG FORMAT.

BASE PDF PROVIDED BY THE CLIENT "1970 topo_UBC_1977_A6_7.pdf".

0 50 100

1:2,500 METRES

CLIENT
DISTRICT OF SUMMERLAND

CONSULTANT

Golder Associates

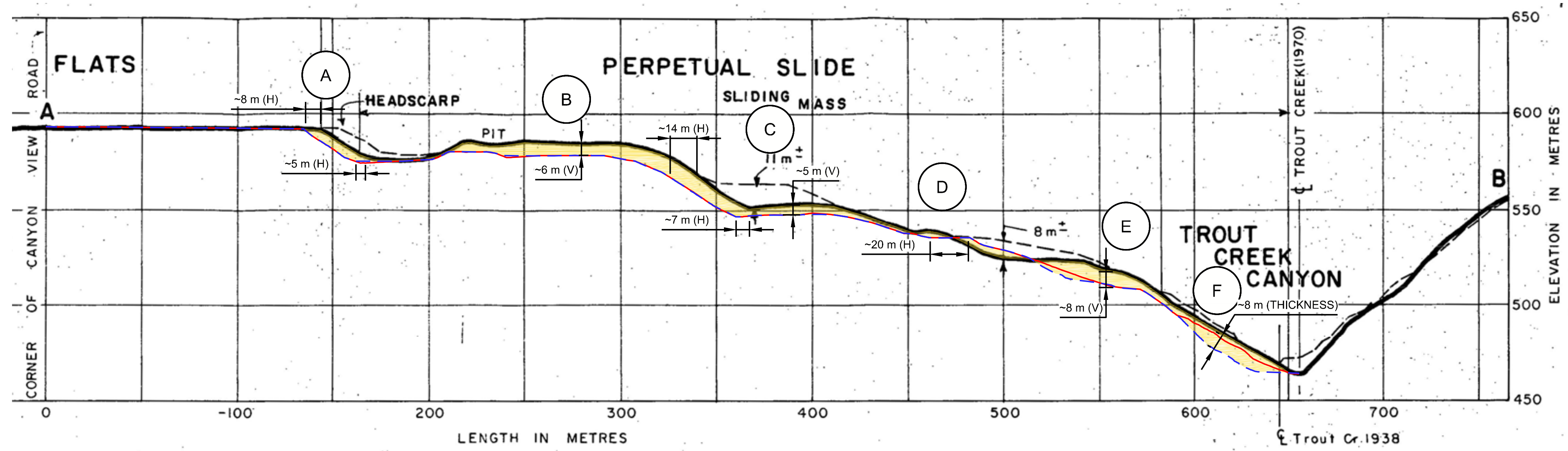
YYYY-MM-DD	2015-03-30
PREPARED	MD
DESIGN	RT
REVIEW	RT
APPROVED	GI

PROJECT
PERPETUAL SLIDE
SUMMERLAND, BC

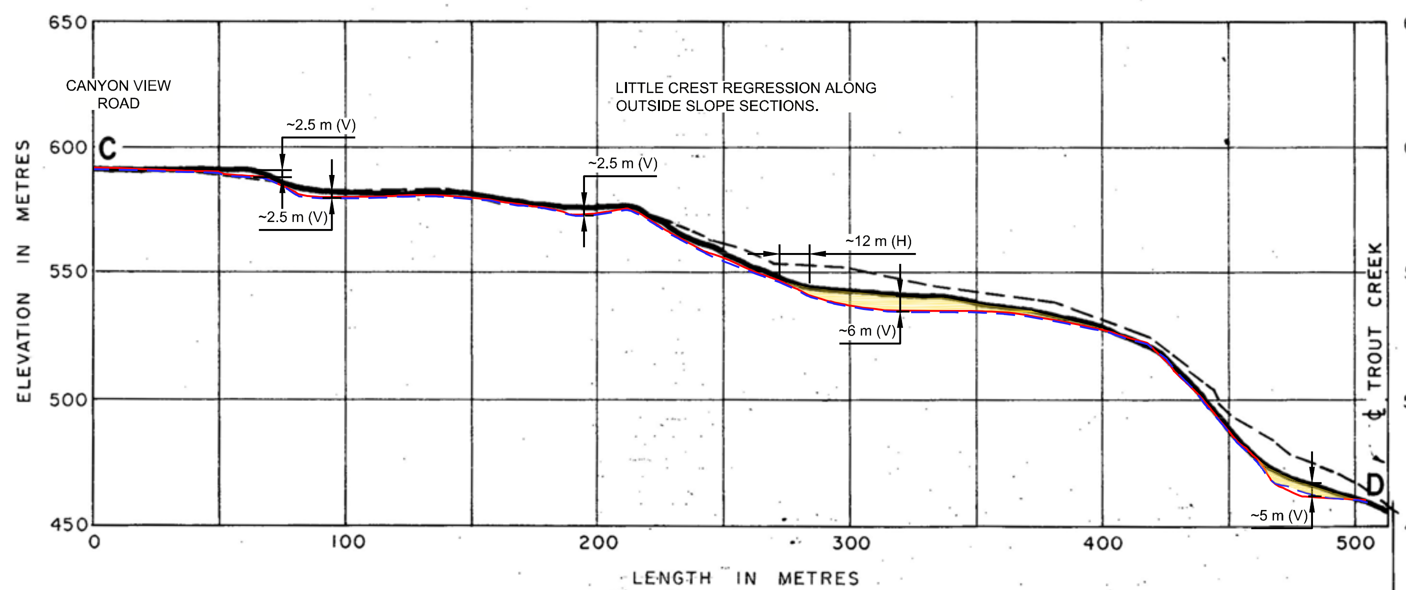
TITLE
COMPARISON OF SLIDE FEATURES

PROJECT No.	PHASE	Rev.	FIGURE
1417553	3000	0	2

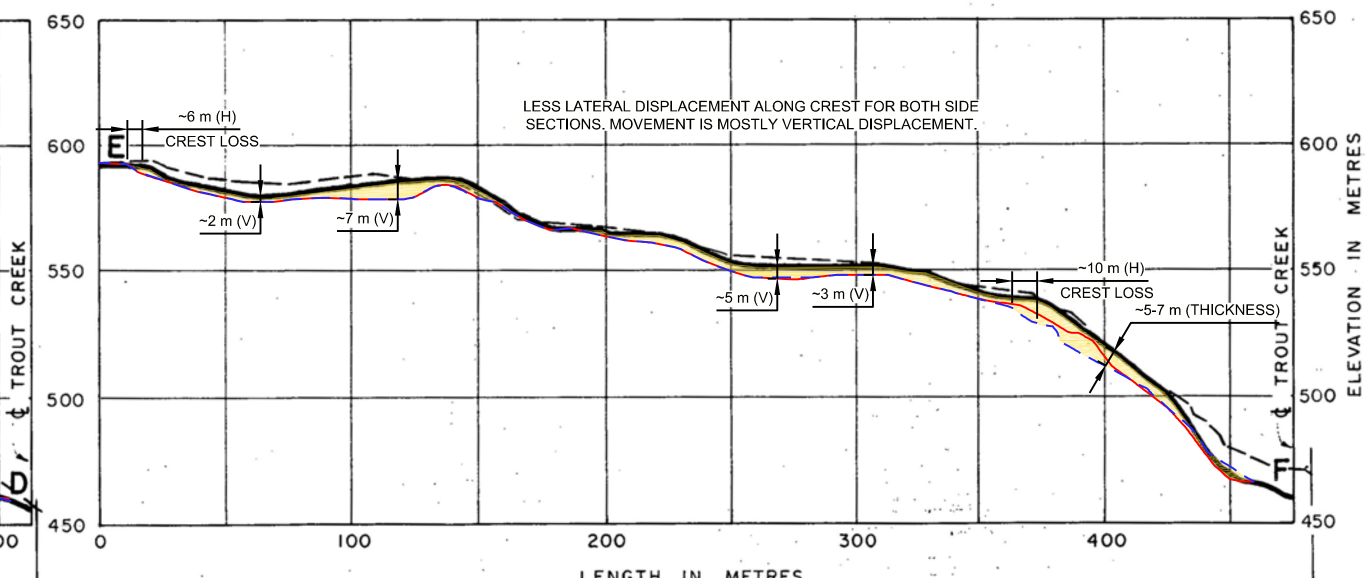
Reference Label	Remarks (1970 to 2012)
A	Head scarp progressed by about 8 m with loss of material along entire slope face
B	Middle bench dropped by about 6 m with downslope face loss of about 14 m thickness
C	Graben below toe of middle bench has dropped by about 5 m with horizontal toe loss of about 7 m
D	Fresh scarps along bottom treeline has advanced downslope by about 20 m
E	Crest of canyon slope has dropped by about 8 m
F	Steep canyon face has regressed into the slope by about 15 m with a corresponding material thickness loss of about 8 m



SECTION THRU A - B
(1)



SECTION THRU C - D
(2)



SECTION THRU E - F
(3)

LEGEND

- 1938 DATA SHOWN
- 1970 DATA SHOWN
- 2005 DATA SHOWN
- 2012 DATA SHOWN
- CHANGE IN PROFILE
- (A) REFERENCE LABEL

REFERENCE
BASE PDF PROVIDED BY THE CLIENT "Sections from 1970 Topo_Summerland Perpetual Slide Thesis UBC_1977_A6_7.pdf".

0 50 100
1:3,000 METRES

CLIENT
DISTRICT OF SUMMERLAND

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-03-30
PREPARED	MD
DESIGN	RT
REVIEW	RT
APPROVED	GI

PROJECT
PERPETUAL SLIDE
SUMMERLAND, BC

TITLE
CHANGE IN SLIDE PROFILES (COMPARISON 1938, 1970,2005 & 2012)

PROJECT No.	PHASE	Rev.	FIGURE
1417553	3000	0	3

Path: \\golder.gds\gal\Kelowna\Graphics\2014 GLOBAL NUMBERING\1417553\CAD\3000\PRODUCTION\ | File Name: 1417553_3000_03.dwg

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

LEGEND

- APPROXIMATE OLD SLIDE LIMITS
- APPROXIMATE AREA OF RECENT MOVEMENT
- GPS REFERENCE LOCATIONS
- MAJOR CONTOUR 5 m INTERVAL (2012)
- MINOR CONTOUR 1 m INTERVAL (2012)
- DEPRESSION CONTOUR (2012)
- VH VERY HIGH
- H HIGH
- M-L MODERATE TO LOW
- I-A AREA OF RECENT INCREASED ACTIVITY
- H SLIDE ZONE ACTIVITY RATING MARKER (INDICATES ESTIMATED AREA OF ACTIVITY RATING BASED ON MOVEMENT)

REFERENCE

CONTOURS AND LEGAL LOT LINES PROVIDED BY THE CLEINT IN DWG FORMAT.

IMAGERY PROVIDED BY THE CLIENT (2012 IMAGERY).

0 50 100
1:2,500 METRES

CLIENT
DISTRICT OF SUMMERLAND

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-03-30
PREPARED	MD
DESIGN	RT
REVIEW	RT
APPROVED	GI

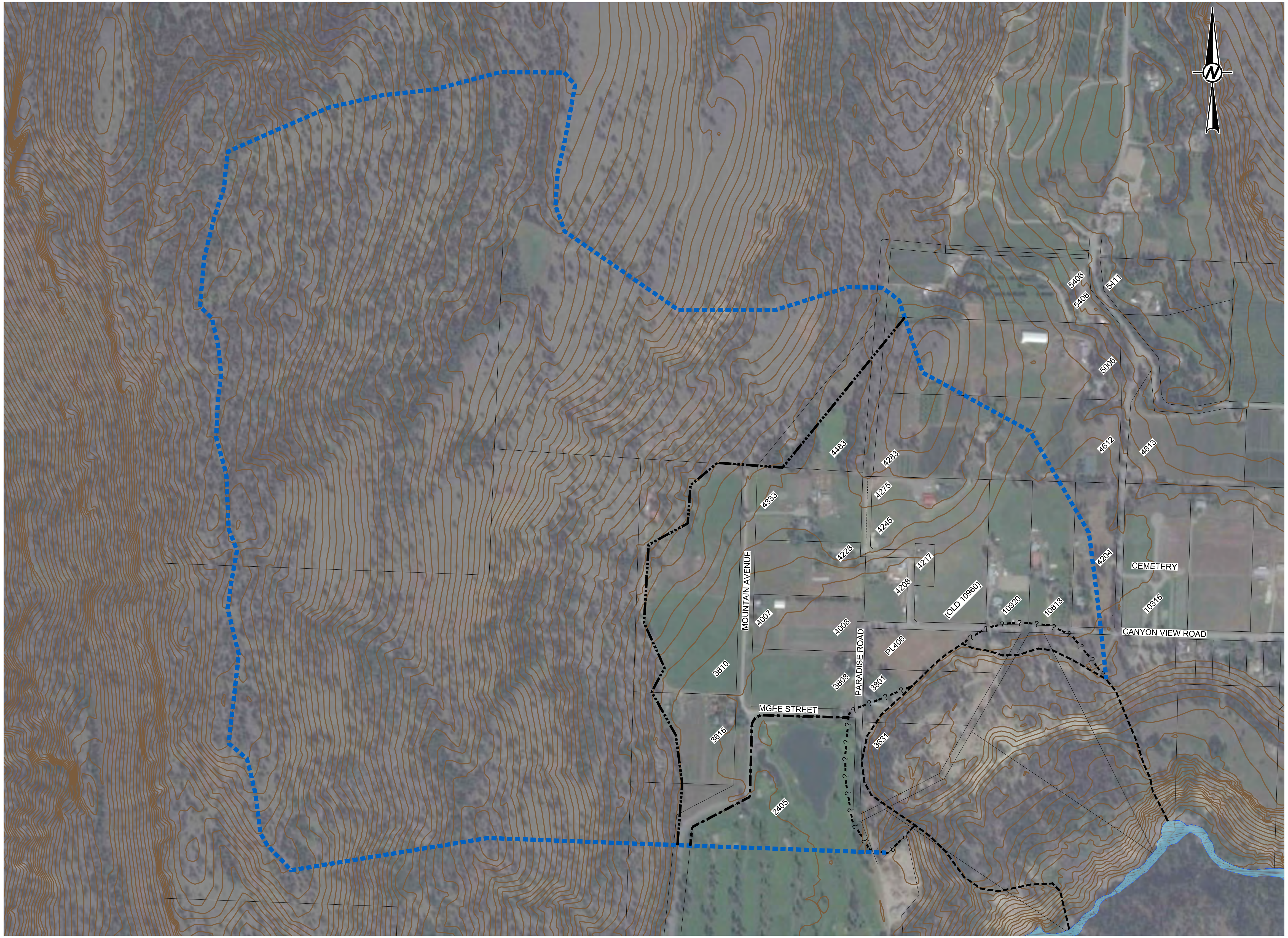
PROJECT
PERPETUAL SLIDE
SUMMERLAND, BC

TITLE
SLIDE ZONE ACTIVITY RATING

PROJECT No.	PHASE	Rev.	FIGURE
1417553	3000	0	4

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

Path: \\golder.gds\gal\Kelowna\Graphics\2014 GLOBAL NUMBERING\1417553\CAD\3000\PRODUCTION\ | File Name: 1417553_3000_04.dwg



LEGEND

- APPROXIMATE OLD SLIDE LIMITS
- APPROXIMATE AREA OF RECENT MOVEMENT
- 5406 CIVIC ADDRESS
- MAJOR CONTOUR 5 m INTERVAL (2012)
- WATERSHED BOUNDARY
- AGRICULTURAL AREA WITHIN WATERSHED BOUNDARY
- GOLF COURSE WITHIN WATERSHED BOUNDARY

REFERENCE

CONTOURS AND LEGAL LOT LINES PROVIDED BY THE CLEINT IN DWG FORMAT.

BING MAPS AERIAL - © 2015 DIGITALGLOBE IMAGE COURTESY OF USGS © 2015 GEOEYE © PROVINCE OF BRITISH COLUMBIA EARTHSTAR GEOGRAPHICS SIO © 2015 MICROSOFT CORPORATION

0 125 250

1:7,500 METRES

CLIENT
DISTRICT OF SUMMERLAND

PROJECT
PERPETUAL SLIDE
SUMMERLAND, BC

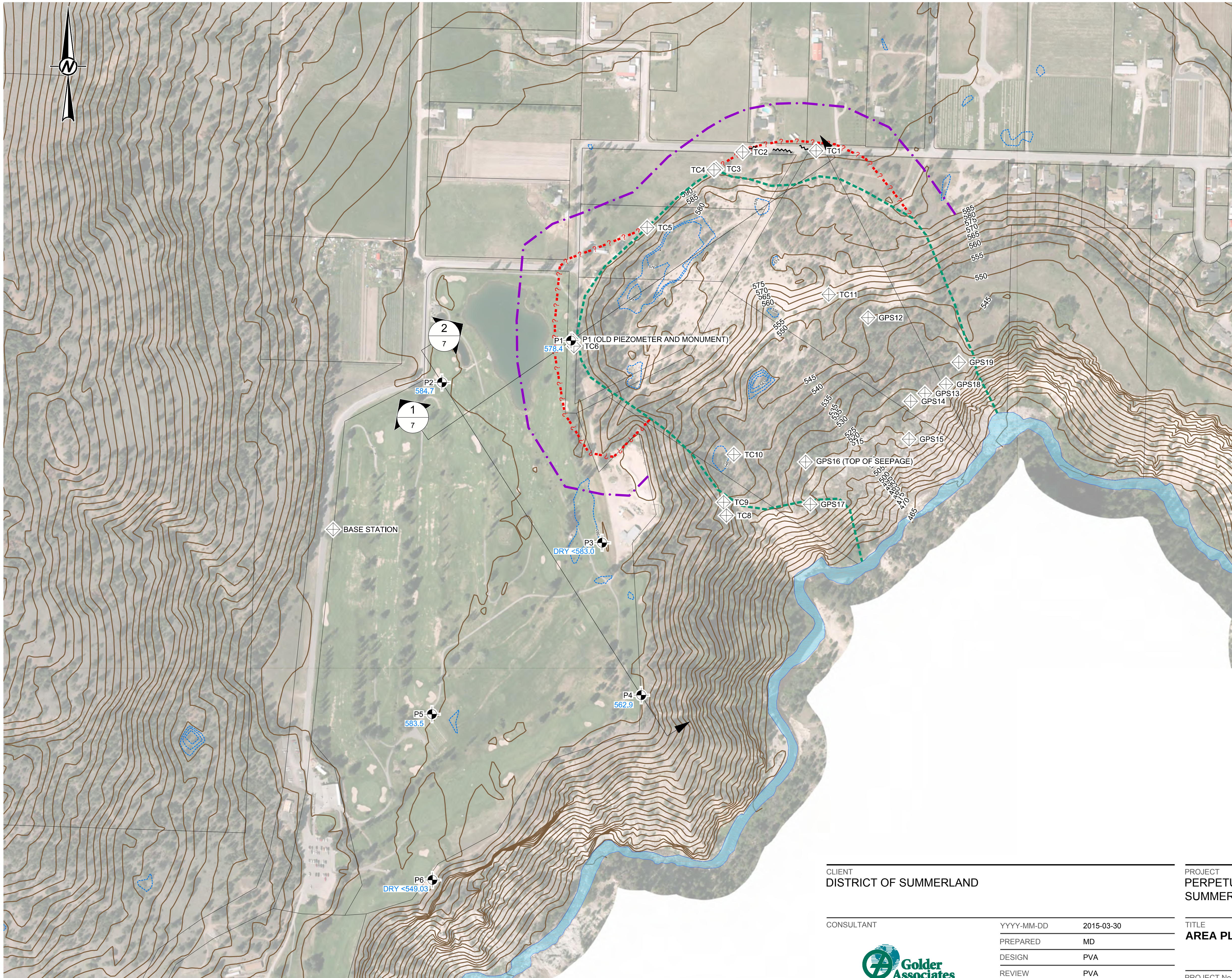
CONSULTANT

Golder Associates

YYYY-MM-DD	2015-03-30
PREPARED	MD
DESIGN	PVA
REVIEW	PVA
APPROVED	JF

TITLE
CONTRIBUTING WATERSHED AREA

PROJECT No.	PHASE	Rev.	FIGURE
1417553	3000	0	5



LEGEND

- APPROXIMATE OLD SLIDE LIMITS
- APPROXIMATE AREA OF RECENT MOVEMENT
- PAVEMENT TENSION CRACKS
- GPS REFERENCE LOCATIONS
- P1 583.1 APPROXIMATE WELL LOCATIONS WATER LEVEL ELEVATION (m) (JULY 1, 1988)
- MAJOR CONTOUR 5 m INTERVAL (2012)
- DEPRESSION CONTOUR (2012)
- 50m SETBACK

REFERENCE

CONTOURS AND LEGAL LOT LINES PROVIDED BY THE CLEINT IN DWG FORMAT.

IMAGERY PROVIDED BY THE CLIENT (2012 IMAGERY).

0 100 200
1:5,000 METRES

CLIENT
DISTRICT OF SUMMERLAND

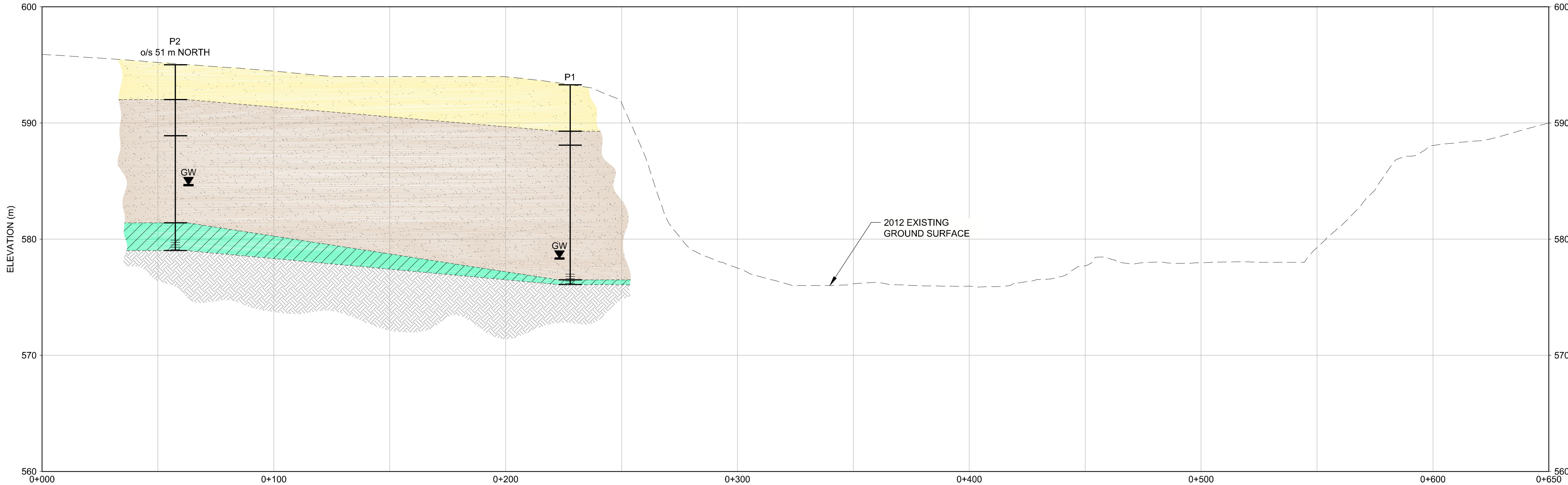
PROJECT
PERPETUAL SLIDE
SUMMERLAND, BC

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-03-30
PREPARED	MD
DESIGN	PVA
REVIEW	PVA
APPROVED	JF

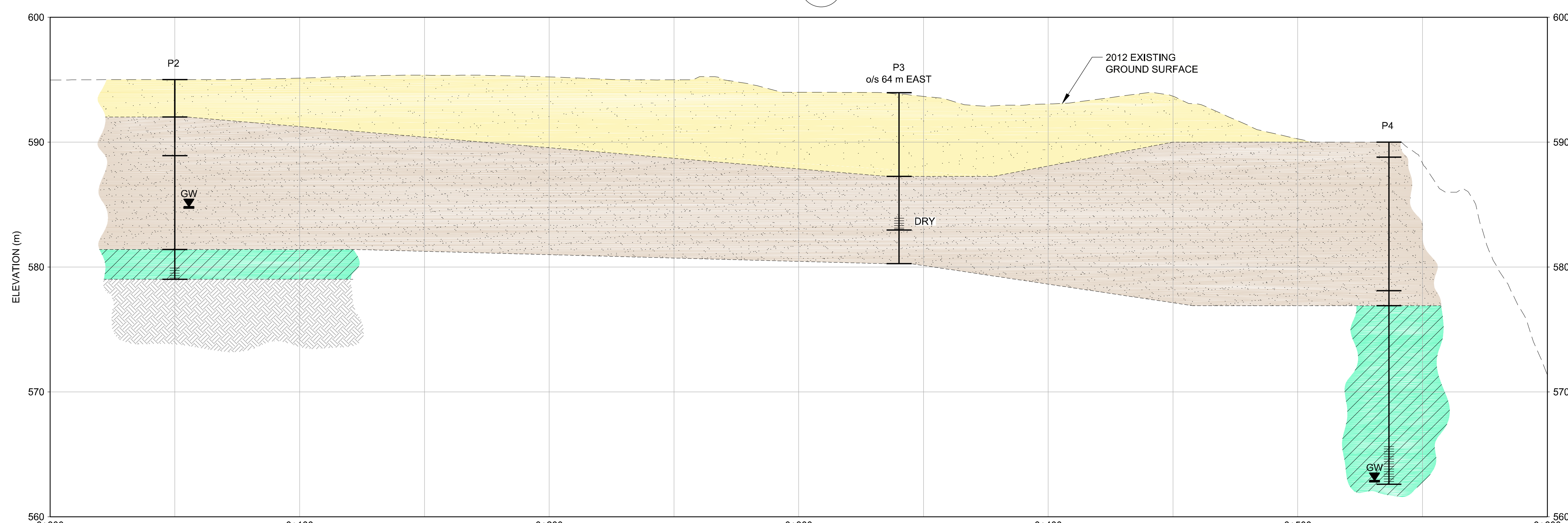
TITLE
AREA PLAN

PROJECT No.	PHASE	Rev.	FIGURE
1417553	3000	0	6



SCALE 1:2000
VERT. SCALE 1:400

1 / 6 CROSS-SECTION 1



SCALE 1:2000
VERT. SCALE 1:400

2 / 6 CROSS-SECTION 2

LEGEND

- GW — WATER LEVEL ELEVATION (JULY 1, 1988)
- SCREEN
- LOOSE SAND AND GRAVEL
- COMPACT SAND AND GRAVEL CONTAINING COBBLES
- GLACIAL TILL
- BEDROCK

0 10 20
1:400 METRES

0 50 100
1:2,000 METRES

CLIENT
DISTRICT OF SUMMERLAND

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-03-30
PREPARED	MD
DESIGN	PVA
REVIEW	PVA
APPROVED	JF

PROJECT
PERPETUAL SLIDE
SUMMERLAND, BC

TITLE
CROSS-SECTIONS 1 & 2

PROJECT No.	PHASE	Rev.	FIGURE
1417553	3000	0	7

APPENDIX A

Important Information and Limitations of This Report

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Standard of Care**:** Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder can not be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then upon the reasonable request of the client, Golder may authorize in writing the use of this report by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process. Any other use of this report by others is prohibited and is without responsibility to Golder. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client can not rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder can not be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

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.

(cont'd)

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.

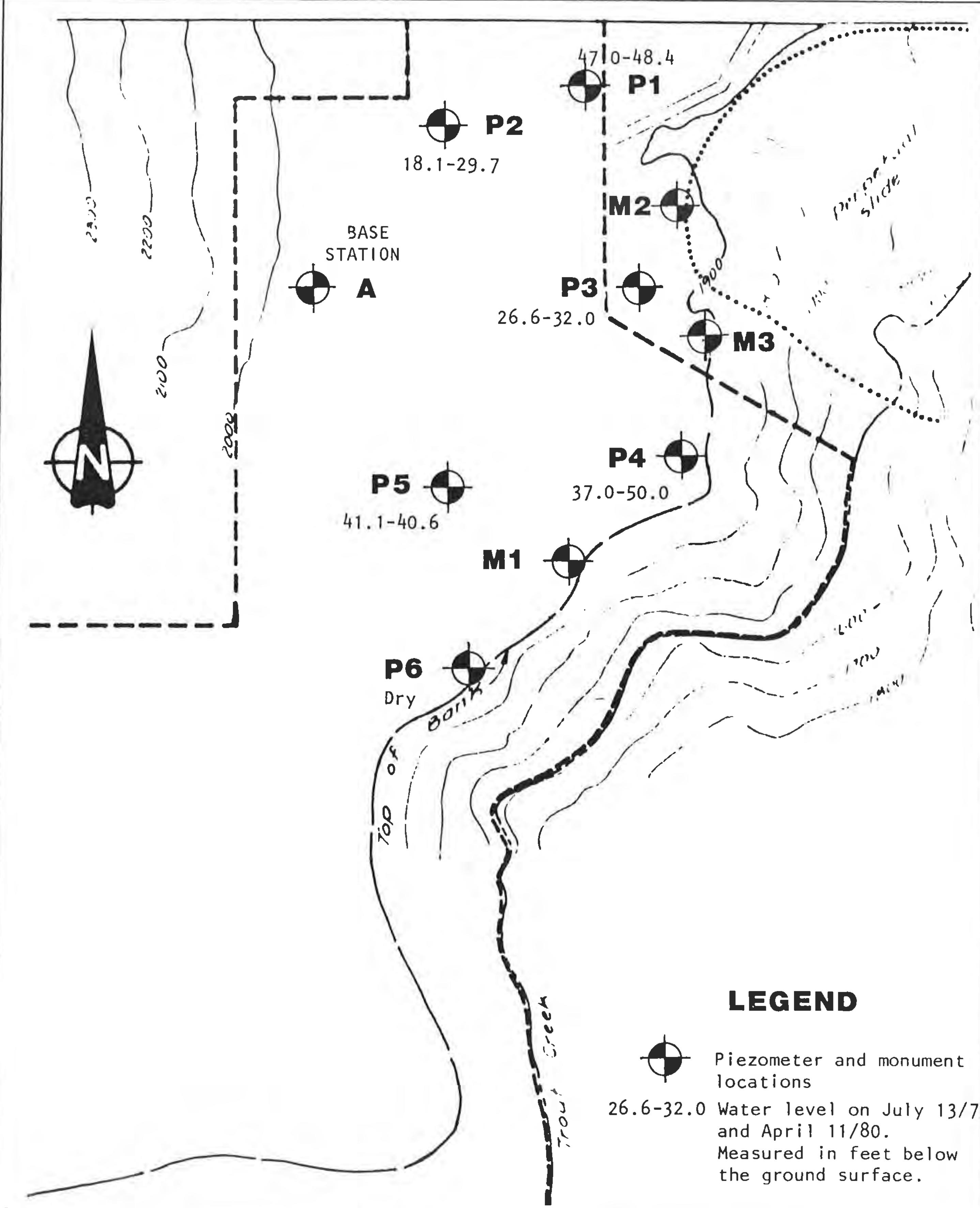
Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided 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.

APPENDIX B

Historical Monitoring Data

PIEZOMETER AND MONUMENT LOCATIONS **Figure 1**

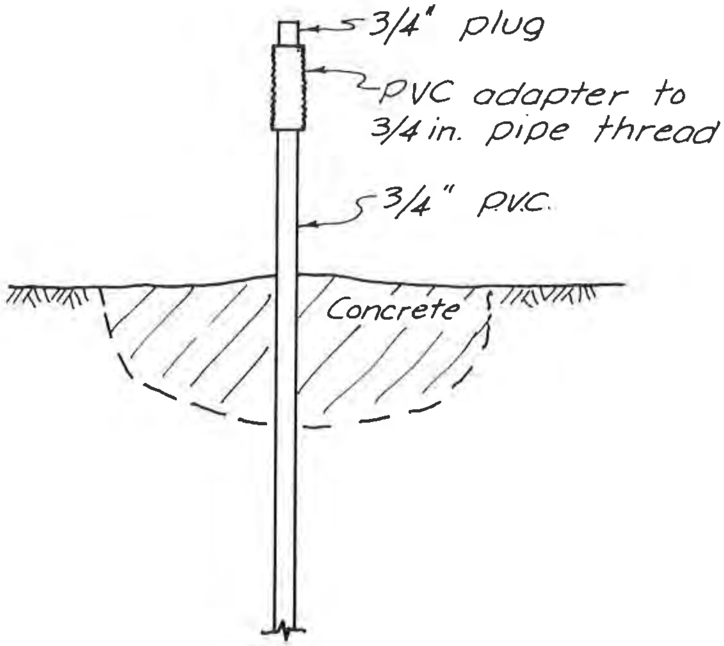


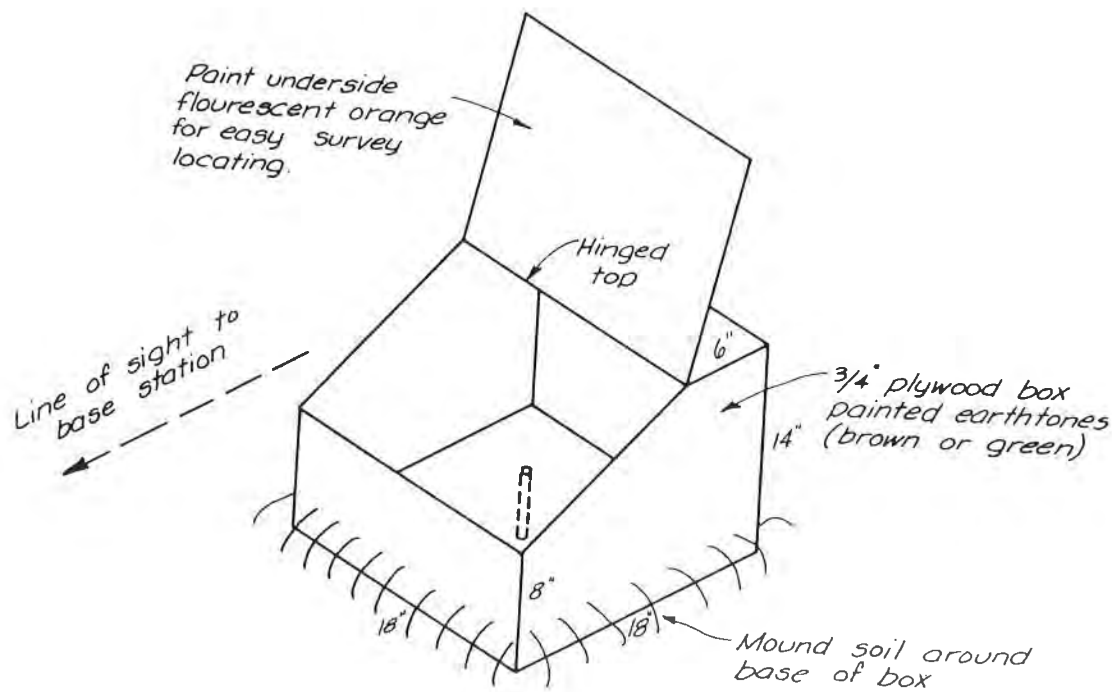
SCALE: 1inch to 500 feet

Golder Associates

Project No 782-4675 rt bc Aug 7,1979

PROTECTION FOR PIEZOMETERS & MONUMENTS **Figure 2**





Project No. ______ Drawn ______ Reviewed ______ Date ______

Golder Associates

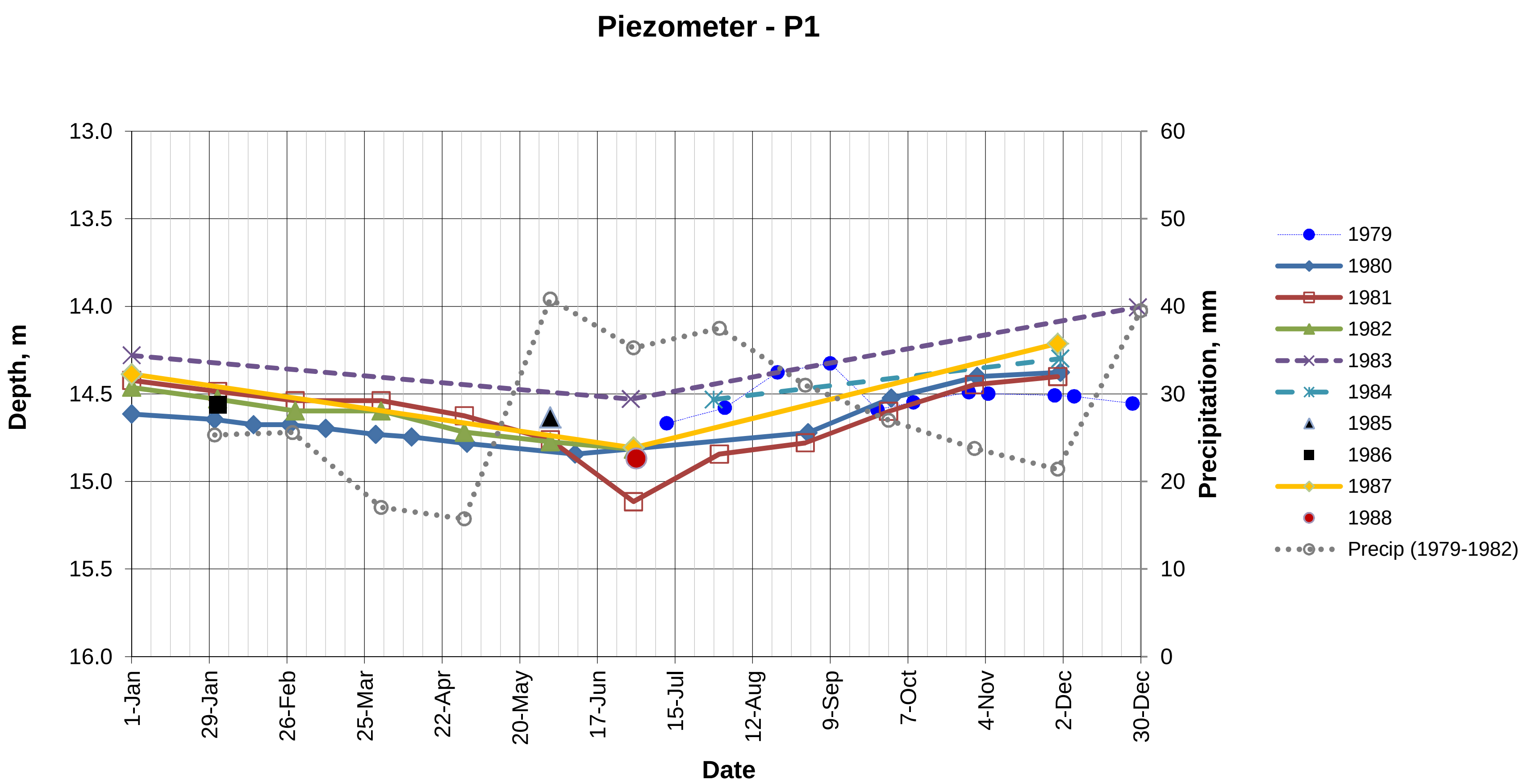
TABLE 1

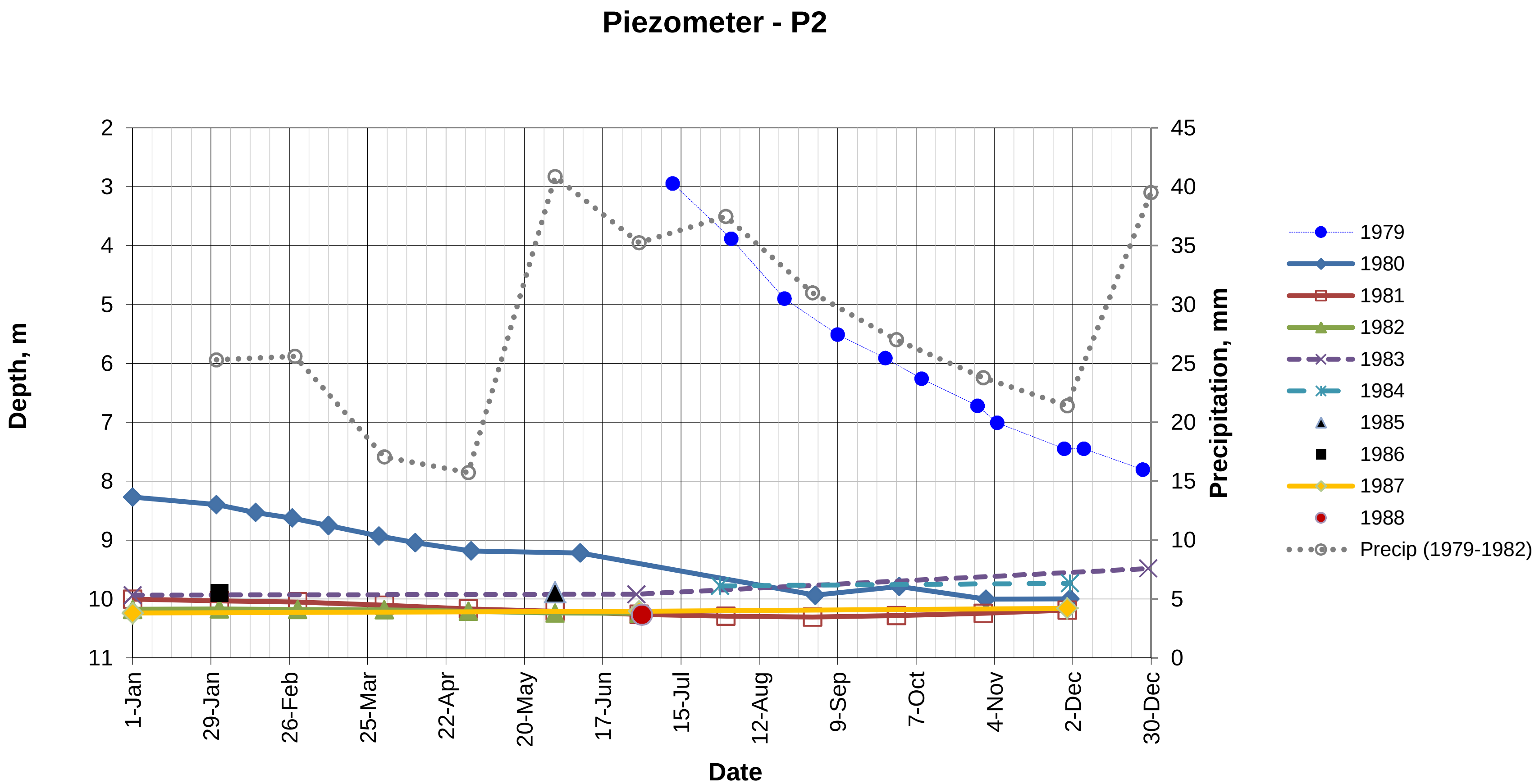
RECORD OF BOREHOLES

Hole Number Depth (ft.)	Strata Description
P1	
0 - 13	Loose, brown SAND with ocasional .5 to 1 ft. gravel layers
13 - 17	Compact brown coarse SAND and GRAVEL
17 - 55	Compact to dense brown medium SAND with some gravel and occasional cobbles
55 - 56.5	Dense grey gravelly SAND (Glacial Till)
56.5	Bedrock
	Piezometer interval from 53.5 to 56.5 ft.
P2	
0 - 10	Loose, brown SAND with a trace of gravel
10 - 20	Compact to dense brown SAND and GRAVEL with occasional cobbles.
20 - 44.5	Dense to very dense, brown medium SAND with a trace of gravel
44.5 - 52.5	Very dense grey gravelly SAND (Glacial Till)
52.5	Bedrock
	Piezometer interval from 49.5 to 52.5 ft.
P3	
0 - 22	Loose to compact brown gravelly SAND with some cobbles and occasional boulders
22 - 36	Dense, brown, medium to fine SAND with a trace of gravel
36 - 45	Dense, brown SAND with some gravel and occasional cobbles

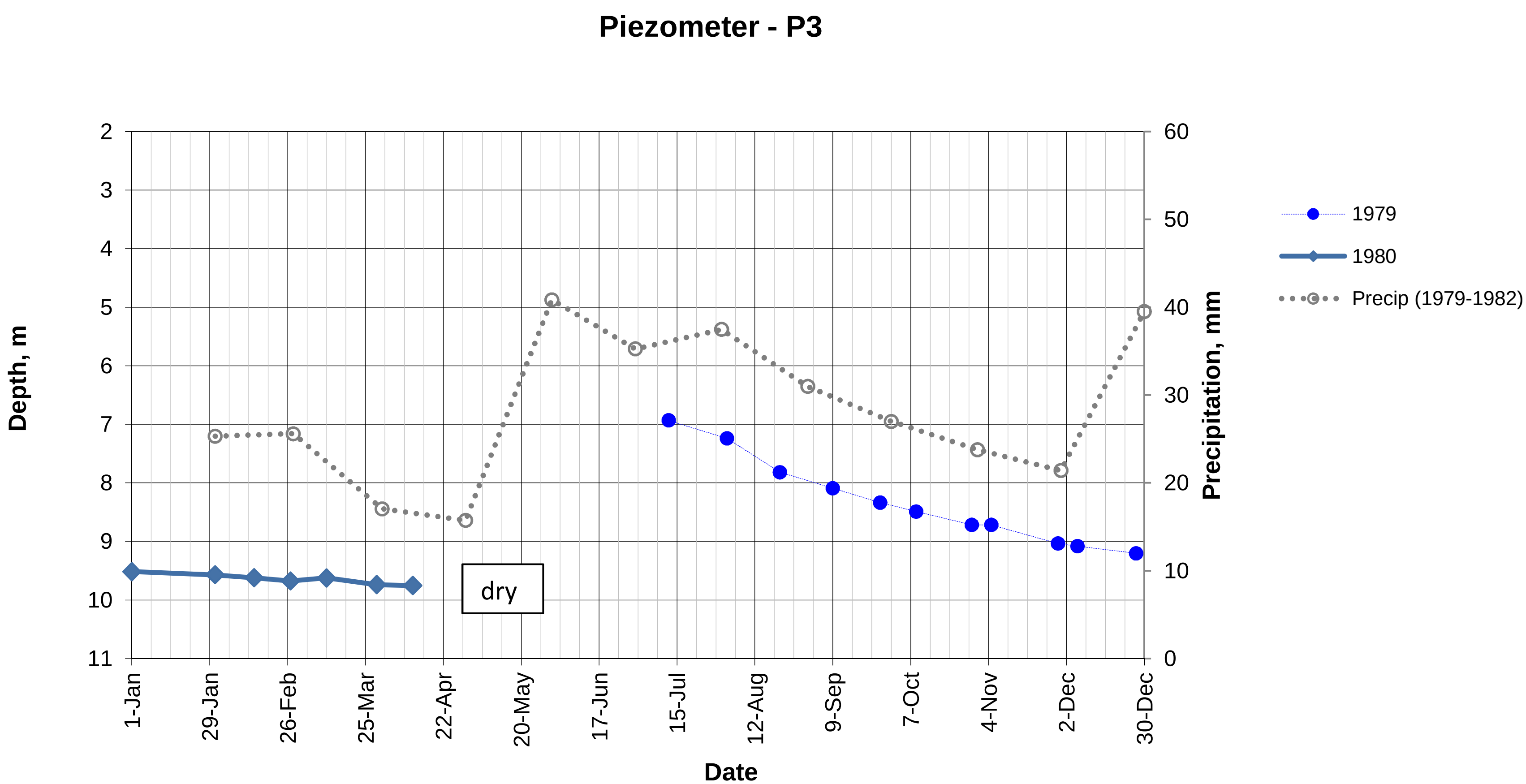
Piezometer set in twin hole 30 - 40 ft. north, interval from 33 to 36 ft.

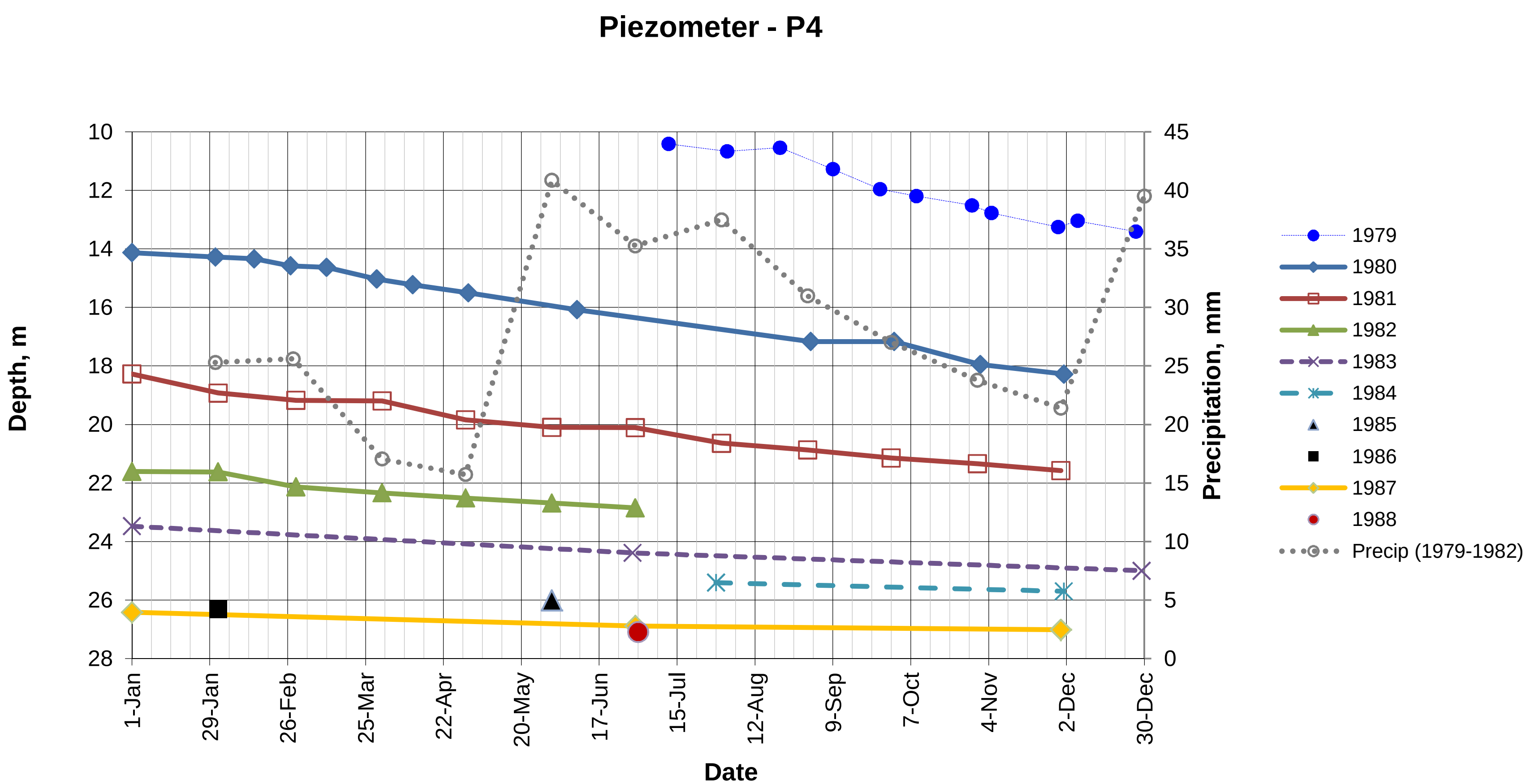
Hole Number Depth (ft.)	Strata Description
P4	
0 - 4	Compact brown gravelly SAND
4 - 39	Compact brown SAND and GRAVEL with occasional cobbles and boulders
39 - 43	Dense brown SAND with some GRAVEL
43 - 90	Very dense grey silty SAND with some GRAVEL (Glacial Till)
	Piezometer interval from 80 to 90 ft.
P5	
0 - 7	Loose, brown SAND with occasional cobbles
7 - 22	Loose to compact brown sandy GRAVEL with some cobbles
22 - 42	Compact, brown interlayered SAND and GRAVEL with occasional cobbles
42 - 45	Compact, brown sandy GRAVEL
45 - 61.5	Very dense, grey silty SAND with some gravel (Glacial Till)
	Piezometer interval from 42 to 45 ft.
P6	
0 - 2	Loose, brown, fine sandy SILT
2 - 18	Loose, brown GRAVEL and SAND with some cobbles and occasional boulders
18 - 33	Compact, interlayered brown SAND and GRAVEL with occasional cobbles
33 - 35	Dense, brownish grey silty SAND (Glacial Till)
35 - 36	Weathered bedrock
	Piezometer interval from 33 to 36 ft.


Piezometer - P1
Depth, m
13.0
13.5
14.0
14.5
15.0
15.5
16.0
Precipitation, mm
60
50
40
30
20
10
0
1-Jan
29-Jan
26-Feb
25-Mar
22-Apr
20-May
17-Jun
15-Jul
12-Aug
9-Sep
7-Oct
4-Nov
2-Dec
30-Dec
Date
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
Precip (1979-1982)

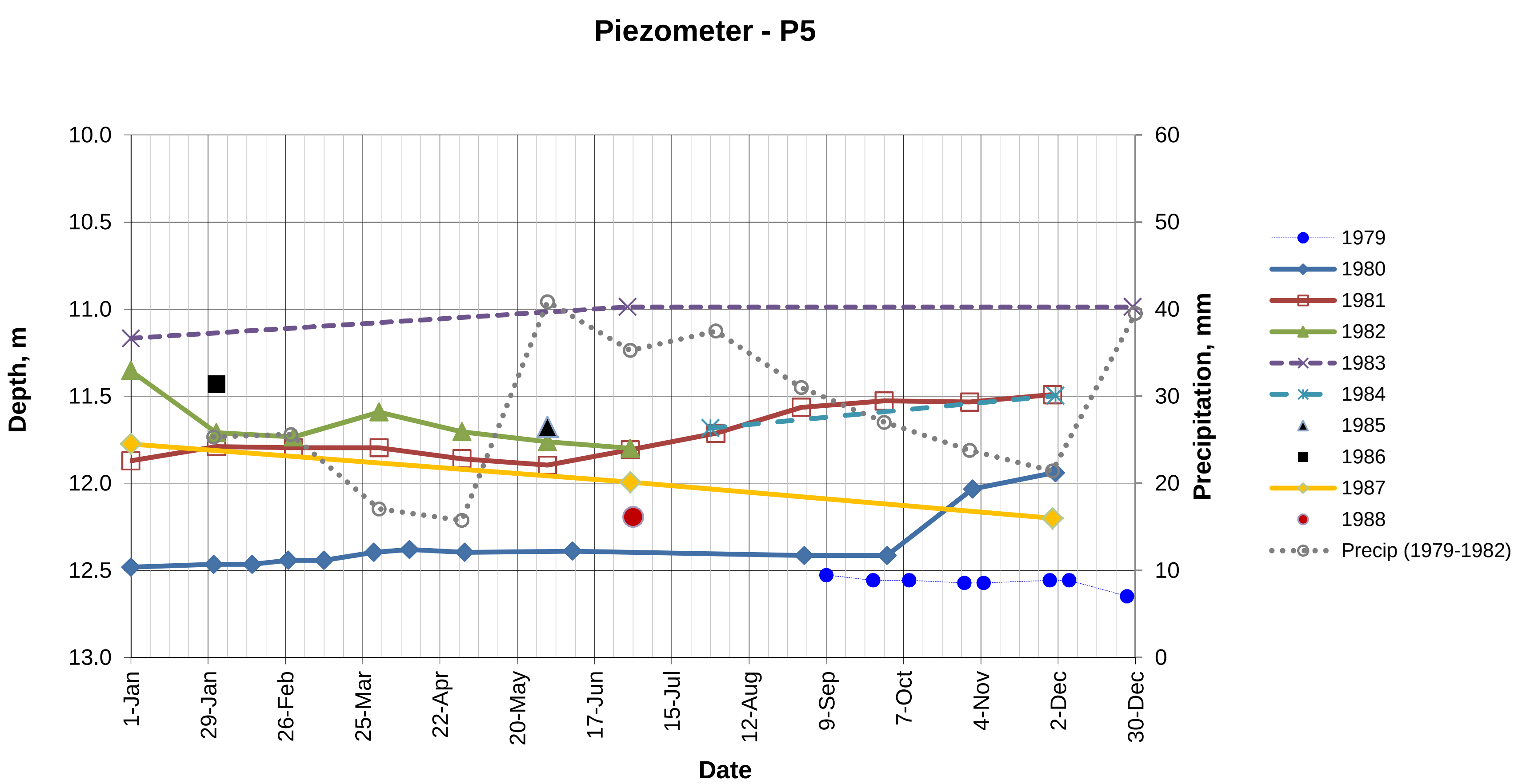


Piezometer - P2
Depth, m
Precipitation, mm
Date
2
3
4
5
6
7
8
9
10
11
45
40
35
30
25
20
15
10
5
0
1-Jan
29-Jan
26-Feb
25-Mar
22-Apr
20-May
17-Jun
15-Jul
12-Aug
9-Sep
7-Oct
4-Nov
2-Dec
30-Dec
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
Precip (1979-1982)


Piezometer - P3
Depth, m
Precipitation, mm
Date
2
3
4
5
6
7
8
9
10
11
60
50
40
30
20
10
0
1-Jan
29-Jan
26-Feb
25-Mar
22-Apr
20-May
17-Jun
15-Jul
12-Aug
9-Sep
7-Oct
4-Nov
2-Dec
30-Dec
dry
1979
1980
Precip (1979-1982)



Piezometer - P4
Depth, m
Precipitation, mm
Date
10
12
14
16
18
20
22
24
26
28
45
40
35
30
25
20
15
10
5
0
1-Jan
29-Jan
26-Feb
25-Mar
22-Apr
20-May
17-Jun
15-Jul
12-Aug
9-Sep
7-Oct
4-Nov
2-Dec
30-Dec
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
Precip (1979-1982)



Piezometer - P5
Depth, m
10.0
10.5
11.0
11.5
12.0
12.5
13.0
Precipitation, mm
60
50
40
30
20
10
0
1-Jan
29-Jan
26-Feb
25-Mar
22-Apr
20-May
17-Jun
15-Jul
12-Aug
9-Sep
7-Oct
4-Nov
2-Dec
30-Dec
Date
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
Precip (1979-1982)

APPENDIX C

Site Photographs

Photograph 3801: Looking west along abrupt roadway depression (dip) that extends across both lanes and to about 5 m into the north property at 10920 Canyon View Road.

Photograph 3818: Looking west along south outside wheel path with numerous pavement cracks along section of embankment fill that occur in a repeating series having a diagonal pattern.

Photograph 3809: Looking west along Canyon View Road at inside crescent shaped crack that extends to about the roadway centre line. This feature has developed within the past year or so. The crack feature is about 25 m in length and has an abrupt drop of about 50 mm.

Photograph 3837: Looking southwest at fresh tension crack along slide head scarp where horizontal and vertical displacements of 10 to 15 cm exist within natural sand deposits.

Photograph 3863: Looking south at pavement crack that runs across the golf course pathway and faintly continues across into the ground surface (right hand side of field book) where a 1 to 2 mm wide cracks runs parallel to the slide head scarp that is located about 10 m to the left of the photograph).

Photograph 3864: Looking north at localized depression along section of access road to the golf course maintenance yard. Piezometer/monument P1 is located about 10 m north of the narrow golf pathway (hidden behind larger trees) that runs to the left on the photograph.

Photograph 3882 (left): Looking southwest along mid slope at recent tension crack (partially obscured by ravelled material) across sand and gravel face overlooking lower slide bench. Lack of grass, shrubs or small tree cover is indicative of ongoing ravelling from continuing creep movements.

Stitched photographs 3963-3965 (below): Looking east-northeast across lower slide bench showing backward lean and rotation of mature trees by about 25 to 35 degrees from vertical. Area of numerous fresh scarp sloughs with groundwater seepage.

Photograph 3998: Looking west-northwest along crest of lower slide bench at rotational block failure where trees are leaning backwards into the slope, especially within graben areas. This area is located just upslope at the top left corner on the stitched photographs 3963-3965.

Photograph 3991: Looking southwest at large area of ponded groundwater seepage near middle of lower slide bench.

Stitched photographs 3940, 3942: Looking west-northwest along lower slide bench where significant slide activity is occurring. This area extends for a width of about 120 m towards the west slide flank.

Photograph 3994: Looking south into Trout Creek canyon from GPS17 location at channel flow impingement caused by accumulation of slide debris resulting in the backup of stream water and pooling within the channel.

n:\active\2014\1447\1417553 dos canyon view road summerland\05_deliverables\1417553-001-r-rev1\appendix c - site photographs\appendix c -site photographs.docx

APPENDIX D

Resident Questionnaire

District of Summerland Canyon View Road Area Questionnaire – In support of ongoing Geotechnical and Hydrogeological Assessment at the Canyon View Slide

GENERAL

1. Name of Resident: ____

   Civic Address: ________________________________ Number of years at address: ______

   Phone number (optional): ______________________

   Approximate parcel size: _______________________ Number of bedrooms: ___________

2. Is your water use metered? ☐ Yes ☐ No

WATER SUPPLY WELL

3. Do you have a water supply well on your property or know of one in the area? ☐ Yes ☐ No

   If yes: What is the purpose of the Well? Check all that apply:

   ☐ Irrigation ☐ Potable Water Supply ☐ Not in Use

   Where is the well located? (meters and direction from your house) ______________________

   Do you have a driller's well log? If so can you please provide a copy or identify a Well Tag Number?____

   What is the frequency and volume of use from the well (i.e. pumping rate)? ____________

   ____

SEPTIC SYSTEMS

4. Do you have a septic field on your property? ☐ Yes ☐ No

   Where is it located? (meters and direction from your house) __________________________________

   What is the age of the septic field? ☐ less than 10 ☐ 10 to 20 yrs ☐ greater than 20 yrs

   When was the last time your septic field was serviced (i.e. pumped out and/or inspected)___________

   ____

IRRIGATION

5. What percent of your property is irrigated for: (less than 25% / 25-50% / 50-75% / or greater than 75%)

   Manicured Lawn: ___________________ Agriculture:_________________________

   Other: ____________________________ Crop Type: _________________________

6. Method of irrigation:

   Do you hand water or use a hand sprinkler: ____

   Frequency of irrigation:

   Daily: __________ hrs Weekly: __________ hrs Monthly: ______________hrs

   Do you have an Automatic Sprinkler System with Controller: ___________________________________

   Frequency of irrigation:

   Daily: __________ hrs Weekly: __________ hrs Monthly: ______________hrs

   Do you adjust your irrigation schedule: ______________ If yes, how often: ____________________

   Have you had a break in your irrigation system? ____

   How often do you notice breaks or leaks in your irrigation system?____________________________

   If possible, please provide any copies of irrigation records.

ADDITIONAL COMMENTS

Please feel free to provide any other information regarding water use on-site or any unusual groundwater and/or seepage condition that may have recently developed:

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

____

APPENDIX E

Irrigation Best Management Practices Information

1.0 IRRIGATION AND THE LANDSLIDE STUDY AREA

From a review of the geotechnical and hydrogeological observations, it is apparent that irrigation practices above the landslide area are a potential concern. The intent of the irrigation best practices below is to use current irrigation technology to allow adequate watering for crop and turf management to replace water lost by evapotranspiration, while minimizing excessive irrigation application or irrigation leaks that could increase the risk of landslide below the irrigation sites.

The study area includes golf course, agricultural, and domestic (landscape) irrigation systems.

2.0 RECOMMENDED BEST PRACTICES FOR CONSIDERATION

2.1 Types of Irrigation Best Practices

Irrigation Best Practices fall generally into three categories:

1) HydroZoning: determining what areas need irrigation, and to what intensity and duration. Generally this involves dividing a site into hydrozones – areas of no, low, moderate, or high irrigation need. Generally the irrigation need is heavily influenced by the surface vegetation desired, with turfgrass and golf greens being one of the highest demands for irrigation, and 'xeriscape' drought tolerant plants being the lowest. Unplanted area (e.g., stone mulch) or established native plants (Ponderosa Pine / Bunchgrass) may not require irrigation at all.

2) Irrigation System Design and Installation: including many variables such as precipitation rate based on type of system (spray, rotor or drip), proper or improper head spacing related to surface vegetation and wind, proper pipe sizing, pressure regulation to provide optimum pressure at the heads and avoid misting, proper pipe pressure class, bedding and jointing to avoid leaks and breaks.

3) Irrigation Operations, Timeclock Scheduling and Maintenance: adjusting the timeclock to deliver the optimum amount of irrigation to replace soil water lost to evapotranspiration of the surface soil and vegetation. The amount of water needed varies by season, with the needs in shoulder seasons (spring and fall) being approximately 30% less that water needs at peak season (early July). Water needs also vary day to day based on temperature, rainfall, wind, and solar exposure. Irrigation systems are also highly subject to leaks at heads, valves or pipes related to such variables as vandalism, wear and tear, winter damage or breaks from equipment impact or soil movement. Ongoing inspection and maintenance is required.

2.2 General Irrigation Best Practice Guidelines

General Guidelines

1) Group planting areas into 'hydrozones' of high, medium and low or unirrigated/unwatered areas.

2) Show appropriate use of plant material or crops with similar water demand within hydrozones.

3) Maximize the percentage of landscape area that is unirrigated/unwatered area, commensurate with landscape aesthetics and plant survival e.g., using pervious paving, unplanted stone or organic mulch, pervious deck.

4) Maximize retention or replanting of vegetation with low water-use requirements after the establishment period e.g., existing native vegetation to remain, wildflower meadow, rough grass, xeriscape plant species.

5) Minimize mown turf areas that are high water use areas – substitute with areas of lower water use treatments. Although golf courses will have large areas of turf, there is a trend to allowing verge and rough areas to be a lower standard of irrigation and turf management.

6) Provide mulch cover to shrub and groundcover areas, to reduce evaporation from soil.

7) Use recirculated water systems for any water features such as pools and fountains, and ensure that linings do not leak.

8) Ensure landscape installation standards including growing medium depth and quality meet the requirements of the BC Landscape Standard (Latest Edition) and/or the Master Municipal Construction Document (Year 2000 Gold Edition). Proper growing medium depth and quality including incorporation of organic matter can reduce watering requirements and promote healthy plant and turf growth.

Irrigation System Guidelines

If new irrigation is to be installed, it should be a condition of a Development Permit or other local government permit that the Applicant appoint a Qualified Professional to prepare an Irrigation Plan and supervise installation to produce an irrigation system that:

1) Groups irrigation circuits/ zones into ‘hydrozones’ of high, medium and low or unirrigated areas consistent with the landscape planting plan.

2) Uses reclaimed or recycled water or rainwater capture from roofs or rain barrels for outdoor water use when such is available, as a substitute for use of potable water (this results in the roof water not adding to the runoff or groundwater inputs to the landslide area, until it is applied as irrigation which is typically in a more dry period of the year).

3) Minimizes use of high-volume spray heads, and employs drip or low volume irrigation where practical to meet the watering needs of hydrozones.

4) Uses surface or subsurface drip irrigation or low volume irrigation technology to water long, narrow or irregularly shaped areas including turf areas less than 2.4 m in width.

5) Keeps drip, spray and rotor heads (different precipitation rates) on different irrigation circuits.

6) Designs with irrigation head-to-head coverage in accordance with manufacturer’s specifications.

7) Ensures matched precipitation rates on each irrigation circuit.

8) Minimizes the elevation change in each irrigation circuit – and where required provides pressure compensating devices to minimize pressure variations or check valves to stop low head drainage.

9) Ensures irrigation mainlines are proved leak-free with hydrostatic tests, as a part of the construction quality assurance review. Re-test irrigation mainlines after major repair or nearby excavation work, or known ground movement related to landslides.

10) Provides pressure regulating devices to ensure irrigation outlets are operating at the manufacturer's optimum pressure range.

11) Designs head placement and type, and adjusts head radius, arc and alignment to avoid overspray of paved surfaces or buildings that lead to concentrated runoff over the scarp head or into groundwater.

12) If irrigating slopes greater than 25%, designs an irrigation system with a precipitation rate not greater than 20 mm/hour.

13) Provides automatic shut off devices that shut off the system in cases of pipe leak or breakage, and that shut off the system when rain is present.

14) Installs and programs to minimize water use and match evapotranspiration of the surface vegetation in each irrigation zone -'Smart' automatic controllers with water-conserving functions (e.g., acceptable Smart Irrigation Controllers are identified in the City of Kelowna Water Regulation Bylaw 9784). The Irrigation Plan should include a written Irrigation Schedule or equivalent instructions for operation of the Smart Controller, with a copy stored with the controller cabinet, that adjusts the amount of applied water scheduled to be applied on a daily or a minimum of monthly basis and schedules different run-times as weather changes, either by using the weather-sensitive features of a Smart Controller or by creating adjustments to the run time for each circuit by adjusting the time clock or changing its 'water budget' feature at least once per month to recognize that highest water need is in July and lower water needs exist in other months of the growing season.

15) Ensures irrigation design and installation standards including adjustments and scheduling meet best practices (e.g., the requirements of the Supplementary Specifications in City of Kelowna Bylaw 7900 (Part 6, Schedule 5), or a custom or alternate irrigation specification at a similar level of detail provided by the Qualified Professional).

Irrigation Maintenance Scope Checklist:

Both existing and new irrigation systems require regular and thorough inspection and maintenance, both to optimize their water use, and to avoid leaks and deterioration that can put added stress on the landslide area. We recommend the following checklist of common irrigation maintenance practices be applied to existing and new systems:

1) Irrigation Inspection Frequency: inspect and operate the entire irrigation system at least three times per irrigation season: spring start-up (spring); mid-season (mid-June); and end of season winterization (fall). If a smart irrigation controller is not installed, additional monthly adjustments to the irrigation controller should be made to accommodate changing water needs.

2) Controller Adjustments: better timeclock management is one of the key initial steps to water conservation – ensure that the timeclock settings are appropriate to the current season as well as set within the times allowed in the lawn sprinkling regulations, and that there are written instructions submitted (ideally in the timeclock enclosure) on seasonal adjustments (monthly) to the timeclock program installed. Even if a weather–based ('Smart') irrigation controller is installed, check that the appropriate overall program is set and functioning at each irrigation inspection.

3) Leak detection: at each irrigation inspection, run all zones and check for indication of leaks.

4) At irrigation system winterization: after blowing out all water in the irrigation system, check the irrigation submeter (or the main water meter if all other water use can be stopped for a period) to see that no water is running. At spring start-up review: after opening the water shut off valve to gradually charge the irrigation system, keep all zone valves closed, check the irrigation submeter (or the main water meter if all other water use can be stopped for a period) to see that no water is running. If the meter still flows in either spring or fall tests, check that the main water shutoff is not leaking and/or for leaks in pipe or valves.

5) At each Irrigation Inspection (minimum three times per season): run all valve zones, checking for lateral pipe leaks, and identify any damaged heads. Repair any leaking pipe, missing or damaged heads or nozzles to full function. Retest after repairs. Review and adjust nozzle and spray patterns to minimize overspray and water waste.

3.0 IMPLEMENTING AN IRRIGATION MANAGEMENT SYSTEM ACROSS SUMMERLAND

The above Irrigation Best Practices are a common aspect of current irrigation industry standards, and are also increasingly adopted as a part of local government public information and regulatory systems to encourage public understanding and compliance with the best practices.

These best practices are helpful to promote water conservation in general, but also would reduce excessive irrigation application or leaks that could add to risks of landslide in the study area.

Kelowna (and other BC and North American local governments) have implemented a combination of public awareness, regulation and incentive programs for outdoor water conservation focused on irrigation best practices. Elements have included:

- Comprehensive water metering.
- Educational brochures, videos, workshops and on-line information on irrigation best practices.
- Incorporation of irrigation design standards and specifications into local government engineering standards, so that there is a readily available set of standard details and requirements.
- Creation of MS Excel based ‘water budgeting’ tools that allow an applicant to quickly calculate whether their design exceeds a target amount of water use, and setting a water budget requirement by bylaw. In Kelowna’s case this requirement is in the Water Use Bylaw, so that it applies to existing system retrofit as well as new development.
- Requiring irrigation permits for new systems or major retrofits, and design / installation supervision by a Qualified Professional, including for residential installation as these represent the great majority of land use area and water use. Installations must meet the City’s Engineering standards for irrigation and landscape.
- For major developments, including irrigation plan and water budget requirements as part of Development Permit applications.

- Providing staff information support and spot inspections to encourage compliance, as well as integrating financial security and inspections / certification during the development process for large projects.
- Providing financial incentive programs to promote use of weather-based ‘Smart’ Irrigation Controllers.

These administrative tools could be considered across Summerland. It is possible that a sub-set of the tools could be customized to the risks in the landslide neighbourhood, after detailed geotechnical and hydrogeology studies define the specific objectives for the study area.

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