Clifton Associates

10 January 2018

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Slope Stability and Erosion Control Review and Best Practices Guide **File S2259**
Hunts Cove Hill, Cochin, SK

Introduction

In October of 2017, Clifton Associates Ltd. (Clifton) was retained by the Resort Village of Cochin (Client) to assess Hunts Cove Hill and the surrounding area with respect to slope stability and erosion. The intent of this project was to:

- Identify and assess areas of concern with respect to landslide and erosion risk.
- Provide recommendations for mitigation and/or remediation for identified areas of concern.
- Provide a slope stability and erosion best practices development guide, to assist the Client in developing policies and procedures to minimize slope stability and erosion risk for new developments, and modifications to existing properties.

The above points are addressed in this letter report.

Stratigraphy

Based on aerial imagery and stratigraphic records available online from SaskWater, the stratigraphy in the Cochin area generally consists of a relatively thin layer of glaciolacustrine sediments, overlying glacial till of the Saskatoon Group, which in places is interbedded with sands, or Sutherland Group tills. Beneath the till lies clay shale bedrock of the Lea Park Formation.

A record of stratigraphy of the Hunts Cove Hill area is given in a report provided to Clifton by the Client titled "Geotechnical Investigation and Slope Stability Study, Proposed Residential Subdivision," authored by P. Machibroda Engineering Ltd. (PMEL) and dated 19 December 2007, and briefly summarized here: The stratigraphy of Hunts Cove Hill is variable, and comprised mainly of glacial till, with inconsistent deposits of sands and silt within the till. Clay shale bedrock is present at elevations ranging from approximately 523 meters above seal level (masl) to 529 masl, which is close to the lake level of 530 masl (taken from Google Earth, 2014). SaskWater bedrock geology maps indicate a bedrock high in the area of Hunts Cove Hill as high as 550 masl.

Site Visit

On 17 October 2017, Jon Osback, PEng of Clifton visited the area of Hunts Cove Hill, along with Mr. Peter Wiesner. Mr. Wiesner identified two areas that have been problematic in the past:

- The south end of Hunts Cove Crescent, where slope movement in the east upslope above the road had blocked the ditch, which caused excessive erosion and siltation of the road during rain events. This area has been remediated and is under monitoring.
- The retaining wall along Hunts Cove Crescent (Figure 1) where a section of the retaining wall had failed and deflected excessively outward from the slope. Slope failures were visible in the upslope above the retaining wall. Discussion of the retaining wall failure is included later in this report.

Mr. Wiesner also identified various locations where landowners had constructed retaining walls on their property, commonly by cutting into the base of the hillside to provide a larger level area in the yard.

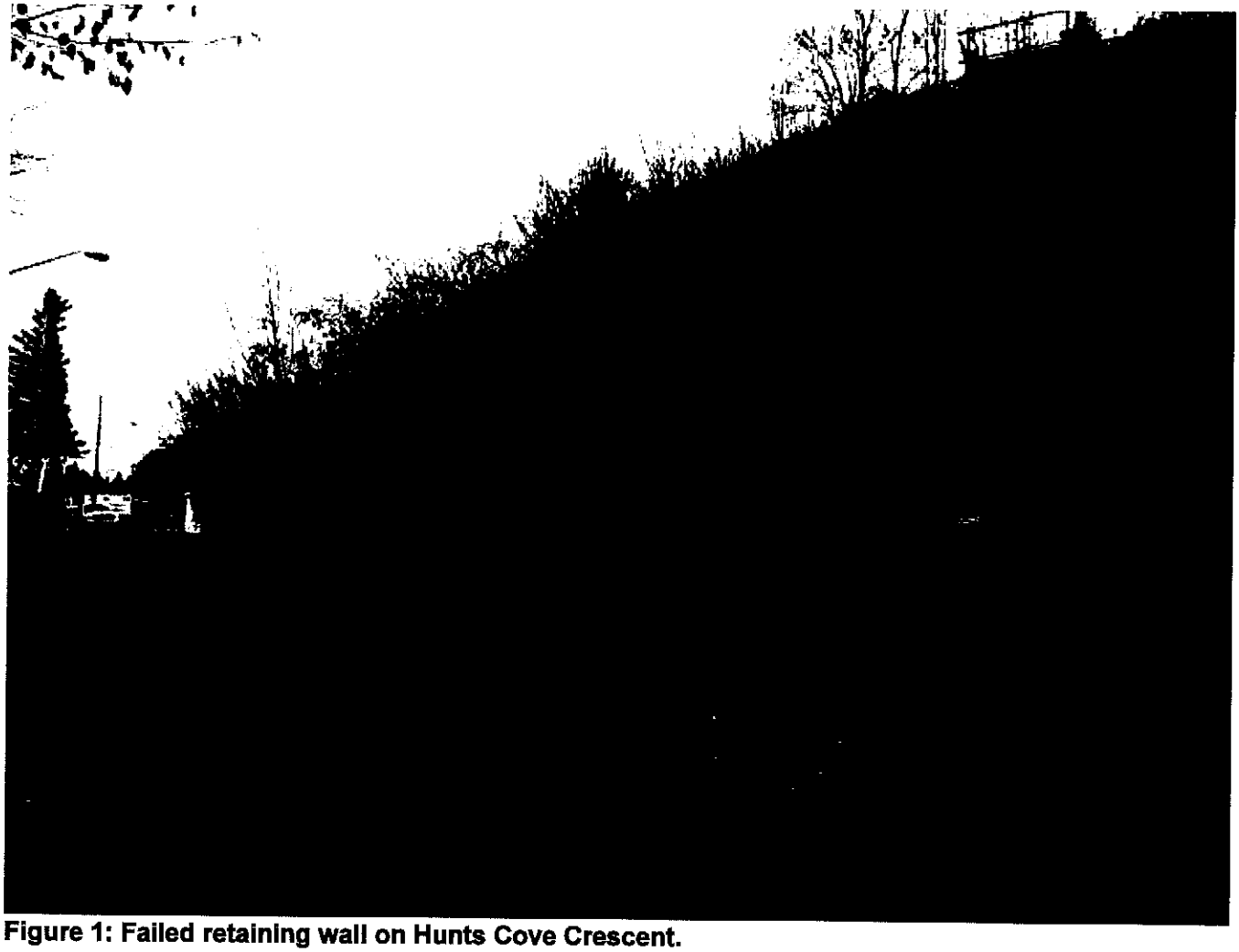

Figure 1: Failed retaining wall on Hunts Cove Crescent.

The site assessment was conducted throughout the following areas:

- Hunts Cove Crescent.
- Archdekin Drive.
- Gentle Place.
- The new subdivision being constructed atop Hunts Cove Hill.

Some past slope movement was visible during the site assessment, possibly due to erosion activity, at various locations along the upslope above Hunts Cove Crescent and Archdekin Drive. These movements were identified by hooked tree trunks and the presence of small head scarps, which are typical indicators of past slope movement. The identified head scarps were in the range of approximately 100 mm to 250 mm in height, with no horizontal separation. No toe bulges or tension cracking was apparent. A photo showing a typical scarp is shown in Figure 2.

The topography of Hunts Cove Hill is generally hummocky, which could indicate past slope movement; however, it is not possible to tell if this hummocky terrain was created from erosion, landslides or both. A photo showing typical hummocky terrain is shown in Figure 3.

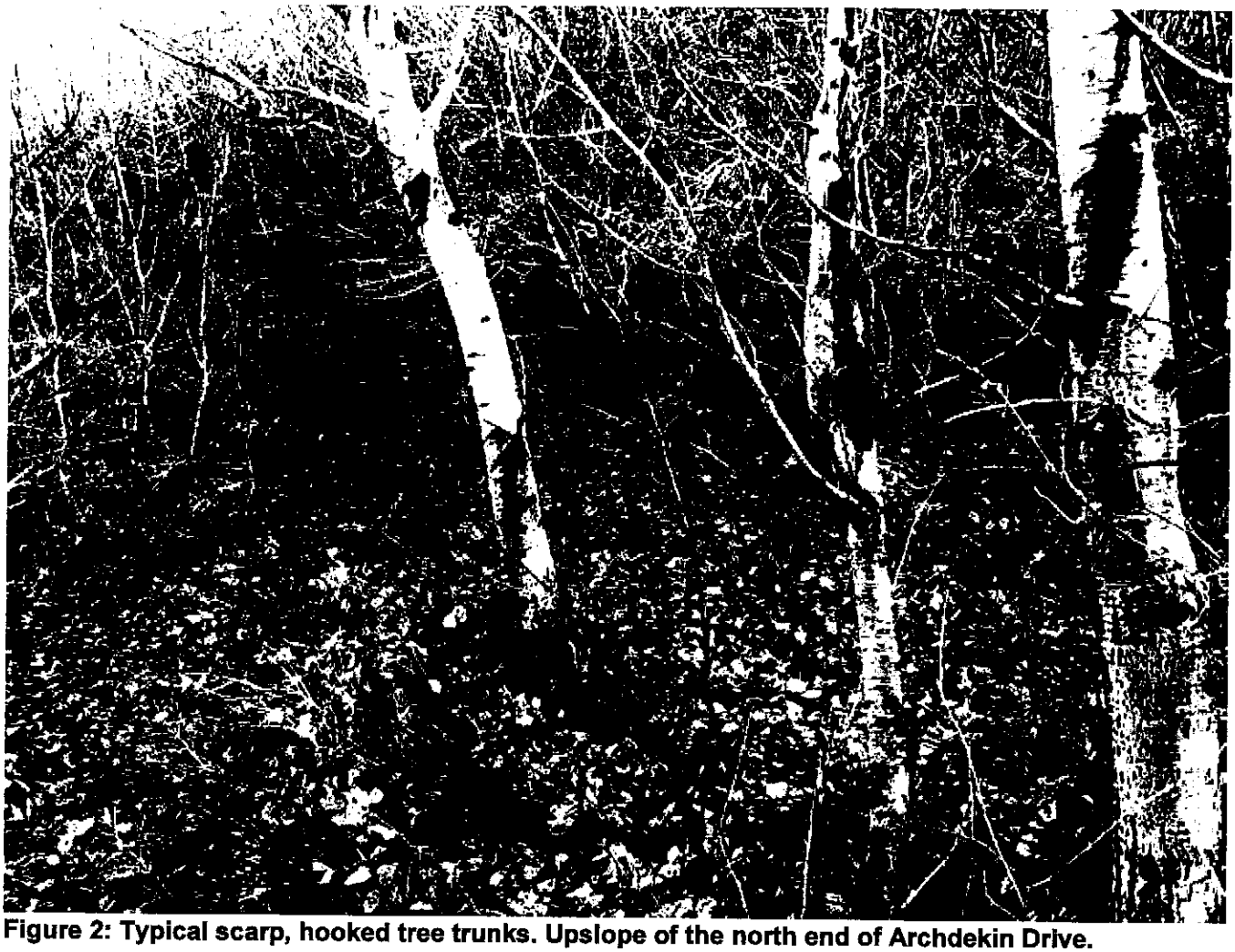

Figure 2: Typical scarp, hooked tree trunks. Upslope of the north end of Archdekin Drive.

Figure 3: Hummocky topography uphill from Archdekin Drive.

Another retaining wall, further south than the failed retaining wall on Hunts Cove Crescent, was observed to have deflected towards the road slightly, as seen in Figure 4. Some scarps and hooked tree trunks were apparent in the backslope above the wall. While the condition of this wall would not be considered failed, the deflection of the wall and visible evidence of movement above it indicate that the slopes on Hunts Cove Hill are prone to slope failures with modification to the current topography.

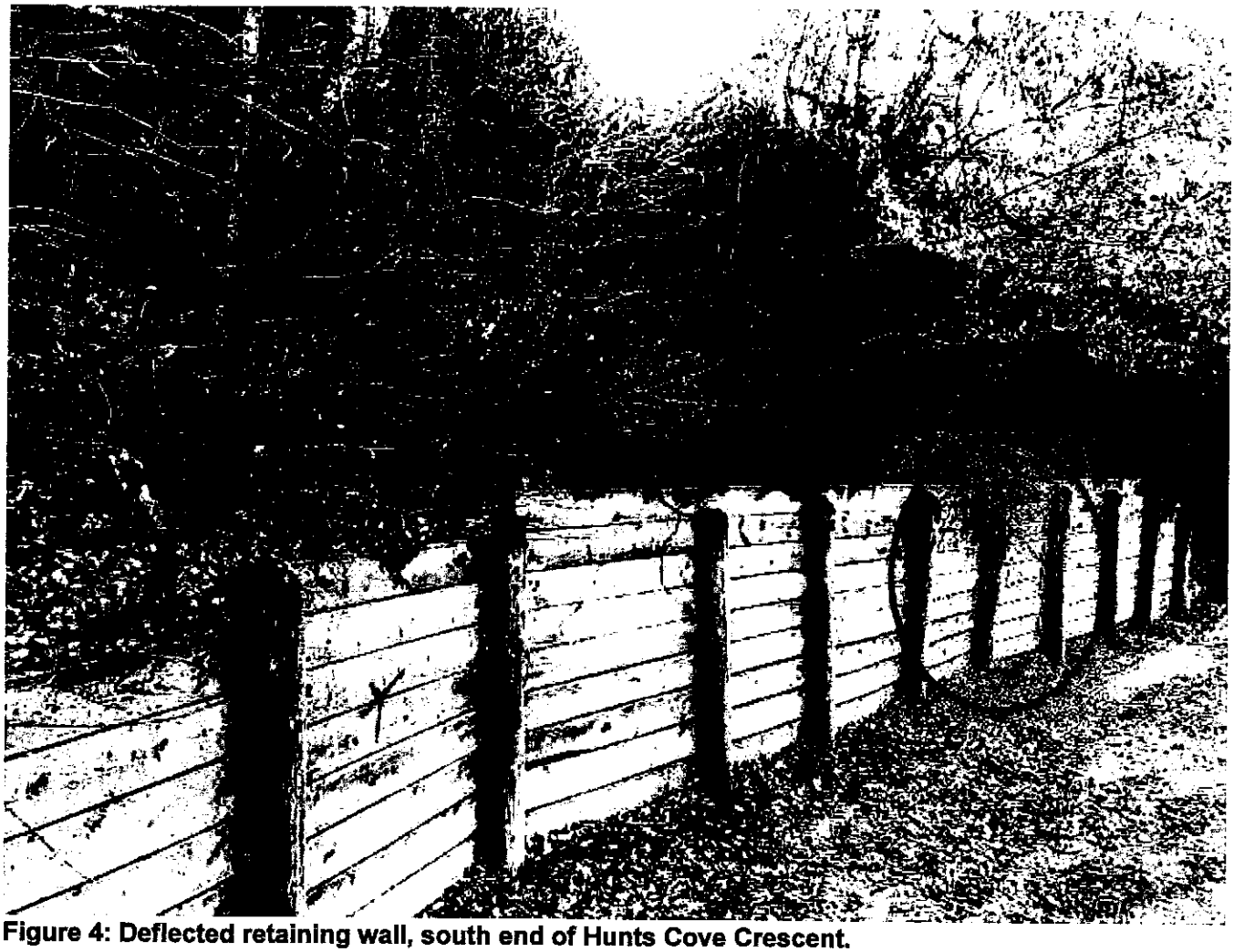

Figure 4: Deflected retaining wall, south end of Hunts Cove Crescent.

Causes of Slope Stability and Erosion Risk with Development

Development on and around slopes can cause slope stability issues. Development that includes changes to the ground surface or vegetation can cause excessive erosion. A decrease in slope stability, or introduction of erosion can present risk to infrastructure, properties and homes. Landowners should understand that, if triggered, landslides and erosion could damage not only their property and the structures built upon it, but adjacent properties and structures as well.

Causes of slope instability include one or more of the following:

- Changes to the ground surface.
- Changes in groundwater levels.
- Variation in lake levels.

Erosion issues are commonly caused by changes to natural drainage paths, or removal of vegetation.

Changes to the Ground Surface

Changes to the ground surface, or site grading, include excavation, placing fill, and maintaining or changing the ground surface to accommodate surface water and surface water drainage. Most landslides occur in nature as a result of removal of soil at the toe of the landslide (erosion), usually by running water. This results in a loss of support for the slope. This effect can also be realized during development if soil is removed from the base of a slope. Instability can also result if additional load is placed on top or mid point of the slope. While this rarely occurs in nature, it becomes a significant factor in new developments where there is a desire to create a relatively level area large enough to construct a house or yard.

During development near or on slopes, significant quantities of earth should not be added to an area, since this will increase the forces which can cause landslide movement. Construction of a typical bungalow will not add a significant load to the slope. The total weight of a typical bungalow might be equivalent to less than 0.3 m of soil. It is for this reason that no more than about 0.5 m of soil should be placed on the surface, or removed (cut) during development in the area of potentially sensitive slopes, such as Hunts Cove Hill.

Slopes should not be over steepened. Excavations at the bottom of slopes or on a slope must consider the stability of soil on the slope above, as removal of soil can destabilize the upper slope – for example, this is a risk during construction of a retaining wall on or near a slope. Very stiff or hard soil will typically stand when excavated, even if the excavated slope is close to vertical; this may give the impression that conditions are favourable. However, this must be considered a temporary condition, since the slope will eventually return to an angle that is close to the original slope by erosion or from small local failures. If the excavation is for a basement, the basement wall will retain the soil if designed properly.

Overall site grading must ensure that surface runoff does not pond. Development of a lot will tend to concentrate the flow of runoff as it flows across roofs and paved areas. Ponding of water can increase the rate of infiltration, resulting in a higher groundwater level, and reduced stability. Erosion control measures must be incorporated into areas where surface runoff has concentrated so that gullies are not created. Erosion gullies, if allowed to grow, can result in damage to infrastructure and buildings, and can destabilize nearby slopes if enough material is allowed to erode away, as was seen in the backslope of the now remediated hill at the south end of Hunts Cove Crescent.

Groundwater

Irrigation, in general, should be avoided. Landslides can be triggered by a rise in the groundwater level, and irrigation of lawns and landscaping can contribute to groundwater rises and subsequent loss of slope stability. Although natural changes in groundwater levels will vary depending on location, soil conditions, climate, and many other factors, regular and sustained irrigation of a lawn or garden can result in significantly greater increases. Xeriscaping can be practiced to help minimize this risk. Poor site drainage as described in the aforementioned section on grading can increase the groundwater level and destabilize the slopes.

Changes in Lake Level

A rise in the lake level would increase the groundwater level near the shoreline, and could result in increased erosion of the shore. Alteration of the shoreline can also result in increased rates of erosion. Higher water and shoreline erosion can affect the stability of the shoreline itself, the property near the lake, or nearby slopes.

Some shorelines in glacial till deposits become naturally armoured with gravel and cobbles over hundreds of years as silt and clay is eroded leaving the coarser material behind. The natural armour resists further erosion. However, the rate of erosion can be significantly increased if the armour is removed. Shorelines where bedrock shale is exposed tend to erode more easily because they are not self armouring and are generally poorly vegetated.

Discussion

Although some areas of past erosion/slope movement were identified during the site visit, there were no areas identified that would pose immediate risk to the developed properties around Hunts Cove Hill, other than the failed retaining wall, which is addressed in a dedicated section below.

It should be noted that slow slope movement is sometimes not perceptible without sensitive monitoring equipment, so it was not possible during the site visit to confirm if the head scarps and hummocky terrain were actively moving.

The soil in some exposed sections of the hillside appeared to consist of predominantly silty sand with some clay, such as the open cliff near the end of Archdekin Drive (Figure 5), and behind the failed retaining wall. PMEL also identified significant deposits of silt in the area. These materials are readily erodible, meaning small changes to the ground surface or vegetation could result in excessive erosion and formation of erosion gullies. Silts and sands will generally possess a higher permeability than glacial tills, meaning they could conduct water more readily. Water bearing soil layers can act as a weak layer in landslides, or contribute to saturation and softening of other soil layers, which in turn can create a weak layer.

Bedrock clay shale is present near the lake level. In Saskatchewan river valleys, landslides can originate in upper, weathered and disturbed shale when it is present at elevations near or above the water level. The presence of shale, presence of erodible material, and indications of past slope movement around Hunts Cove Hill suggests that slight changes to the current conditions of Hunts Cove Hill could increase the likelihood of slope stability risk. Excessive erosion and slope failures were realized in the past along Hunts Cove Crescent Hill, and similar conditions could occur in the future in other areas if erosion or slope movement occurs unchecked. Particular concern exists with regards to new development atop Hunts Cove Hill – development will inherently influence drainage and groundwater conditions, so it will be critical that these new properties be developed with this in mind, and that the recommendations below be followed closely.

The following recommendations are provided as a best practices reference to minimize the risks discussed above. We have reviewed the recommendations provided previously by PMEL for slope stability, and agree that their recommendations are suitable – their recommendations are paraphrased and included below along with our recommendations.

Figure 5: Exposed cliff, north end of Archdekin Drive, silty sand with some clay.

Best Practice Recommendations for Minimization of Landslide and Erosion Risk

- Properties on or near hills should be constantly monitored for signs of slope instability and erosion – if tension cracks, toe bulges, ground settlement or heave, or erosion are noted, Clifton should be contacted immediately for assessment and provision of site specific remedial recommendations.
- Site grading should prevent standing water. This is essential to reducing the risk of groundwater level increases. Site grading cuts and fills should be reduced to the absolute minimum required to promote positive drainage. No more than 500 mm of fill should be added or removed during development.
- Culverts and existing drainage -ways should be continually maintained and monitored – this includes removal of excess sediment, and repair if any damage or erosion is noted.
- Irrigation and excessive watering should be kept to an absolute minimum, since groundwater increases may trigger or re-initiate landslide movement. Irrigation lines must be carefully monitored for leaks.
- Concentrated runoff can result in erosion gullies. If erosion gullies occur, they should be filled in with clay rich soil, then the ground surface armoured. Armoured ditches, such as recently constructed along the hill at the south of Hunts Cove Crescent, should be constructed to carry water in erosion prone areas. Vegetation should be maintained to reduce erosion. Water flow from eaves trough downspouts should be monitored, and erosion protection implemented if erosion occurs. Generally, erosion protection can include placement of a nonwoven geotextile and armouring with rip-rap. Other methods and materials are available, and can be discussed based on site specific requirements.
- Erosion along the shoreline should be monitored, and the shoreline armoured if it progresses.
- In-ground swimming pools are not recommended due to the risk they pose should a leak occur.
- Septic fields shall not be installed as they would increase groundwater levels and decrease slope stability. Septic tanks should be monitored and leaky septic tanks should be repaired or replaced.
- The recently constructed seepage inlet at the base of Hunts Cove Crescent Hill should be carefully monitored. If standing water is still present in the inlet the day after a rain event, a culvert should be installed. Excess water in this area could destabilize the nearby slope, posing risk to the properties above.
- New development near the lake should be designed to an elevation consistent with Community Planning Standards to prevent flooding and erosion damage during times of high water. A one in five hundred (1:500) year flood event is a common design requirement. Clifton can provide analysis and design with respect to flooding risk.
- Natural drainage patterns should not be altered. If development must include modification to a natural drainage path, the flow volume should be maintained and suitable erosion protection implemented.
- Existing vegetation shall not be removed from areas on or near slopes. Removal of vegetation can cause increased erosion, or destabilize a slope, since the roots assist in providing strength to the soil.
- A setback distance from the hill crest for the new development atop Hunts Cove Hill of 12 m was provided by PMEL. It is outside the scope of this project to assess this recommendation; however, we maintain that a minimum setback is necessary.
- New construction on the slopes above Hunts Cove Crescent and Archdekin Drive should be avoided. Minor disturbances of these slopes could result in slope failure.
- Construction of retaining walls near or on Hunts Cove Hill should be avoided. A properly engineered and constructed retaining wall is an option if absolutely necessary; however, the cost would likely be too great for the average homeowner. The risk of slope failure due to an

improperly constructed wall could lead to damage of local infrastructure and other properties.

Retaining Wall Remediation

The failure in the retaining wall along the north end of Hunts Cove Crescent, as discussed above (Figure 1) may have occurred due to insufficient design/construction, or lack of drainage, or both. Retaining walls must be constructed with provisions for drainage through the face of the wall, to avoid mounding of groundwater behind the wall, which can destabilize the slopes above.

The approximate 2 m high wall was deflected excessively as shown in Figure 1, and slope failure was visible above the wall, as shown below in Figure 6.

Figure 6: Slope failure above retaining wall on Hunts Cove Crescent.

The retaining wall consisted of corrugated steel sheet without obvious provision for drainage. The steel sheet was supported by horizontal timbers with ½" steel tieback rods at approximate 2.5 m intervals. Penetration details of the steel sheet and rods is unknown. The top of the head scarp of the slope failure was approximately 6 m in height above the roadway, and the horizontal distance from the retaining wall to the head scarp was approximately 4 m to 7 m. Measurement of the vertical and horizontal displacement of the head scarp was not possible due to heavy vegetation. The elevation difference between Hunts Cove Crescent and Archdekin Drive was approximately 18 m. Trailers, cottages and patios were present along the hill crest on Archdekin Drive above the failed retaining wall, as can be seen in Figure 6. Further movement of the retaining wall could put these properties at risk.

The design of a new retaining wall is beyond the scope of this project, so the following recommendations are provided as a general guide only. We recommend that further study be undertaken to assess remediation requirements for the wall and upslope, which would include a slope stability study at this particular location, analysis of retaining wall requirements by a structural engineer, and provision of design drawings and specifications for a new retaining wall. Many options for retaining wall design and construction area available, and could be discussed in more detail during design. A proposal outlining scope and costs for this work can be provided if required.

Replacement of the retaining wall should be completed in short sections, or "panels," to minimize upslope disturbance. Panels should be no more than 5 m wide.

The following sequence for reconstruction of the retaining wall is suggested:

- Remove a 5 m wide section of the failed wall.
- Cut back the base of the failed slope to allow space for placement of a 0.5 m wide drainage layer of granular material (clean sand or gravel) against the new wall. Nonwoven geotextile shall be placed between the native soil and the drainage material.
- Construct the new 5 m section of wall.
- Place the geotextile and granular drainage layer.
- Rebuild the slope by stripping the topsoil and organic material from above the 5 m panel, removing and recompacting the disturbed material, and placing and compacting common fill up to the top of the head scarp. Compacting may consist of "bucket packing" with a hydraulic excavator.
- Replace the stripped material and seed the new slope.
- Continue this sequence for the entire length of the new wall.

Closure and Limitations

The recommendations provided herein are based upon the inspections on 17 October 2017, the published geological information referenced herein, the reports provided to Clifton authored by PMEL, and information provided by the Client during the site visit, and are applicable only to the area of Hunts Cove Hill in Cochin, Saskatchewan. If conditions should vary significantly from those conditions described, then we should be notified immediately so that we may reassess our recommendations. The use of this report is intended specifically for the Resort Village of Cochin. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Clifton accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Our recommendations are general, and based on a visual site inspection, as well as subsurface exploration conducted by PMEL. We recommend that any landowner that undertakes new development, or modification to existing developments, invest in a site-specific assessment, and engineered design for the development. Our recommendations do not constitute a design, in whole or in part, of any development. Incorporation of any or all of our recommendations into the design of any element of development does not constitute us as designers or co-designers of such elements, nor does it mean that such design is appropriate in geotechnical terms. The designers of such elements must consider the appropriateness of our recommendations in the light of all design criteria known to them, many of which may not be known to us. Our mandate has been to inspect and recommend which we have completed by means of this report. We have had no mandate to design, or review the design of, any elements of development, and accept no responsibility for such design or design review. Design or design review can be provided for geotechnical aspects of development in the future under separate contract.

We trust that this letter is adequate for your present needs. Please contact us should you have any questions regarding this matter.

Yours truly,

Clifton Associates Ltd.

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