GOLDER

REPORT

Shoreline Erosion Assessment

Cultus Lake Park Board, Cultus Lake, BC

Submitted to:

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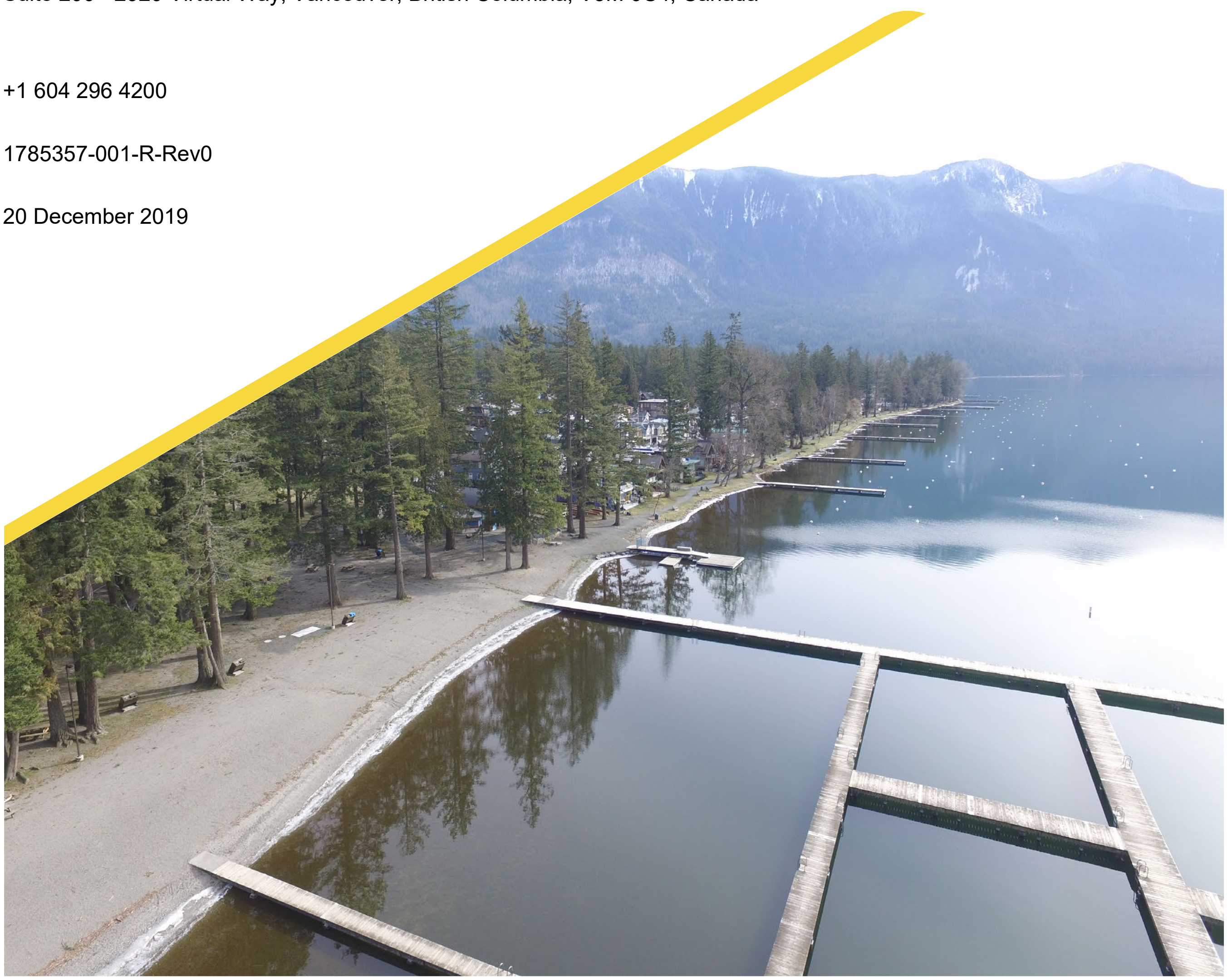
20 December 2019



Distribution List

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FIGURES

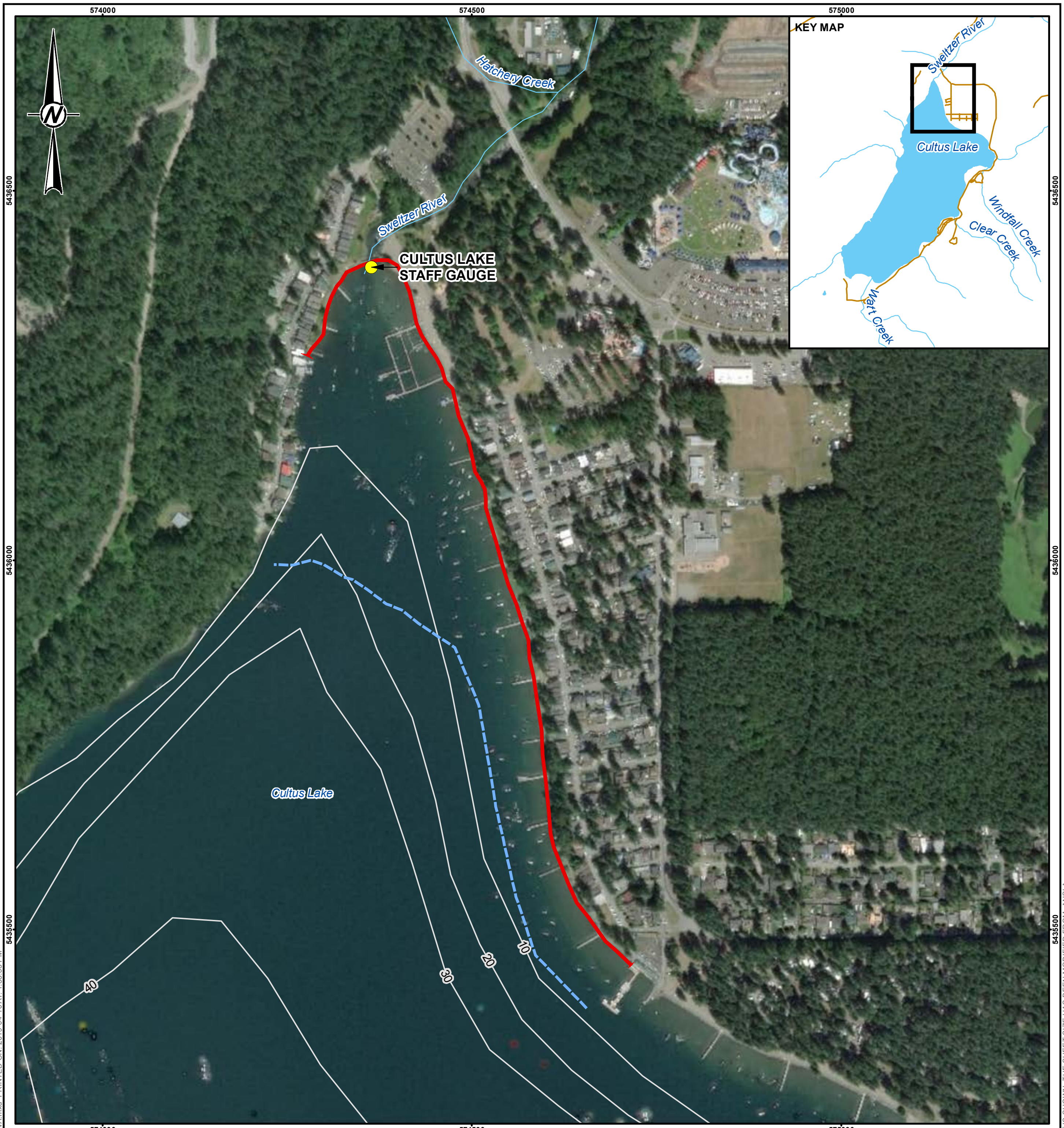
1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by the Cultus Lake Park Board to carry out an assessment of shoreline erosion along sections of the shoreline of Cultus Lake. Cultus Lake is located in the Fraser Valley region of British Columbia, approximately 30 km east of Abbotsford and 10 km south of Chilliwack. The Cultus Lake Park includes 640 acres of park land and beach on the eastern shore of Cultus Lake and is the direct responsibility of the Cultus Lake Park Board. The study area for this project (the Project Site) is located along the north and east shoreline of Cultus Lake, either side of the Sweltzer River. The Project Site is shown on Figure 1.

The purpose of this shoreline erosion assessment is to characterize the nearshore processes that are currently leading to erosion and use this information to develop potential mitigation options. In recent years, certain areas of shoreline within the Project Site have experienced erosion stemming from nearshore processes (i.e. winds, waves and water levels) along the shoreline.

As part of the shoreline erosion assessment, Golder carried out the following tasks:

- Task 1: Site Visit (Section 2.0)
- Task 2: Data Analysis (Section 3.0)
- Task 3: Conceptual Sketches (Section 4.0)
- Task 4: Reporting and Cost Estimates (Section 4.0)



LEGEND

- CULTUS LAKE STAFF GAUGE
- 5 km/h ZONE
- BATHYMETRY CONTOUR (10 m INTERVAL)
- EXTENT OF STUDY AREA
- WATERCOURSE

0 100 200

1:7,500 METRES

REFERENCE(S)

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DATUM: NAD83 PROJECTION: UTM ZONE 10

CLIENT
CULTUS LAKE PARK BOARD

PROJECT
CULTUS LAKE SHORELINE EROSION ASSESSMENT

TITLE
SITE PLAN

CONSULTANT
GOLDER

YYYY-MM-DD	2019-12-20
DESIGNED	DH
PREPARED	AA
REVIEWED	JMO
APPROVED	PO

PROJECT NO.	CONTROL	REV.	FIGURE
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2.0 SITE VISIT

2.1 Introduction

On 7 February 2019, Golder carried out an inspection of the shoreline erosion that is occurring at the Project Site. This included photographing and characterizing shoreline erosion (i.e. shoreline orientation, morphological indicators of erosion and material grain size), collecting aerial imagery of the shoreline to delineate areas and mechanisms of erosion, and recording basic elevations and slopes of the shoreline, beach and lakebed.

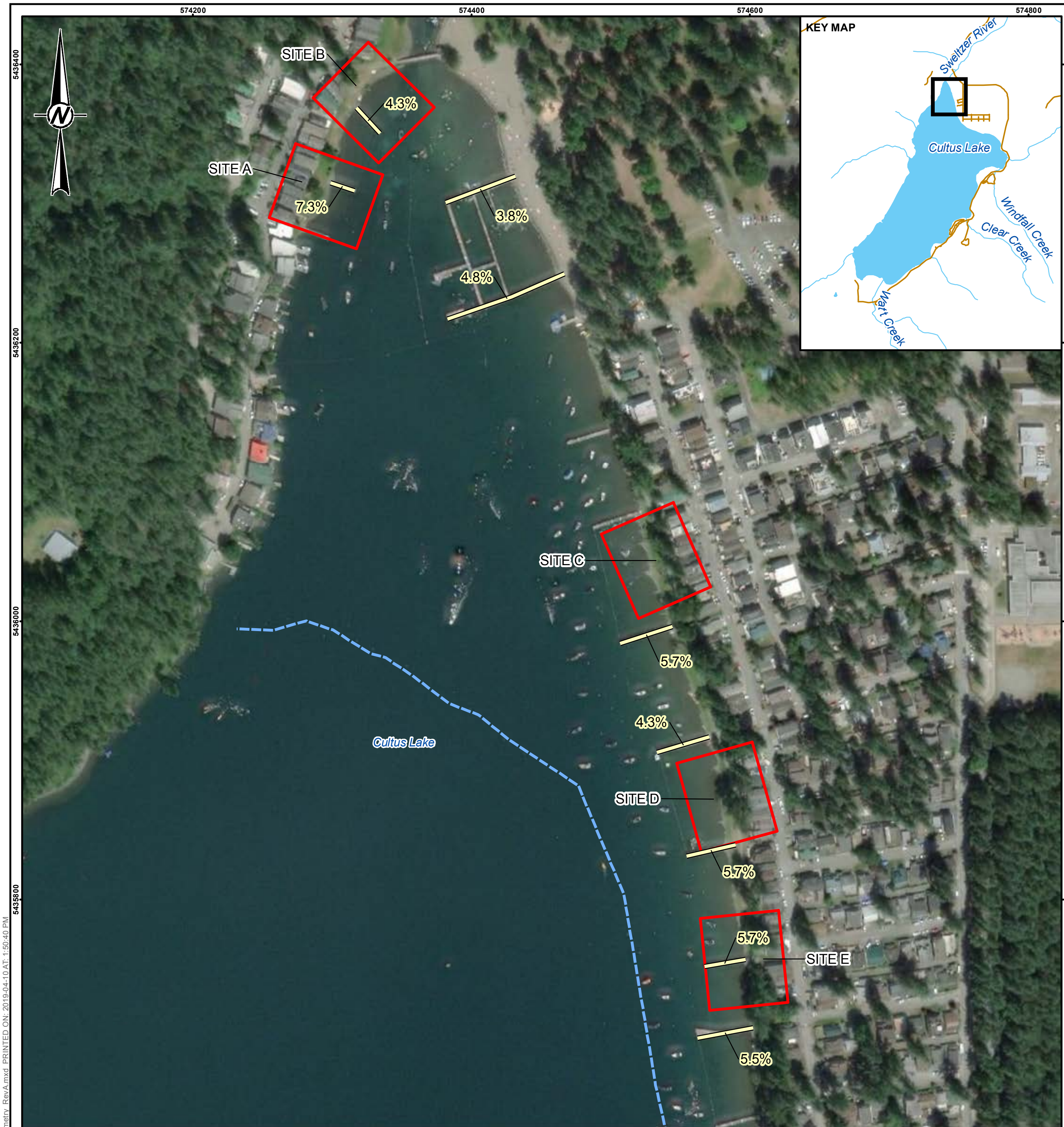
The site visit was carried out during clear and dry weather. At the time of the site visit, the staff gauge located at the outlet to the Sweltzer River indicated a water level of 44.36 meters above sea level (masl). This represents a water level 0.08 m lower than the February mean water level over a period of 7 years from 2012 to 2019 (described further in Section 3.0), so can be considered typical for the time of year.

2.2 Observations

Figure 2 provides a summary of the shoreline area assessed during the site visit, including observations and estimated shoreline slopes. Figure 3 through Figure 7 provide details on specific observations made in selected areas, to provide representative examples of the indicators of erosion that were observed.

The following list summarizes the key observations that were consistent for the entire Project Site.

- Vertical bank escarpments were observed up to an elevation of approximately 45.0 masl. In some areas of the shoreline the bank escarpment is locally undermining constructed shoreline structures.
- Gravel of a size 3”-minus and larger was found on the lower beach. Gravel/sand of a size 1”-minus and smaller was found on the upper beach. Evidence of woody debris accumulation above the bank escarpment suggests potential for wave and water level overtopping of the escarpment.
- Asymmetric shoreline orientation (indicative of erosion and deposition processes) is leading to lateral erosion of beach material to the north of constructed groynes, up to approximately 2-3 m in some locations, and deposition of beach material to the south of constructed groynes. In some places, rock protection has been placed to control erosion in these areas.
- Locally-constructed shoreline structures (i.e. groynes, riprap material) are increasing the effects of erosion processes. This is discussed in more detail in Section 2.3.
- Observed erosion and deposition patterns indicate net direction of material transport is from south to north.
- Upland erosion was observed in some areas of the shoreline. This is likely from surface runoff due to heavy rainfall and surface flow, but was not considered further in this scope of work.



LEGEND

- 5 km/h ZONE
- ESTIMATED LAKEBED GRADE
- SPECIFIC SITE OBSERVATION

0 50 100

1:4,000 METRES

REFERENCE(S)

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DATUM: NAD83 PROJECTION: UTM ZONE 10

CLIENT
CULTUS LAKE PARK BOARD

PROJECT
CULTUS LAKE SHORELINE EROSION ASSESSMENT

TITLE
SITE VISIT OBSERVATIONS

CONSULTANT

GOLDER

YYYY-MM-DD	2019-12-20
DESIGNED	DH
PREPARED	AA
REVIEWED	JMO
APPROVED	PO

PROJECT NO.	CONTROL	REV.	FIGURE
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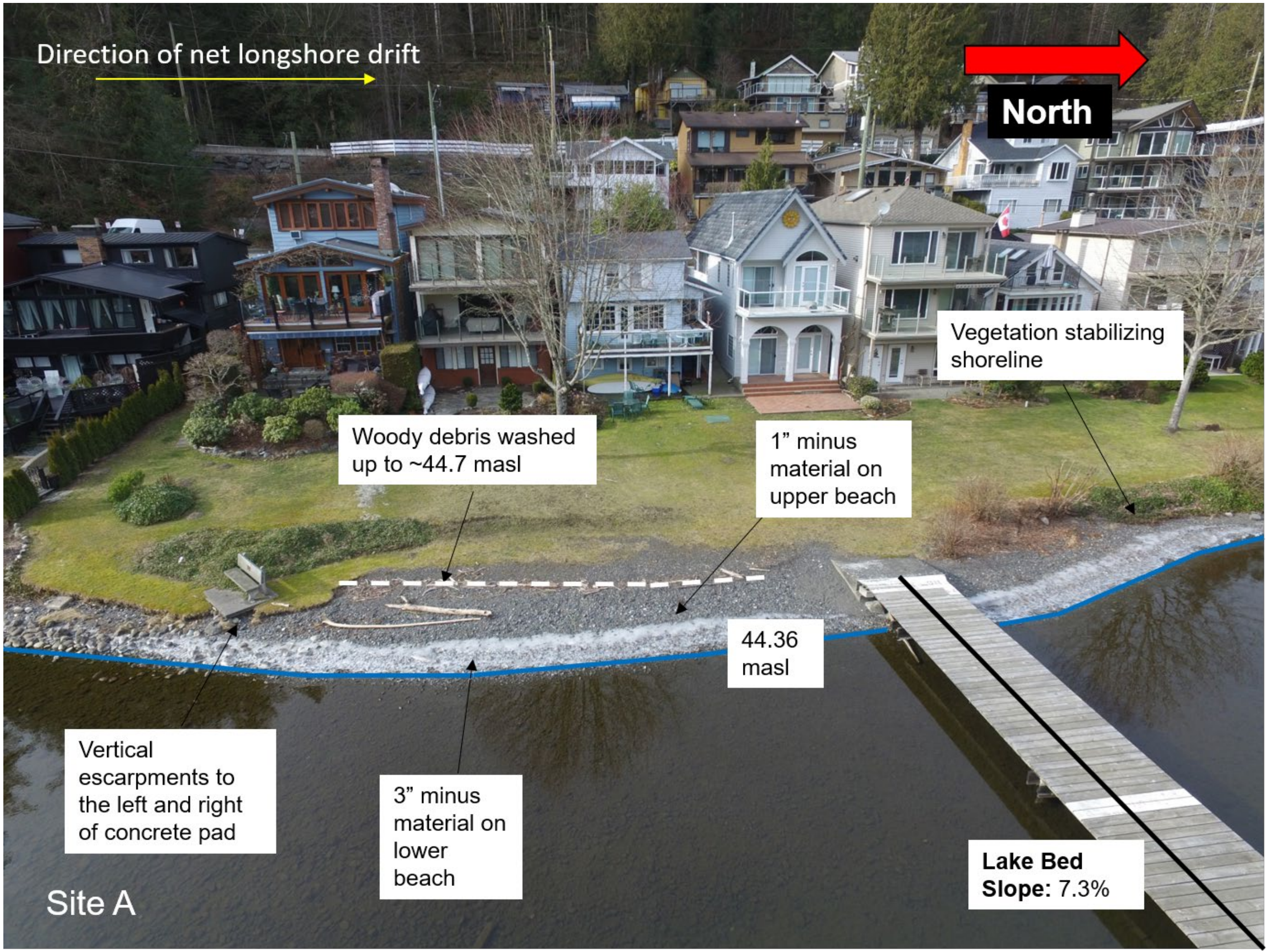

Figure 3: Site visit observations for Site A

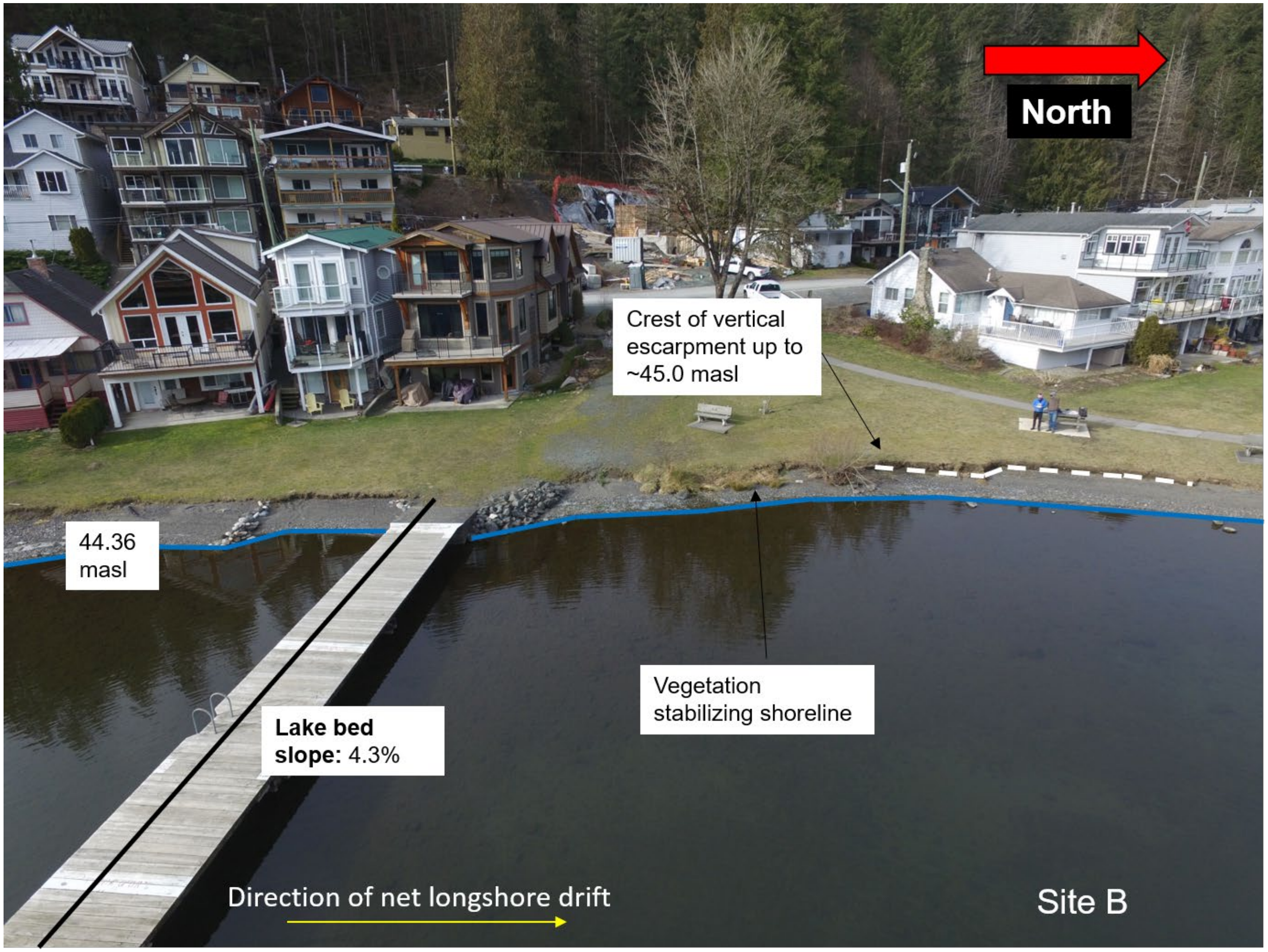

Figure 4: Site visit observations for Site B

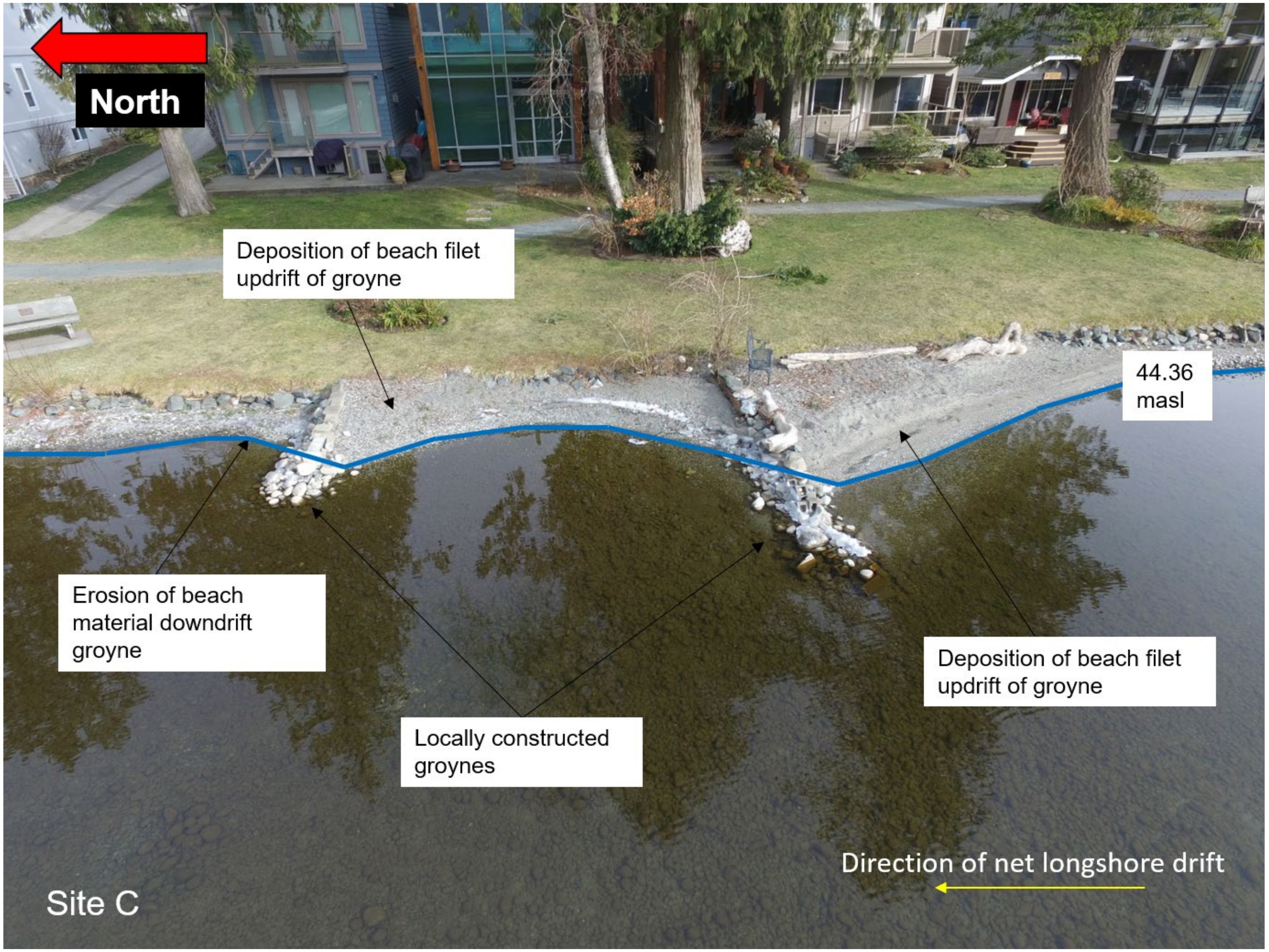

Figure 5: Site visit observations for Site C

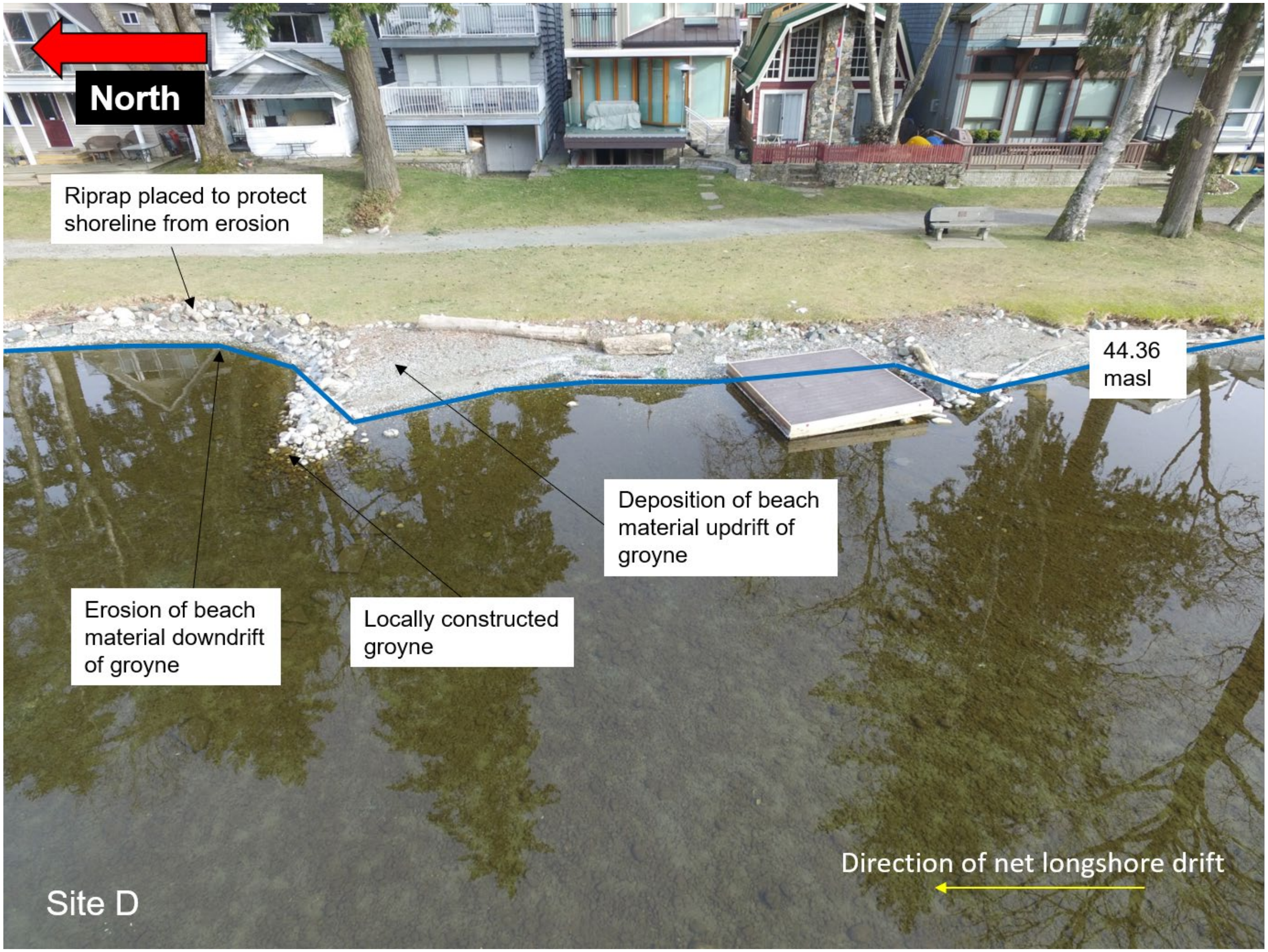

Figure 6: Site visit observations for Site D

Figure 7: Site visit observations for Site E

2.3 Observed Indicators of Erosion

Along the shoreline of Cultus Lake, morphological indicators of bank erosion were largely observed in locations where the beach had receded enough that waves had the potential to runup the beach and overtop the bank. Ad hoc shore protection has been placed to mitigate erosion of beach scarps both as direct placements in beach scarps and as a series of groynes perpendicular to the shoreline to trap sediment. Generally, bank erosion and beach recession were exacerbated to the north of these ad hoc constructed shoreline structures, suggesting there is longshore sediment transport, the movement of sediment by oblique wave action and currents parallel to the shoreline, in a south to north direction.

Longshore sediment transport (or longshore drift) is often caused by waves arriving at the beach at an oblique angle (i.e. wind waves from the south through southwest at the Project Site) and creating asymmetry in wave uprush and backwash or by creating a longshore current. The waves can be naturally occurring due to winds or be caused by wakewash from boats.

In either case, when a structure is placed in the path of the longshore sediment transport, the sediments moving towards the structure may become trapped on the updrift side (Figure 8). At the same time the transport of sediments in the immediate downdrift lee of the structure (i.e. area sheltered from the incoming waves) continues but are no longer replenished. Over time, this causes the beach to recede in the immediate lee of the structure and grow on the updrift side. The alongshore groyne placement (spacing) and shore perpendicular length of groynes along the Project site appear to be relatively ad hoc with each individual home taking independent measures to mitigate erosion in front of each property. This has led to variable results in terms of erosion protection performance and a progressive reduction in supply of sediment to beaches with distance along the beach cell. The latter ultimately leads to a sediment deficit and exacerbated erosion of downdrift beaches.

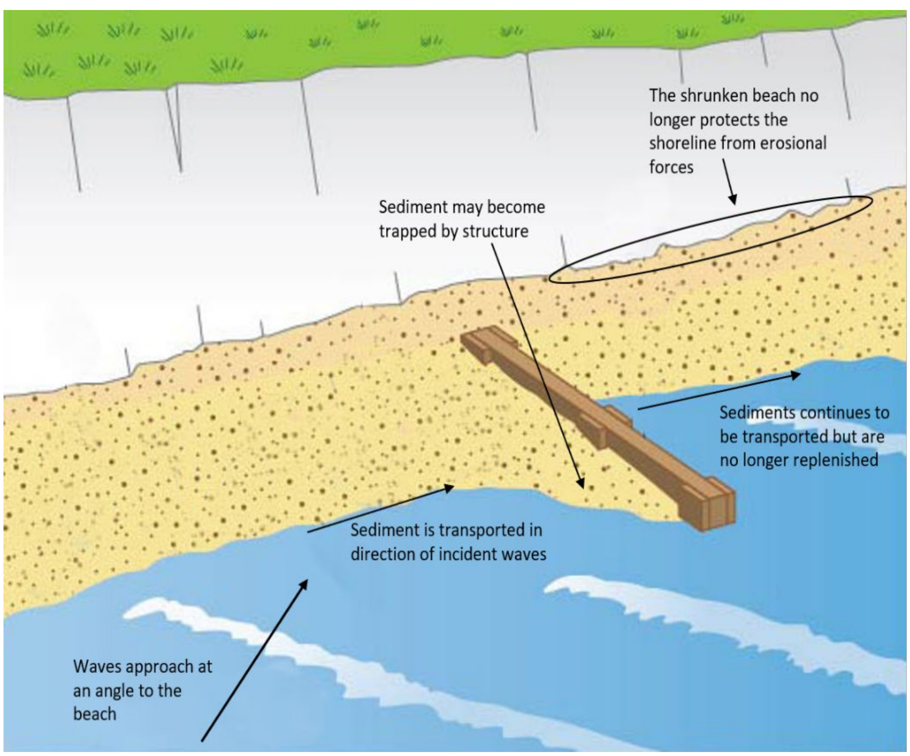

Figure 8: Illustration of groyne effect on longshore sediment transport

3.0 DATA ANALYSIS

3.1 Introduction

This section presents a summary of the data analysis that has been carried out as part of this assessment. Data have been reviewed to characterize and understand the nearshore processes at the Project Site that are leading to erosion issues along the shoreline.

The following data were collected and reviewed:

- Water levels (Section 3.2)
- Wind speed (Section 3.3)
- Wave heights (Section 3.4)

3.2 Water Levels

3.2.1 Water Level Data

Water level data was provided to Golder by the Cultus Lake Park Board. Water levels for Cultus Lake have been recorded using a manual staff gauge, maintained by the Cultus Lake Park Board, and located at the north end of the lake near the outlet for the Sweltzer River (shown on Figure 1).

Daily water levels have been recorded manually between 2012 and 2019 (Figure 9). However, approximately 47% of the recorded daily data is missing and the reason for the gaps in the provided data is unknown. It is also noted that gaps in data occur more frequently during the winter months.

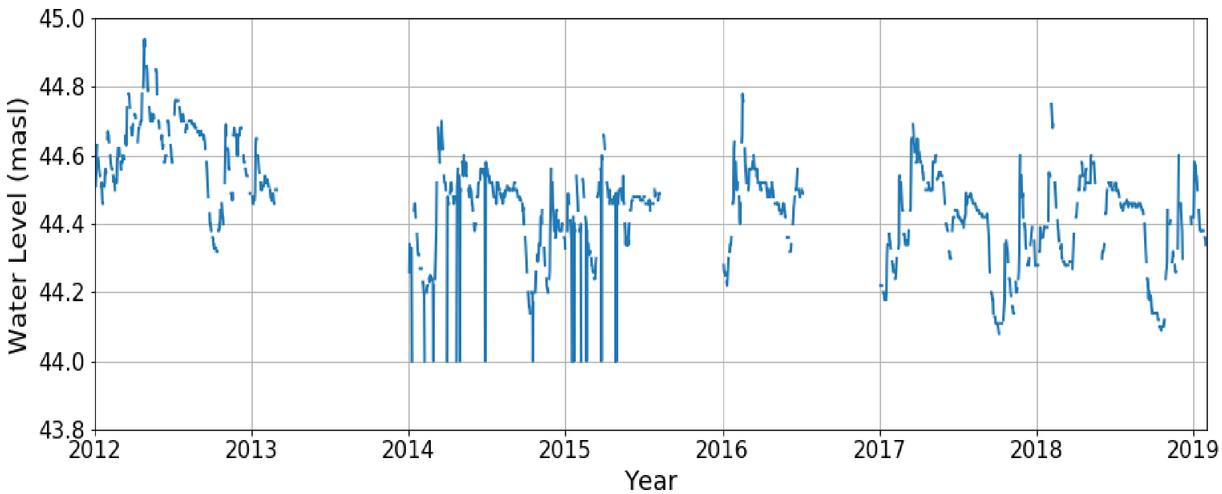

Figure 9: Cultus Lake water levels during the period 2012 to 2019

Between March 15th and September 15th each year, the water level is controlled by a weir at the lake outlet for the Sweltzer River, which maintains a water elevation of 44.5 masl for recreational purposes during the summer months. Outside of this period the water level fluctuates naturally in response to precipitation and flow within the Cultus Lake catchment. Figure 10 presents water level distributions for each month.

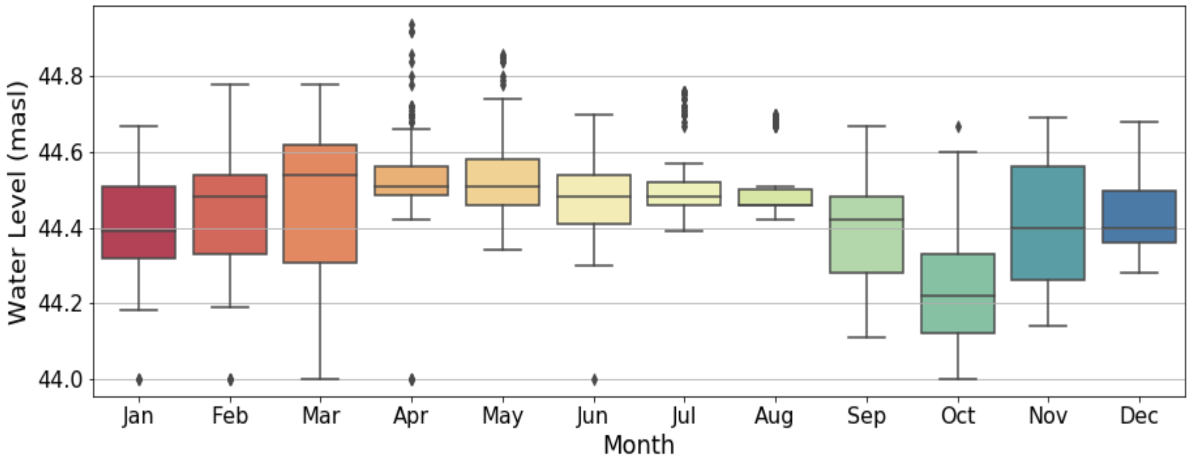

Figure 10: Monthly water level distribution in Cultus Lake during the period 2012 to 2019

Monthly and annual water level statistics are presented in Table 1 and Table 2. For the purpose of this analysis the **weir-controlled** period has been defined as April 1 to August 31, and the **non-controlled** period has been defined as September 1 to March 31.

Table 1: Summary of monthly water level data for Cultus Lake

Month	Minimum Water Level (masl)	Mean Water Level (masl)	Maximum Water Level (masl)
January	44.00	44.40	44.67
February	44.00	44.44	44.78
March	44.00	44.49	44.78
April	44.00	44.53	44.94
May	44.34	44.54	44.86
June	44.00	44.48	44.70
July	44.39	44.51	44.76
August	44.42	44.51	44.70
September	44.11	44.40	44.67
October	44.00	44.24	44.67
November	44.14	44.40	44.69
December	44.28	44.43	44.68

Table 2: Maximum water levels during weir-controlled and non-controlled periods.

Year	Maximum Water Level during weir-controlled period (masl)	Maximum Water during non-controlled period (masl)
2012	44.94	44.78
2013	-	44.65
2014	44.60	44.70
2015	44.64	44.66
2016	44.56	44.78
2017	44.61	44.69
2018	44.60	44.75
2019	-	44.58

3.2.2 Water Level Data Analysis

The length of the water level record and percentage of missing data makes the record too short and incomplete for a meaningful analysis of long-term water levels using an extreme value analysis. As extreme value analysis involves extrapolating normally distributed data beyond the record length, typically extreme values can not be computed for more than twice the record length. In this case the water level data is not normally distributed, and the percentage of missing data and record length is too high and too short, respectively.

Instead, a statistical analysis was used to estimate water levels for selected percentiles for Cultus Lake. For example, the 80th percentile represents the water level above which 20% of the record occurs.

Estimates of maximum water levels were computed for selected percentiles during the weir-controlled period and the non-controlled period. The entire water level record during the period 2012 to 2019 was used. It is noted that there is a high percentage of missing data during the non-controlled period, which could alter the reported statistics for this period. A summary of the water levels for selected percentiles is presented in Table 3.

Table 3: Maximum water level (masl) for selected percentiles

Period	80th	85th	90th	95th	99th
Weir-controlled	44.58	44.63	44.69	44.72	44.85
Non-controlled	44.56	44.58	44.62	44.66	44.75

3.3 Winds

3.3.1 Wind Data

Wind speed and direction have been measured at Abbotsford Airport station 702 (Environment Canada) for a period of 66 years (1953 to 2019). During the winter season, typically November to March, the predominant wind direction is from the north-northeast with less frequent but strong winds from the south-southwest (i.e. storm events). In the summer season, typically May to August, the predominant wind direction is from the south-southwest. In general, the winds in the summer months are weaker than those observed in the winter from either the south-southwest or north-northeast directions. This is illustrated in Figure 11.

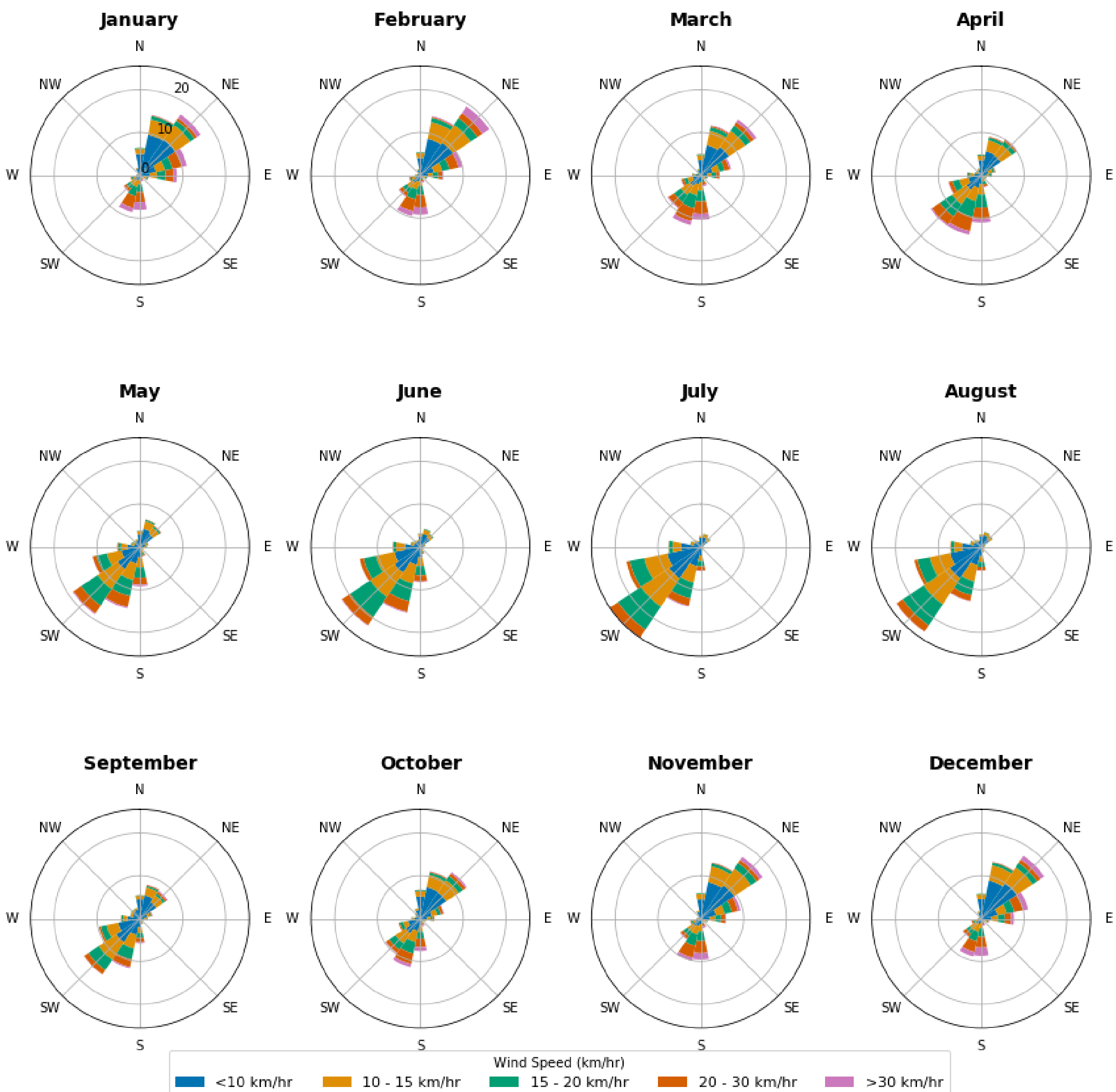

Figure 11: Monthly winds measured at Abbotsford Airport during the period 1953 to 2019

In addition to the Abbotsford airport data, Golder also obtained data from a local meteorological station located at the Cultus Lake Marina (Laval 2019, pers. comm). This station has collected wind data for the period 2016 to 2018. Although this dataset length is considered too short for a meaningful analysis of long-term winds, it can be used for a sensitivity analysis to compare the Abbotsford airport data to a more local dataset.

A sensitivity analysis of Abbotsford Airport and Cultus Lake Marina winds revealed that winds between the two stations are generally in good agreement when winds are from the south through southwest direction. This analysis is presented in Figure 12. However, northerly reported winds at Abbotsford Airport over-estimate the observed winds on Cultus Lake by a factor of 3 to 4 and easterly reported winds at Abbotsford Airport underestimate the observed winds on Cultus Lake by a factor of 4 to 5. For the purpose of this study only the south through southwest winds are considered (i.e. the long fetch direction) and the data from Abbotsford Airport is scaled to data from Cultus Lake Marina using a factor of 0.95 (Sumka 2017).

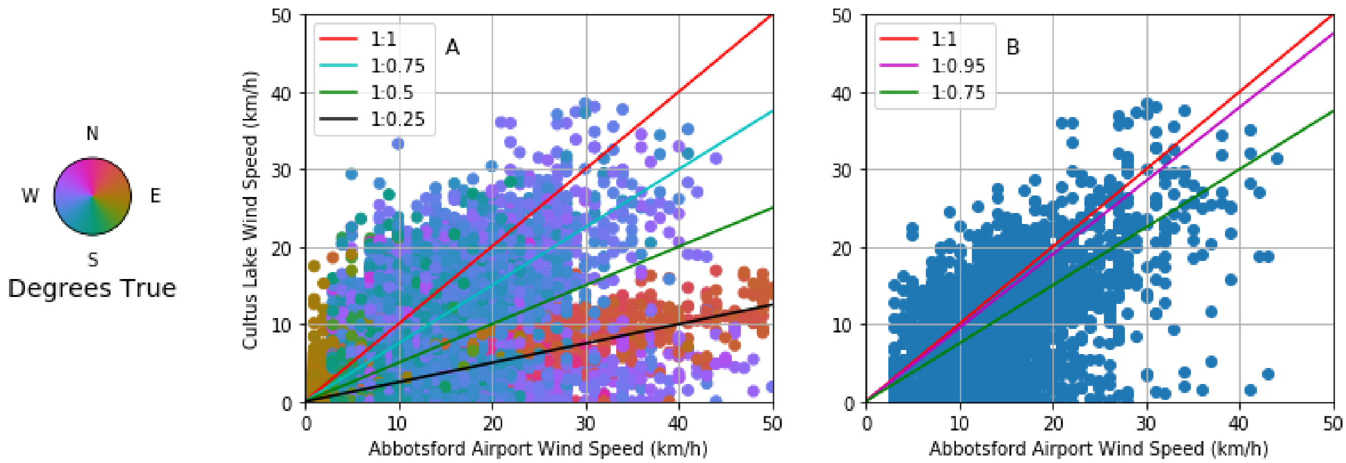

Figure 12: Wind speed sensitivity analysis for Cultus Lake Marina and Abbotsford Airport for the period 2016 to 2018 (A) and for the period 2016 to 2018 using winds between 170 and 230 degrees (B).

3.3.2 Wind Data Analysis

An extreme value analysis was used to estimate wind speeds for selected return periods for Cultus Lake using scaled south and southwest winds speeds from Abbotsford Airport. A Peak Over Threshold (POT) method was used to identify wind speeds above a defined threshold for the selected direction sectors on an annual basis and during the period April through August and September through March (Figure 13). The threshold was selected as the 98th percentile of the analyzed data (this varied based on the data subset) and identified peaks were filtered to have a minimum separation of 48 hours (Palutikof et al. 1999).

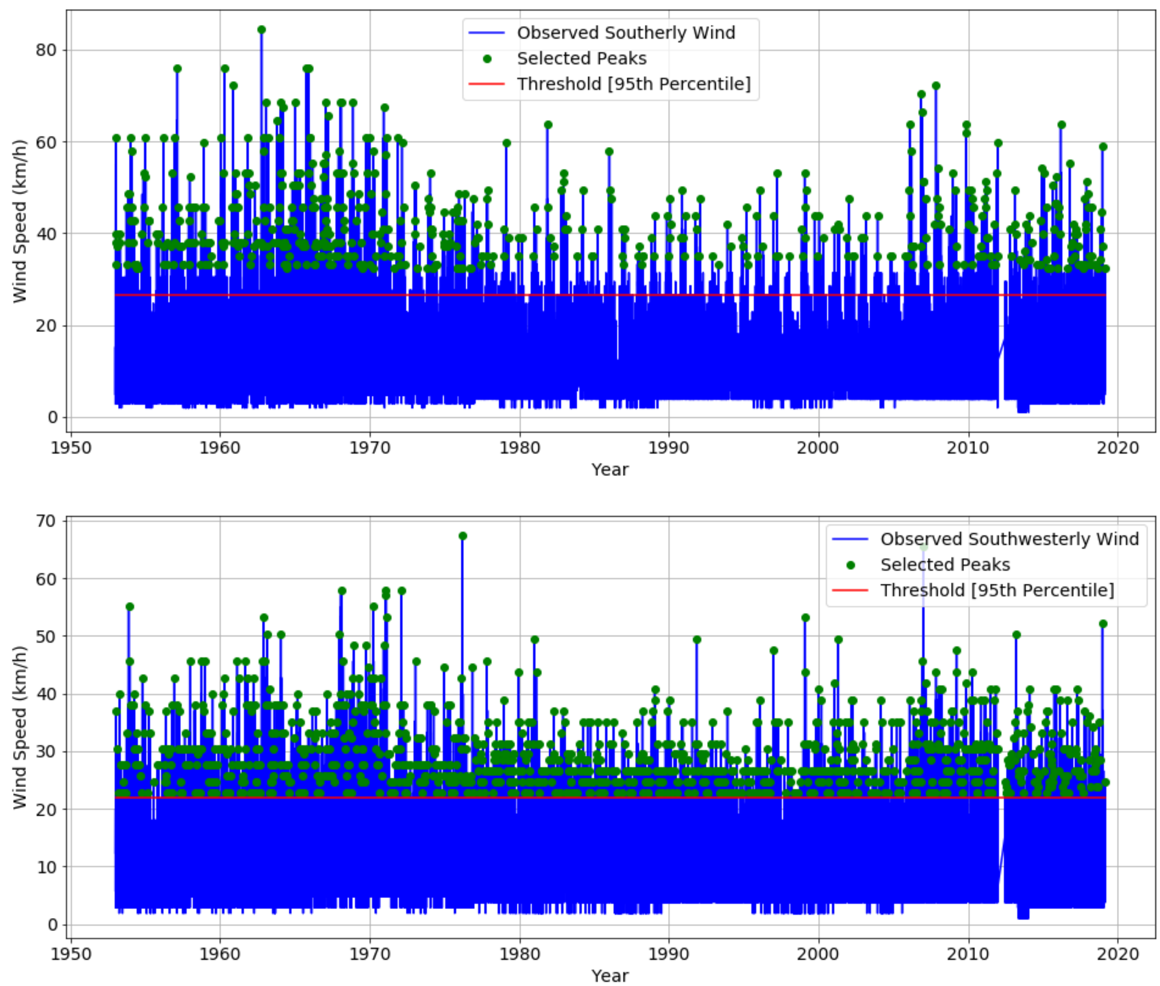

Figure 13: Illustration of Peak Over Threshold (POT) method for annual south and southwest winds using a threshold cut-off of the 95th percentile

Return periods and 95% confidence intervals were estimated by fitting a selection of statistical distributions to the selected peak wind speeds and extrapolating the fit to more extreme events (Palutikof et al. 1999). The best fit distribution was determined through the Anderson-Darling test statistic. A summary of the extreme value analysis for selected return periods is presented in Table 4, Table 5 and Table 6.

Table 4: Maximum wind speeds (km/h) for selected return periods over the record

Period	2-Year	5-Year	10-Year	25-Year
S	44.9	53.3	58.8	65.6
SW	32.1	37.8	42.0	47.2

Table 5: Maximum wind speeds (km/h) for selected return periods during the weir-controlled period

Period	2-Year	5-Year	10-Year	25-Year
S	34.0	39.7	44.0	49.8
SW	27.3	31.3	34.2	37.9

Table 6: Maximum wind speeds (km/h) for selected return periods during the non-controlled period

Period	2-Year	5-Year	10-Year	25-Year
S	50.1	58.2	63.3	69.4
SW	35.6	42.0	46.3	51.8

3.4 Waves

3.4.1 Wave Data

Measured wave data for the Project Site were unavailable, but wind and water level data have been used to estimate likely wave conditions for waves caused both by wind and by boat wakes. The following sections presents the results of the wind and vessel wake wave analysis. The analysis was completed for both the April through August (weir-controlled season) and September through March (non-controlled season).

3.4.2 Wind Waves

Extreme values of wind wave parameters (i.e. significant wave height and peak period) were estimated in Cultus Lake using the Simulating Waves Nearshore (SWAN) wave generation and transformation model (Booij et. Al. 1996). SWAN is a third-generation wave model that computes random, short-crested wind-generated waves on a two-dimensional grid in coastal regions and inland waters. SWAN accounts for most of the relevant physical processes involved in wave generation and propagation in time and space, including: shoaling, refraction, wave-current and wave-wave interactions, reflection, diffraction, white-capping, and breaking.

Wave events were modelled in SWAN using literature-reported depths of Cultus Lake and under a combination of water levels and south-southwest winds (i.e. long fetch direction). As there are no nearshore wave measurements available in Cultus Lake, modeled wave heights were compared to empirically derived fetch limited wave heights. The modeled wave heights showed good agreement with the fetch limited wave heights, generally within 0.05 m.

Modelled wave heights under the 90th percentile high water level and 10-year south-southwest wind during the non-controlled period are shown in Figure 14 and Figure 15. Wave heights are largest along the northern shore of Cultus Lake (i.e. the Project Site) and decrease near the outlet for Sweltzer River and vicinity of the shoreline as a result of the shallowing depths. Modelled deep water and shallow water wave heights, extracted form the model at the locations indicated in Figure 15, for various combinations of water levels and winds during the weir-controlled and non-controlled periods are presented in Table 7 and Table 8.

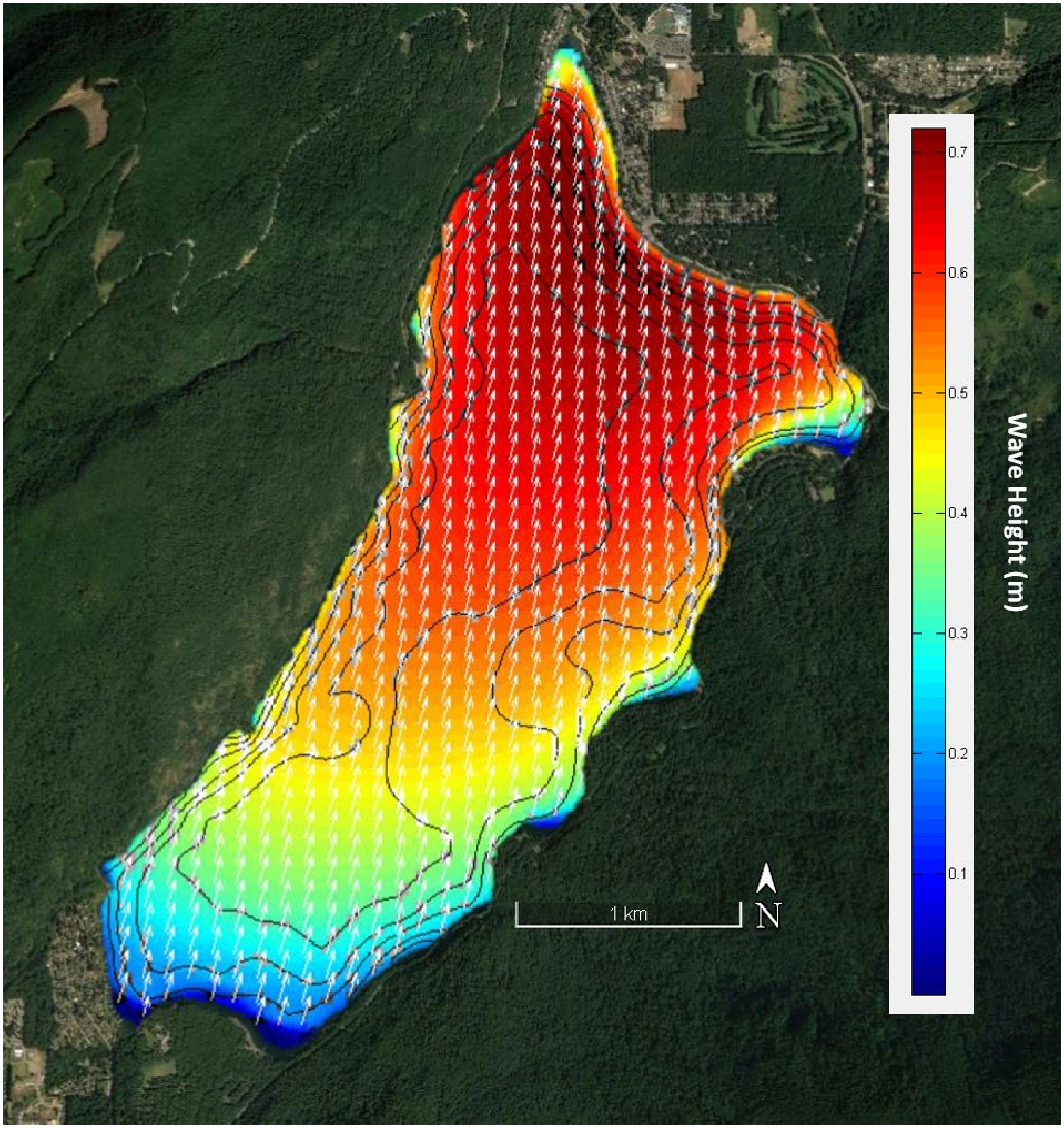

Figure 14: Modelled wave heights (colour) and direction (arrows) on Cultus Lake during the non-controlled period. Combination of a 90th percentile high water level and 1 in 10 year south-southwest wind. The 5, 10, 20, 30, and 40 m bathymetric contour are indicated.

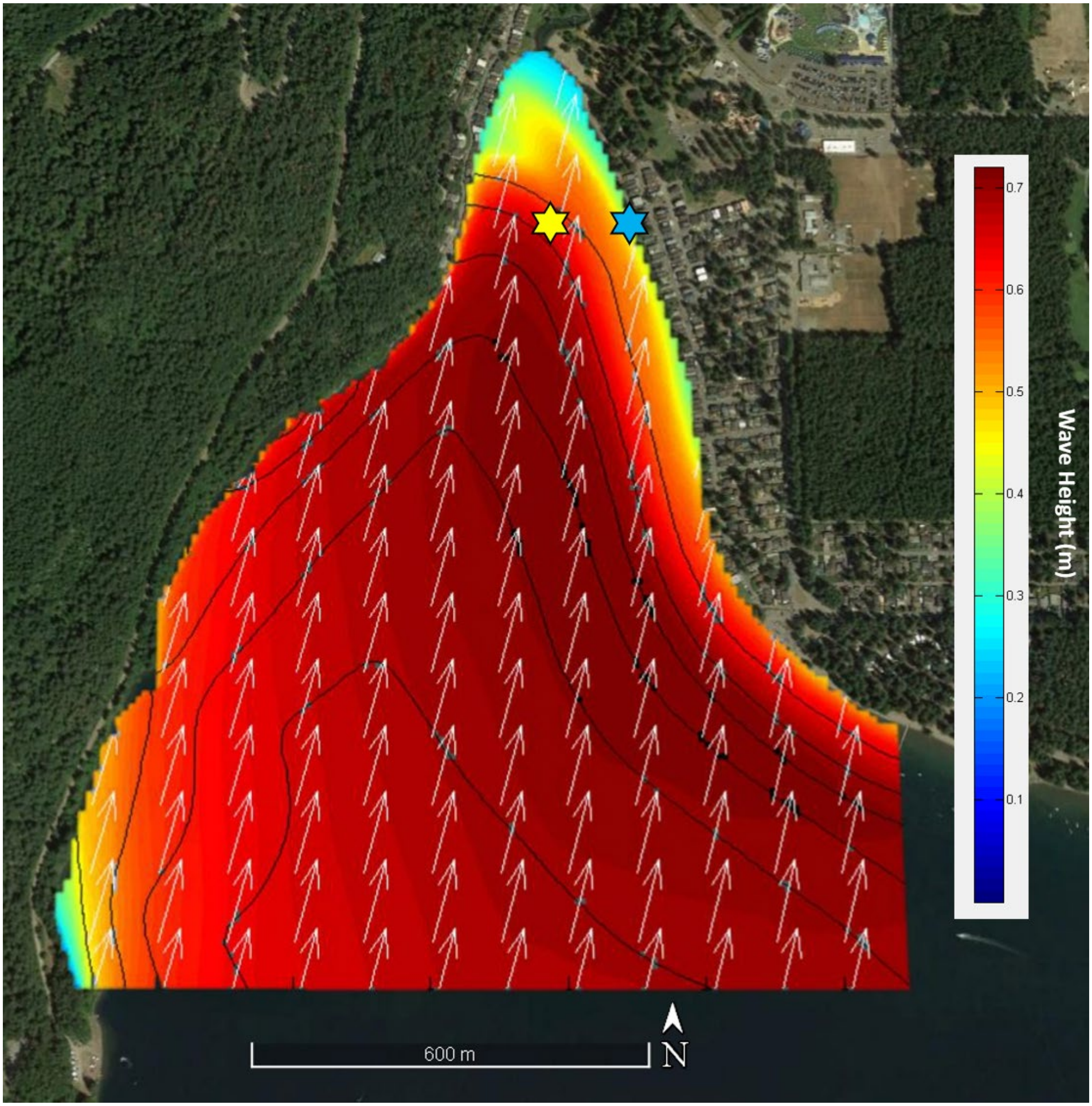

Figure 15: Modelled wave heights (colour) and direction (arrows) near the Project Site during the non-controlled period. Combination of a 90th percentile high water level and 1 in 10-year south-southwest wind. The 5, 10, 20, 30, and 40 m bathymetric contour are indicated. The yellow and blue star indicate the location of reported deep water and shallow water wave heights and periods in Table 7 and Table 8, respectively.

Table 7: Modelled deep-water and shallow-water wave heights (m) and wave period (s) under a range of south-southwest winds and a 90th percentile high water level during the weir-controlled period

	Return Period South-Southwest Wind Speeds			
	2-Year	**5-Year**	**10-Year**	**25-Year**
Deep Water Wave Height (m) and Period (s)	0.35 m (1.85 s)	0.42 m (2.02 s)	0.46 m (2.11 s)	0.54 m (2.26 s)
Shallow Water Wave Height (m) and Period (s)	0.29 m (1.80 s)	0.31 m (1.98 s)	0.37 m (2.08 s)	0.36 m (2.18 s)

Table 8: Modelled deep-water and shallow-water wave heights (m) and wave period (s) under a range of south-southwest winds and a 90th percentile high water level during the non-controlled period

	Return Period South-Southwest Wind Speeds			
	2-Year	**5-Year**	**10-Year**	**25-Year**
Deep Water Wave Height (m) and Period (s)	0.55 m (2.30 s)	0.64 m (2.48 s)	0.71 m (2.59 s)	0.80 m (2.50 s)
Shallow Water Wave Height (m) and Period (s)	0.42 m (2.21 s)	0.47 m (2.34 s)	0.37 m (2.42 s)	0.36 m (2.73 s)

3.4.3 Vessel Wakes

Vessel-generated wakes were estimated for the largest expected vessel size on Cultus Lake using the method of Bhowmik et al. (1991). The vessel chosen as a typical vessel used on Cultus Lake was the Heyday WT-Surf (Driediger 2019, pers. comm).

The vessel speed was chosen as 10 km/h. This is double the speed that is allowed inside the No Wake zone and could be reasonably expected by boats traveling just outside the No Wake zone.

Vessel generated wave heights can generally be expected during the weir-controlled period in the summer months. Results from this assessment are presented in Table 9. Results indicate that vessel generated wave heights are generally smaller than wind waves during this period.

Table 9: Vessel parameters for a typical wakeboard boat with ballast water tank and expected wave height

Parameter	Value	Source
Vessel speed	10 km/h	Bylaw No. 1083
Vessel distance from shore	30 m	Based on “No Wake” zone and infrastructure in aerial imagery
Vessel length	7.5 m	Communication with Dave Driediger and observed boats in aerial imagery
Vessel draft	0.74 m	Manufacturer specifications
Vessel generated wave height	**0.32 m**	**Bhowmik et al. (1991)**

3.4.4 Summary

A summary of the wind wave and vessel wake analysis is included below.

- Wind waves are most sensitive to wind speed as the water level variation in Cultus Lake, even between the weir-controlled and non-controlled periods, is minimal.
- Wind waves are largest at the Project Site during the non-controlled period as a result of increased wind speeds from the south-southwest, which could also cause a storm surge (i.e. temporary increase in water level).
- Wind wave heights near the outlet for the Sweltzer River and along segments of the Project Site are reduced as the depth shallows. It is likely that waves in these regions are breaking a distance before the shoreline.
- Waves from vessel wakes can reach heights of approximately 0.3 m, which is lower than wind wave heights modelled during the weir-controlled period.

4.0 POTENTIAL MITIGATION OPTIONS

4.1 Introduction

Based on the indicators of erosion observed at the Project Site and a review of relevant nearshore processes data, Golder has developed an understanding of the erosion mechanisms likely to be occurring. Using this information and using typical approaches to shoreline protection as a guide, Golder has developed several potential mitigation options that could be implemented to control or reduce the erosion that is occurring.

4.2 Typical Approaches

Typical approaches to shoreline protection can be categorized as 'green' options, indicating softer more natural engineering approaches, or 'grey' options, indicating harder engineering approaches like coastal structures. The range of typical approaches is illustrated in Figure 16.

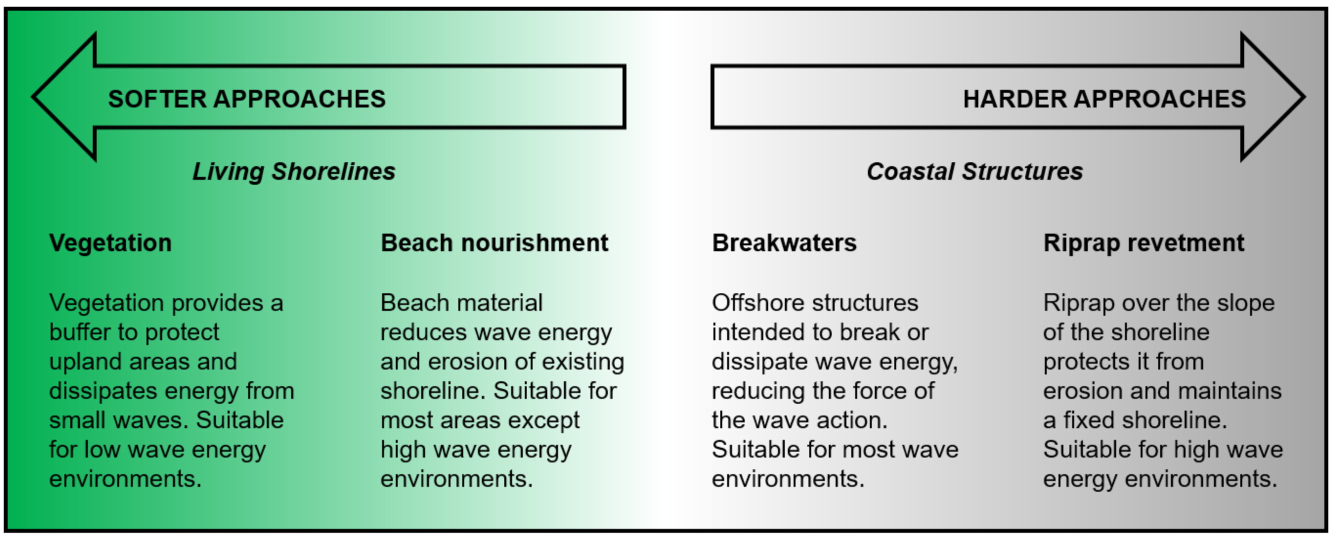

Figure 16: Typical approaches to shoreline erosion protection

Hard engineering approaches to shoreline protection include coastal structures like seawalls, breakwaters or riprap revetments. These structures are effective in preventing erosion but can also prevent the shoreline from carrying out natural processes, may be less suited to adaptation and generally provide low habitat values. On the contrary, soft engineering approaches like living shorelines have been shown to restore, protect, and stabilize shorelines. These approaches have a lower capital cost, may be more readily adaptable to long term change and can provide economic, ecological, and aesthetic benefits, but may come with higher long-term maintenance costs.

Considering the suitability of typical approaches to the Project Site, Golder suggests the following high-level approaches are considered in this case.

- **Management approach** (i.e., mitigate vessel wake waves through additional controls on boat speeds and boat-use areas).
  - May be difficult or unpopular to implement with lake users.
  - Does not provide erosion protection against wind waves, shown to be the primary driver of erosion experienced at the Project Site.
- **Soft engineering approaches** (i.e living shorelines, beach nourishment, placement of gravels and woody debris).
  - Solves the erosion issues but will require maintenance over the project life.
  - Lower capital cost, but ongoing long-term maintenance costs.
  - Improves aesthetic value of shoreline and is compatible with recreational uses.
  - Increases habitat value so should make the permitting process easier.
- **Hard engineering approaches** (i.e. seawall, riprap or log wall revetment, fixed or floating breakwaters)
  - Solves the erosion issues by fixing the shoreline in place.
  - Result in loss of recreation and aesthetic value, and potential loss of beach and habitat value.
  - Stakeholders (i.e. residents, regulators, park users) may be unlikely to support.
  - Higher capital cost, but minimal long-term maintenance costs.
- **Hybrid approaches** (i.e. combination of engineering and living shoreline concepts)
  - Solves the erosion issues but will require some level of maintenance.
  - Higher capital cost, but lower ongoing long-term maintenance costs.
  - Increase habitat value and improve aesthetic value of shoreline compared to existing condition.
  - Easier to permit than hard engineering approaches.

4.3 Proposed Options

Based on the typical approaches described above and an understanding of the erosion mechanisms occurring at the Project Site, Golder is proposing three (3) options for consideration at the Project Site. These options have been proposed as they represent a range of feasible and effective erosion mitigation solutions.

Conceptual sketches have been provided for each option to illustrate how these solutions could be implemented at the Project Site. These are presented in the following section. The options proposed assumed indicative dimensions and materials for cost estimating purposes. Design details, including information on material types, material volumes, site layout, and constructability will need to be determined during the engineering design phase.

4.4 Conceptual Sketches

4.4.1 Option 1: Living Shoreline

This option includes recontouring the shoreline to eliminate existing groynes and erosion escarpments, and using a combination of beach nourishment and vegetation to control erosion and establish a living shoreline.

This is an example of a soft engineering approach. The existing shoreline planform, profile and condition varies so a combination of approaches (i.e. beach nourishment, vegetation and natural woody debris) provides flexibility in the design to suit specific site conditions for different areas of the shoreline. A conceptual sketch illustrating these concepts is shown in Figure 17 below.

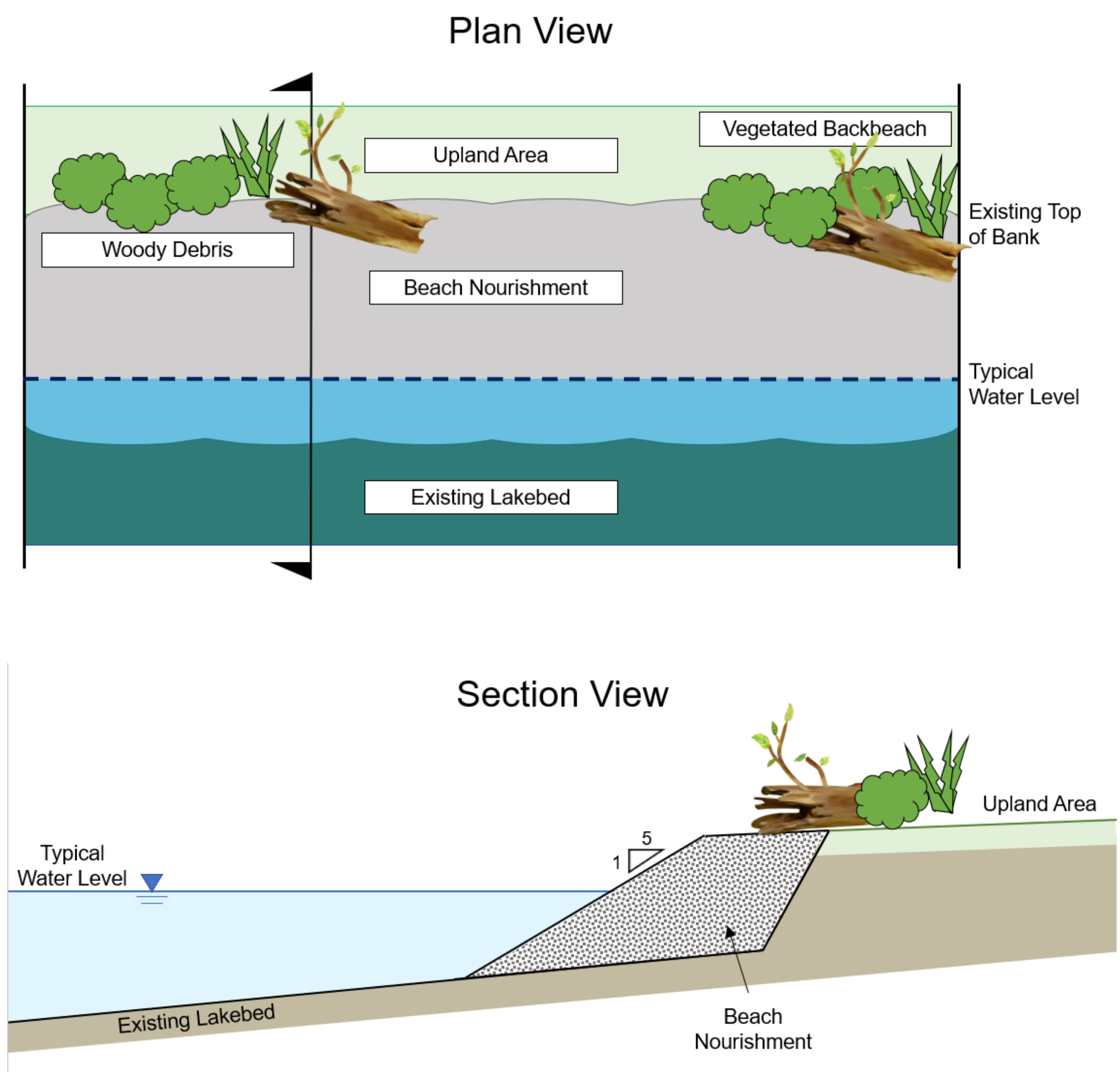

Figure 17: Option 1 Conceptual Sketch: Plan and Typical Section (not to scale)

4.4.2 Option 2: Log Wall Revetment

This option includes recontouring the shoreline to eliminate groynes and erosion escarpments, and constructing a log wall revetment and gravel beach to act as shoreline protection.

This is an example of a hard engineering approach, although on the softer side than other coastal structures. This approach would fix the shoreline in place to prevent future erosion, although the gravel beach would require maintenance and future nourishment. A conceptual sketch is shown in Figure 18 below.

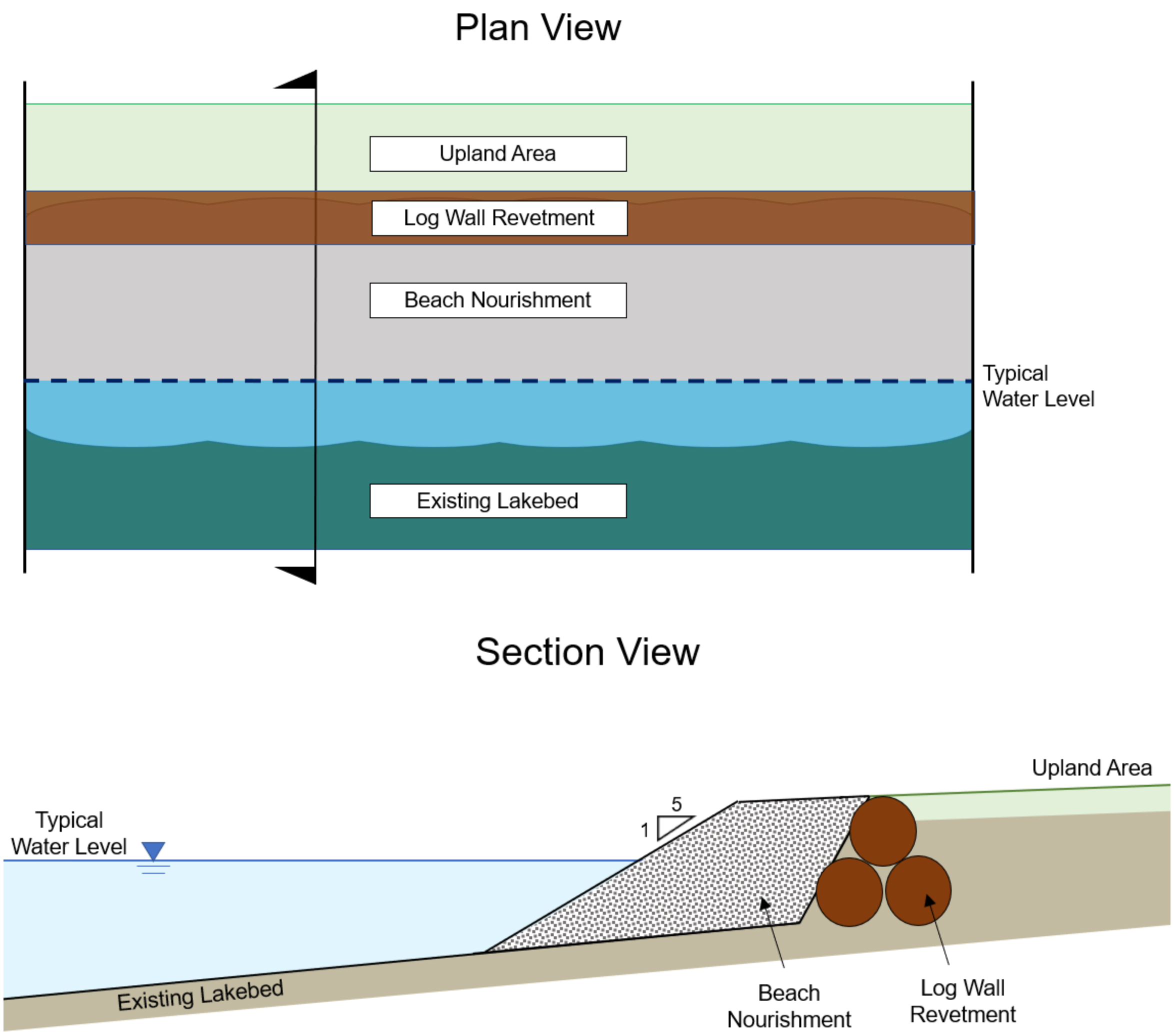

Figure 18: Option 2 Conceptual Sketch: Plan and Typical Section (not to scale)

4.4.3 Option 3: Hybrid approach

This option is a hybrid approach combining features of Option 1 and Option 2. The proposed approach includes combining beach nourishment with vegetated headlands and gently bayed beaches, with some larger cobble gravel to protect the vegetation, a transition to gravel and then sand beaches between the vegetated headlands.

This approach would help develop an asymmetric shoreline configuration with beaches perpendicular to the dominant wave direction, which would help reduce the effects of erosion and sediment transport. A conceptual sketch is shown in Figure 19.

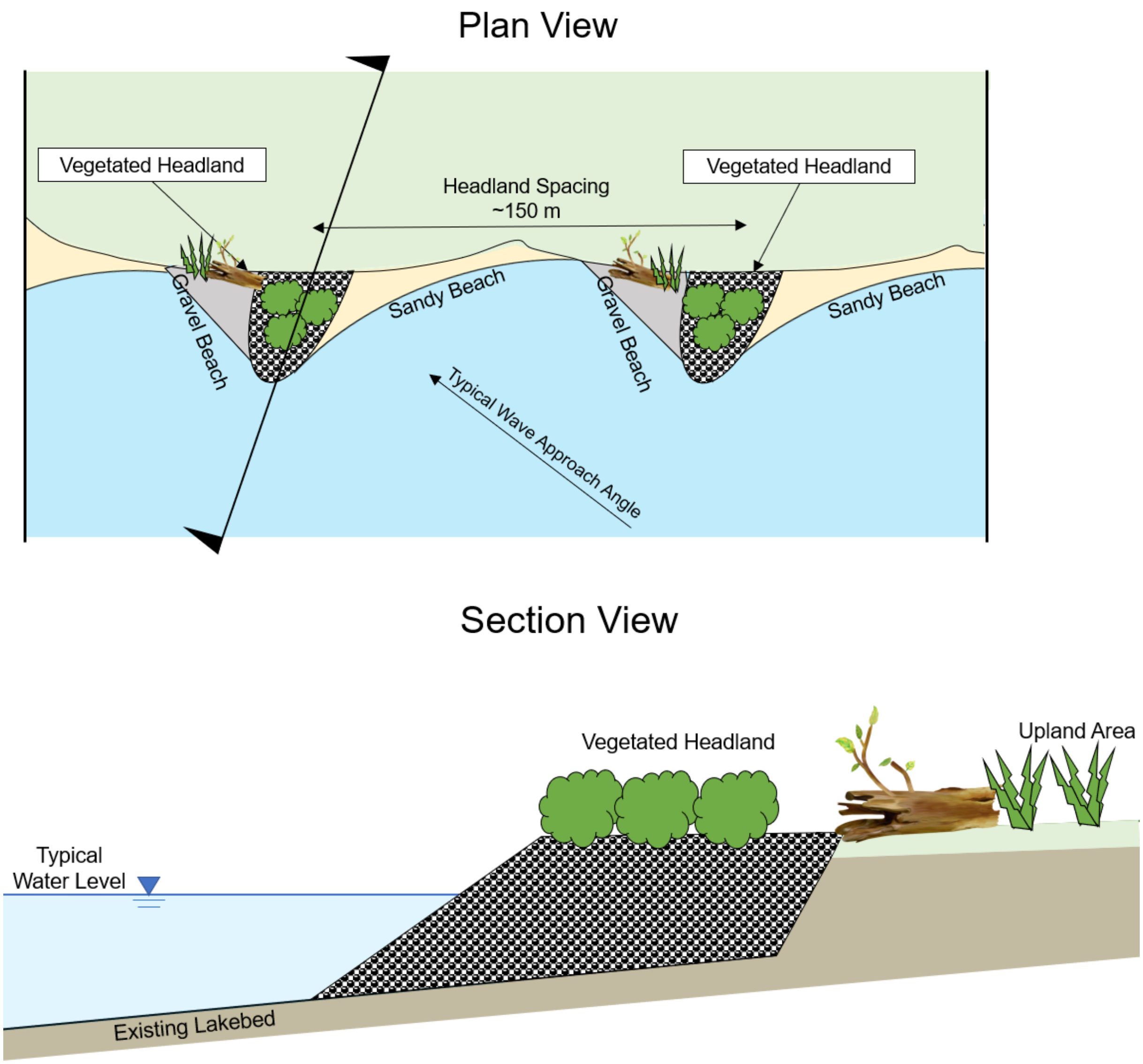

Figure 19: Option 3 Conceptual Sketch: Plan and Typical Section (not to scale)

4.5 Cost Estimates

Indicative construction cost estimates have been prepared to provide a means for comparing the relative capital cost of proposed options. These costs have been prepared with minimal design information and are for relative comparison purposes only. Estimated construction costs for Option 1, Option 2 and Option 3 are provided in Table 11, Table 12 and Table 13, respectively.

Material quantities have been estimated based on the conceptual sketches and an assumption to repair 1,000 m of shoreline; these numbers can be refined once designs are progressed further. More detailed cost estimates and construction planning can also be developed at that time.

Unit rates for construction materials and installation have been estimated based on Golder's knowledge of costs for similar marine construction projects in similar areas, and known construction access for the Project Site.

Table 10: Option 1 Cost Estimate Summary

Item #	Description	Qty	Unit	Unit Rate	Cost
1	Mob and demob	1	LS	$ 20,000.00	$ 20,000.00
2	Recontour shoreline	1000	m	$ 10.00	$ 10,000.00
3	Supply and place beach nourishment	1000	m^3	$ 75.00	$ 75,000.00
4	Supply and plant vegetation	500	m	$ 30.00	$ 15,000.00
	Contingency	*20*	*%*		*$ 24,000.00*
TOTAL (excluding GST)					**$ 144,000.00**

Table 11: Option 2 Cost Estimate Summary

Item #	Description	Qty	Unit	Unit Rate	Cost
1	Mob/Demob	1	LS	$ 20,000.00	$ 20,000.00
2	Recontour shoreline	1000	m	$ 10.00	$ 10,000.00
3	Install log wall revetment	1000	m	$ 150.00	$ 150,000.00
4	Supply and plant vegetation	1000	m	$ 90.00	$ 90,000.00
	Contingency	*20*	*%*		*$ 54,000.00*
TOTAL (excluding GST)					**$ 324,000.00**

Table 12: Option 3 Cost Estimate Summary

	Description	Qty	Unit	Unit Rate	Cost
1	Mob/Demob	1	LS	$ 30,000.00	$ 30,000.00
2	Recontour shoreline	1000	m	$ 10.00	$ 10,000.00
3	Construct headlands (riprap)	500	m^3	$ 125.00	$ 62,500.00
4	Supply and place sand	500	m^3	$ 75.00	$ 37,500.00
	Supply and place gravel	500	m^3	$ 90.00	$ 45,000.00
	Contingency	*20*	*%*		*$ 37,000.00*
TOTAL (excluding GST)					**$ 222,000.00**

4.6 Recommendations and Next Steps

Based on the proposed options and costs, Golder recommends taking forward one of these options for further consultation, design and permitting. The options presented cover a range of engineering techniques and each have varying capital costs, maintenance costs, and environmental benefits.

Given the location, aesthetics, and public use of the Project Site, it is recommended that the Cultus Lake Park Board take forward options to develop a nature-based geomorphological approach to shoreline restoration, as opposed to a hard engineered structural approach.

Golder understands construction along the shoreline of Cultus Lake will be a challenging task and recommends the following next steps for consideration:

1) Review the proposed approaches, options and costs with the Cultus Lake Park Board and other local stakeholders. Golder is able to help support this process if required.

2) Determine a preferred path forward and proceed to a preliminary design that can be used to obtain the required permits. Further design will require additional site data and analysis, including detailed bathymetry and topography, detailed analysis of wave conditions and sediment transport, and construction planning and support.

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5.0 CLOSURE

We trust this report meets your current requirements for the shoreline erosion assessment. If you have any questions or require additional clarification, please contact James Ogilvie at James_Ogilvie@Golder.com or 603-297-7332 or Phil Osborne at Phil_Osborne@Golder.com or 604-297-4601.

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