City of Oak Harbor Residential Bluff Conservancy

Policy and Regulation Review - Final
Project Number 20-011

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COASTAL GEOLOGIC SERVICES

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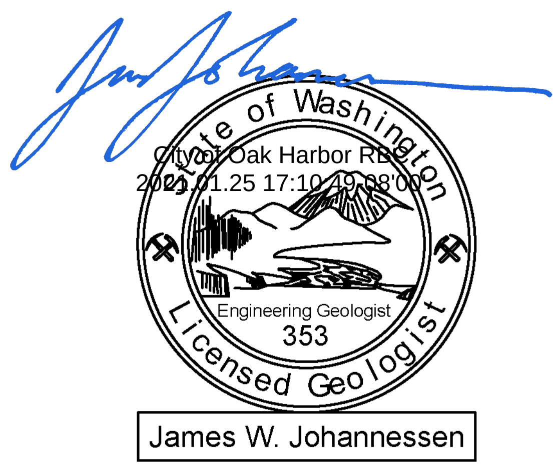

Introduction

The City of Oak Harbor's Shoreline Master Plan (SMP) designates seven shoreline environments for the shoreline within the city limits: Maritime, Residential, Residential Bluff Conservancy (RBC), Conservancy, Urban Mixed Use, Urban Public Facility, and Aquatic. The existing RBC boundaries encompass approximately two-dozen shoreline residential lots atop the northern end of Blowers Bluff on the east side of SW Scenic Heights Street, extending from Freund Marsh at the north end to Oak Harbor city limits at the south end (Figure 1). The stated purpose of the RBC as stated in the SMP is "to accommodate existing and future residential development on more suitable portions of lots that contain geologically hazardous slopes, while preserving the ecological functions of natural bluff areas and shorelines." In essence, the policies of the RBC may be viewed as a balancing act between the reasonable need for development and the imperative for ecosystem preservation, framed by the governing context of private property rights and public safety.

The purpose of the report is to provide recommendations for practical, efficient, and effective policy revisions to protect the City of Oak Harbor Residential Bluff Conservancy's economic and ecological resources into the future. This report describes existing site conditions and analysis critical to policy assessment including bluff recession, slope stability, waves, sea level rise, and hydrologic storm analysis. Additionally, this report summarizes existing shoreline and critical areas policies to determine their effectiveness in protecting and preserving the safety and ecology of the bluff system and private properties included within the RBC and inform our policy revision recommendations.

Existing Site Conditions

Geology and Bluff

The greater northwest Whidbey Island area is composed of a series of glacial and non-glacial units from multiple glacial ice sheet advances and interglacial periods in the Quaternary period (Easterbrook, 1992; Easterbrook et al., 1967). The surficial geology of the majority of the uplands and upper bluff elevations was mapped as Vashon glacial till (Qgtv) consisting of clay, silt, sand, and gravel in various proportions (known as a diamicton) (Figure 2). Till is locally known as "hardpan." The till was compacted under the full thickness of the Vashon Ice Sheet. This consolidated the till and it is typically dense to very dense in the RBC, and is able to withstand a high angle of repose for considerable lengths of time (GeoEnginners, 2014). Glaciomarine drift (Qdgmed) was mapped in the upland surface of the southern region of the RBC (at the southern 6-7 parcels) consisting of clay and clast rich diamicton.

Whidbey Formation (Qcwf) deposits were mapped over the majority of the mid and lower bluff elevations below Vashon till (Figure 2). The Whidbey Formation consists of fluvial floodplain facies deposits comprised mostly of fine-grained, interbedded sand and silt with minor gravel and coarse sand lenses (Dragovich et al., 2005). These deposits were consolidated beneath the Vashon Ice Sheet and can have relatively steep faces for extended periods of time.

Limited exposures in the northern third of the study area observed during the field reconnaissance revealed the bank crest appeared to be dense till and that the lower bank was dominated by dense silt and clay beds (Figure 3). Portions of the middle bank face were exposed which also contained dense silt and clay beds along with compacted sand. These were interpreted as Whidbey Formation deposits and confirmed previous mapping.

The general bluff height was measured at between 40 and 55 FT, with the bluff crest elevation scaled at approximately 50 to 65 FT in relation to the North American Vertical Datum of 1988 (NAVD88). The bluff face slope was measured at 50-82 degrees (from horizontal) on the upper approximately 40% of the bluff height and at 16-50 degrees on the lower bluff face where some amount of colluvium (slide debris) was present in the 2014 LiDAR mapping (Figure 4).

Moderate seepage was present throughout the northern half of the RBC bluff, where silt beds with lower permeability than the sandy deposits above direct water onto the bluff face as seepage. This was observed most commonly in the middle and lower portions of the bank face, with piping occurring over the dense silt beds. Seepage heights were measured at between 19 and 24 FT above the bluff toe using a laser rangefinder. Discrete areas of seepage were also observed in the central and southern portion of the RBC bluff. Field indicators included extensive horsetail and other hydrophilic (water loving) species on the mid and lower bluff face. Cattails were present at the bluff toe in a few locations.

The bluff along the site was mapped as “stable” in the southern half of the site and “unstable” in the northern half of the site in the Coastal Zone Atlas of Washington (Figure 5; WDOE, 1979). The unstable slope stability designation was applied to the majority of steep bluffs of Whidbey Island. Unstable slopes are considered unstable because of geology, groundwater, slope and/or erosional factors. They include areas of landslide and talus too small or obscure to be individually mapped.

Detailed landslide mapping has not been conducted at this site, however Johannessen and Chase (2005) mapped one landslide at the north end of the site. During our site visits we identified four locations of bluff exposure and minor sloughing (Figure 6).

The bluff at the site was mapped as a “feeder bluff”(Johannessen and Chase, 2005; MacLennan et al., 2013). This term refers to the bluff being a sediment source for the beach and beaches in the drift cell. The feeder bluff transitions into a transport zone for a few hundred feet just north of the RBC boundary. On these transport zone shorelines, beaches are backed by relatively stable bluffs with little active erosion. They do not contribute appreciable amounts of sediment to the littoral system. In front of Freund Marsh, directly north of the RBC boundary, the coastal landform was mapped as an accretion shoreform, which describes depositional beaches that have developed seaward of the original landform. Here it is characterized as a distinct ridge of sand and gravel with a wetland on its landward side.

Bluff Vegetation

Aerial photos taken at an oblique angle were reviewed from 1993, 2001, 2006, and 2016 (Photo Page 1). There does not appear to have been a drastic change in the bluff face character and bluff crest position along this shoreline since 1993. Vegetation density on the bluff face appears to have decreased between 1993 and 2001, which appears to be due to some amount of increased erosion and landslides, particularly in the north half of the RBC. However, this is also partially due to the season in which the photos were taken. A close-up example of the increased bluff face vegetation from the central reach is presented in Figure 6. The decrease in bluff face vegetation in 2001 was likely due to the widespread occurrence of shallow landslides in the region during the 1996-1997 New Year’s rain-on-snow event (Gerstel et al., 1997), combined with above average landslide occurrence in the following several winters. A modest amount of upper bluff face and crest recession appears to have occurred within the period from 1993-2001, based on slightly larger areas of the bluff exposed. These appear to have been caused by shallow, surficial landslides on the upper to middle elevations of the bluff. Photos from 2016, show that the bluff face was generally well vegetated, with approximately 80-90% vegetation cover with large trees growing on the low to mid bluff face.

During site visits to the RBC in 2020, the northern approximately 40% of the study area bluff face was almost exclusively covered by English ivy (*Hedera helix*) and Himalayan blackberry (*Rubus armeniacus*), which are Class C invasive weeds (Washington State Noxious Weed Control Board, 2020). Only a few trees were present in this reach including red alder (*Alnus rubra*), willow (*Salix* spp.), and bigleaf maple (*Acer macrophyllum*) mostly in the lower half of the bluff, with many growing sub-horizontally. Otherwise, the two invasive, exotic species were completely dominant.

The central portion of the study area bluff also had extensive English ivy and blackberry growing along with native alder and willow trees.

The southern extent of the RBC also had extensive invasive exotic species growing on the bluff face. This primarily consisted of the same two species – English ivy and Himalayan blackberry. Alder and willow trees were more present in the southern reach of the bluff compared to the central reach as well as snowberry (*Symphoricarpos albus*) and sword fern (*Polystichum munitum*).

Figure 7. Example of increased vegetation cover between 2001 (bottom) and 2006 (top) in the central reach of the RBC. Photos from the WA Department of Ecology Shoreline Viewer.

Beach and Backshore Area

The beach along the RBC is part of a long-term littoral sediment system transport system known as a net shore-drift cell. A net shore-drift cell represents a natural system with sediment input from feeder bluffs (and other sources) to a beach, transport alongshore with intermittent additional sediment input, and deposition in one or a number of accretion areas in the down-drift end of the drift cell where wave energy diminishes or some barrier limits the further littoral transport (MacLennan and Johannessen, 2007). The RBC is within net shore-drift cell ISWH011 (Figure 1; Coastal Geologic Services, 2017; Johannessen, 1992; MacLennan et al., 2013). This drift originates at Blowers Bluff, just south of Klootchman Rock, and extends all the way to the north shore of Oak Harbor, to near Smith Park where SE Bayshore Dr turns into Midway Blvd. Drift is generally to the northeast. As the majority of the bluff within the RBC is at least partially vegetated, feeder bluff reaches from outside (south) of the RBC boundary are considered to be the dominant sediment input for the beaches within the RBC.

Along the length of the study area the mid and lower intertidal portions of the beach face contained abundant boulder and cobble, along with pebble. Beneath this layer sand was mixed in. These coarse deposits appear to be mostly natural along with a likely small source of boulders and other sizes that were used as shore protection over the years. This type of boulder and cobble cover is termed natural beach armor and has resulted in what appears to be relatively slow beach erosion rates.

The upper beach above mean high water (MHW) was a mixture of pebble, sand and cobble. This is the most dynamic portion of the beach and likely changes daily or weekly in surface sediment composition. The sandy area was much narrower or non-existent in parts of the south end of the study area beach.

A drift log zone was present through almost the entire study area where shore armor was not present. The log zone width varied depending on the backshore width but was generally 5-15 FT wide during the few site visits.

Shore Armor

Shore armor, also called bulkheads, rockery walls, seawalls etc., were present along 53% (approx. 1,250 FT) of the project site. By comparison, only 33% of the net shore-drift cell containing the RBC is armored (Coastal Geologic Services, 2017). Most of these structures appeared to be old, consisting mostly of rockery walls (steep, carefully placed stacked rock) along with a smaller number of vertical wood (soldier) pile walls.

Several long reaches of wood pile walls were located in the south-central portion of the study area (Photo Page 1). Further north, shorter reaches of wood pile walls were present. These pile walls all showed considerable rot and deterioration, with several leaning waterward with substantial structural impairment.

Many of these shore armor structures protruded a significant distance waterward of the bank toe. Some of these extended beyond mean higher high water and had either built platforms or colluvium (landslide debris) collected atop them. A maximum distance from wall face to adjacent unarmored bluff was measured at 26 FT in the south-central portion of the study area. Some functioned as very small groins causing a partial interruption of littoral transport/net shore-drift. One structure in the study area also contained a large log anchored across the beach acting as a groin. This was causing a moderate amount of shore offset.

Seismic Hazard

The Pacific Northwest is seismically active and there is potential for large, sustained earthquakes of magnitude 9.0 or greater in the entire Puget Sound region. The behavior of steep coastal bluff soils during large seismic events is difficult to predict, perhaps even more so than for comparably steep inland slopes. Several potentially significant faults are found in the northern Puget Lowland and eastern Strait of Juan de Fuca region (Gower et al., 1985). These include the Southern Whidbey Island Fault, the Devils Mountain Fault, and associated structures (Gower et al., 1985; Johnson et al., 1996) as well as the more recently identified Oak Harbor Fault (Dragovich et al., 2005). The Oak Harbor Fault crosses the shoreline just north of the northern boundary of the RBC through Freund Marsh (Figure 2). This fault was presented as a "possible Pleistocene active structure" by Dragovich et al. (2005) and is considered a possible Pleistocene active structure (GeoEnginners, 2014).

The Utsalady Point fault No. 1 is mapped approximately 2 miles north of the northern boundary of the RBC. The Utsalady Point fault is a north-trending subvertical fault that cuts across Whidbey Island and has a slip rate category of less than 0.2 millimeters/year (Dragovich et al., 2005). Studies suggest that the most recent surface-deforming earthquake on this fault occurred less than 500 years ago. This represents a potential seismic hazard to residents of Puget Lowlands as studies have suggested that magnitude 6.0 or greater earthquakes have occurred and may have produced tsunamis (Johnson et al., 2004).

The project site is also located approximately 8 miles north of the South Whidbey Island Fault (SWIF), where it crosses to the west of Keystone (Johnson et al., 1996). The SWIF Zone is an approximately 4-mile wide, complex system of varied faults running roughly southeast to northwest from the Darrington-Devils Mountain fault zone in the Cascade Mountains to the Strait of Juan de Fuca and southeast Vancouver Island. Proximity to the fault zone or the individual faults within it bears a risk of larger and more frequent seismic events.

The Liquefaction Susceptibility Map of Island County (Palmer, 2010) classifies the project site and surrounding area as 'Very Low' liquefaction susceptibility.

Seismic loading generally causes greater disturbance to loose, saturated, sandy soils compared to fine-grained, cohesive soils above the water table. Much of the RBC region has heavily compacted glacial till at the surface and relatively thick deposits of partially compacted Whidbey Formation deposits present in the remainder of the bluff height. Unless the till soils are disturbed by major development activities, they should be expected to provide above-average support during seismic loading compared to many other near-surface soil units in the area. Whidbey Formation deposits are not as loose or weak as other common deposits in the mid and lower bluff elevations around Whidbey Island, such as the Vashon advance outwash sand and gravel. There is still a clear risk of small or large earthquake-induced landslides in the RBC, but the soils should not be considered especially susceptible to failures from seismic activity in general.

Geologic & Engineering Analysis

Fetch and Wave Energy Assessment

The RBC's shoreline has a maximum fetch of 10.95 miles at the most northern parcel and 7.23 miles at the most southern parcels, from the southeast (Coastal Geologic Services, 2017). This moderate fetch environment, in Puget Sound terms, means that the wave environment at the site can be moderate if a wind event occurs from the southeast. However, the geography of Oak Harbor limits wave energy from most directions.

Local mean higher high water (MHHW) and the highest astronomical tide (HAT) elevations provide useful estimates of current higher water levels expected at the property due to tides (Table 1). Storm surge and waves further increase water levels causing greater potential inundation above tides, presented in Table 1. The storm surge and wave height data come from two recent studies from the Pacific Northwest National Laboratory (PNNL) (Yang et al., 2020, 2019).

Table 1. Local water levels and model estimates of flood and storm conditions.

Water Level	FT Above MLLW
MHHW	11.5
HAT	13.4
Condition	**Height (FT)**
Storm Surge	2.7
Wave Height (Hs)	1.3

Sea Level Rise Assessment

In 2018, the Washington Coastal Resilience Project (WCRP) published updated projections of relative SLR which incorporates absolute sea level rise (SLR) and vertical land movement (uplift and subsidence) for Washington State (Miller et al., 2018). For this analysis we assessed two scenarios based on the high greenhouse gas scenario RCP 8.5 for 2050 and 2100 (Table 2). We assessed the 50% and 1% probability of exceedance, or the percent chance that absolute sea level will rise by at least that amount.

Table 2. Sea level rise scenarios and local projected magnitudes (Miller et al. 2018) assessed in this report.

Scenario	Sea Level Rise (FT)
2050 RCP 8.5 50%	0.8
2050 RCP 8.5 1%	1.4
2100 RCP 8.5 50%	2.2
2100 RCP 8.5 1%	5.0

To assess SLR at this project site we combined current conditions and SLR predictions to estimate water levels for 2050 and 2100 (Tables 3, 4). Combining MHHW with SLR gives a good estimate of the average future high tides at the property, whereas HAT plus SLR estimates the highest water levels of a multi-decade period due to tides alone. Lastly, we combined MHHW with storm conditions and SLR as a worst-case scenario to characterize future storm conditions possible at the shoreline.

Table 3. Predicted water levels by 2050 and 2100 for RCP 8.5 50% probability scenario.

2050	FT Above MLLW
MHHW + SLR	12.3
HAT + SLR	14.2
MHHW + Storm Surge + Hs + SLR	16.3
2100	
MHHW + SLR	13.7
HAT + SLR	15.6
MHHW + Storm Surge + Hs + SLR	17.7

Table 4. Predicted water levels by 2050 and 2100 for RCP 8.5 1% probability scenario.

2050	FT Above MLLW
MHHW + SLR	12.9
HAT + SLR	14.8
MHHW + Storm Surge + Hs + SLR	16.9
2100	
MHHW + SLR	16.5
HAT + SLR	18.4
MHHW + Storm Surge + Hs + SLR	20.5

Plots of these projected SLR results are in Figure 7. Current and future HAT, MHHW, and storm surge with wave projections are compared to the bluff toe elevation as a reference, displaying waver levels as a function of time.

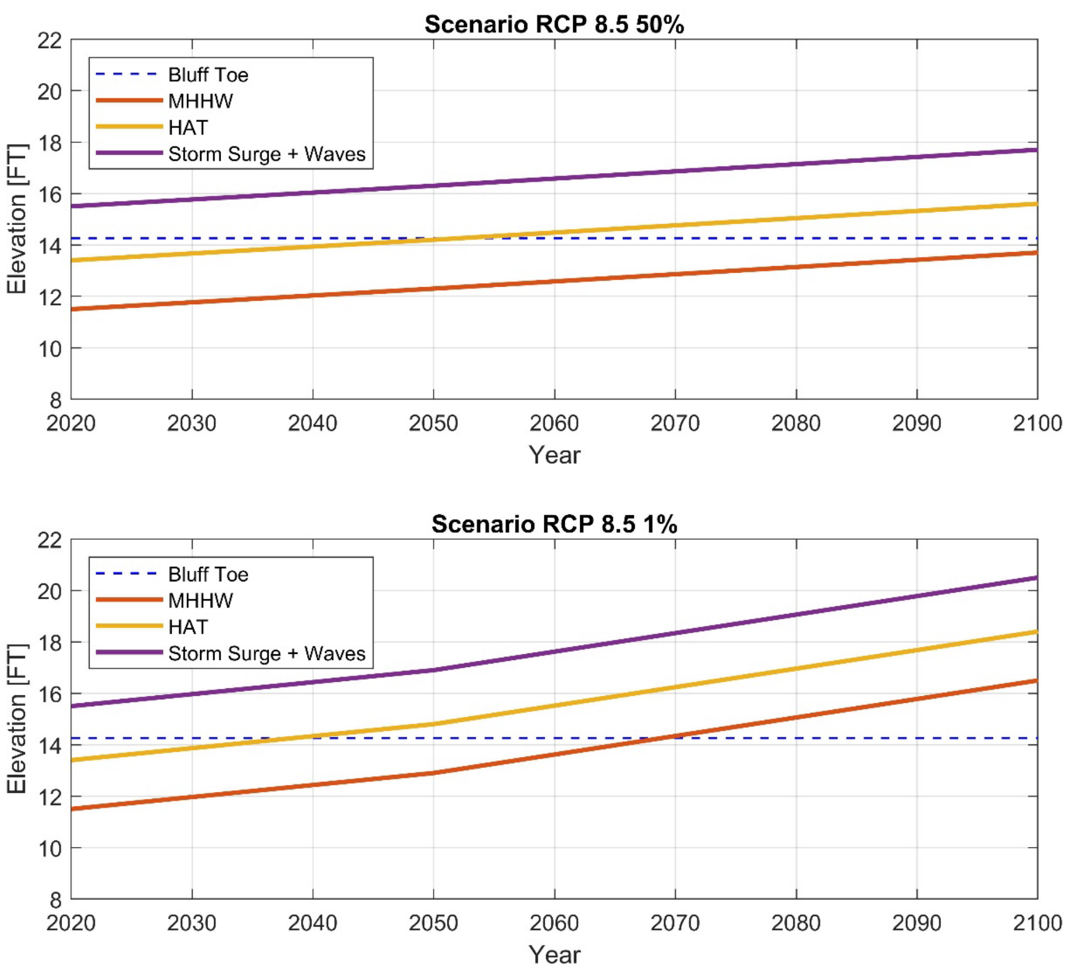

Figure 8. Current and future MHHW, HAT, and MHHW plus storm surge and wave elevation through time compared to the approximate elevation of the bluff toe (14.3 FT MLLW). Top plot incorporated RCP 8.5 50% probability prediction while the bottom incorporates RCP 8.5 1%. Elevations are relative to MLLW.

In unarmored locations, rising seas will cause landward migration of the shoreline. This will enable coastal ecosystems to endure storms, erosion, and rising seas by proving space to migrate landward. However, along the armored stretches at the project site (~50%), the back of the beach will remain fixed preventing it from migrating inland as sea levels rise. This will cause the beach to become submerged more often and will gradually narrow until it no longer exists (Griggs, 2005; Melius and Caldwell, 2015).

As water and wave energy will be able to reach these armored shores more frequently with SLR, wave energy will more regularly interact with the armored structures at the project site. Wave energy reflected off shoreline armoring structures undercuts the beach and could hasten coastal erosion directly in front of the structure in addition to neighboring properties. At the margins of the sea walls, wave action diffraction around the edges especially during high tides and storms has the potential to increase erosion, which is referred to as “end effects” (Melius and Caldwell, 2015).

Bluff Recession Rates

Long-term bluff recession rates were compiled and analyzed by CGS as part of a recent project for the Estuary and Salmon Restoration Program (ESRP) (Coastal Geologic Services, 2018). The bluff recession rate dataset includes 185 long-term bluff recession rates from throughout the region that were measured across several decades; ranging from 23 to 101 years. Recession rates were measured using two different approaches: historical air photo analysis in GIS and field-based measurements from government survey monuments to the bluff crest or toe. Several bluff recession rate measurement sites in this database are located in the vicinity of the RBC including two along Maylor Point and one on the northern shore of Penn Cove (Figure 9). These rates varied between -0.2 and -0.49 feet per year (FT/YR), with an average of -0.31 FT/YR. Likely these locations experience slightly higher rates of bluff recession than the RBC as they are more exposed to wave energy.

This annualized recession rate represents an average rate of change across a long period of time. In most cases in the region, erosion occurs episodically in change events that typically consist of landslides following heavy precipitation or a windstorm that coincides with a high water event with significant toe erosion. Large events that cause considerable bluff recession occur infrequently and are often followed by long periods of stability. In addition, these erosion rates may overestimate actual erosion rates due to the measurement methods applied.

Additionally, we compared aerial imagery from 1957 to 2019 to calculate erosion rates of the bluff along the RBC using the United States Geologic Survey’s Digital Shoreline Analysis (DSAS) Tool in ArcGIS (Figure 10). Erosion rates were calculated at 50-meter intervals, with a total of 12 measurements. To help determine the bluff crest location, we utilized hillshade and slope layers derived from the 2014 Island County LiDAR. Bluff crest recession rates ranged from 0.0 to -0.43 FT/YR with an average of -0.16 FT/YR. Erosion rates were greatest towards the south end of the RBC where the bluff contained moderately more-sandy deposits. Based on our best professional judgement, the average bluff recession rate was -0.16 FT/YR. We used this rate to project the bluff crest locations for 2050 and 2100 (Figure 11).

Future Bluff Recession Rate Estimates

Accelerated bluff recession rates were calculated using an equation well-cited in peer reviewed literature. Research conducted by Ashton et al. (2011) and Walkden and Hall (2011) documented a strong relationship between SLR rate and bluff recession rate (Ashton et al., 2011; Walkden and Hall, 2011). This equation was used to predict future erosion based on future rates of SLR.

Equation 1: $$Future\ Erosion\ Rate = Current\ Erosion\ Rate * \sqrt{\left(\frac{Future\ SLR\ Rate}{Prior\ SLR\ Rate}\right)}$$

Best estimates of current and future SLR rates from Miller et al. (2018) were used to calculate accelerated erosion rates for each SLR scenario. The current SLR rate is from the Port Townsend NOAA tide station. Current and future SLR rates for 2050 and 2100 using the 50% and 1% exceedance rates are in Table 5. Final estimated erosion rates for each planning horizon using Equation 1 are in Table 6.

As with any predictive model, error associated with each variable incorporated into the model calculations can be compounded or magnified in the final outputs.

Table 5. Current and future sea level rise rates based on NOAA tide gauge data and Miller et al. (2018).

SLR Rates (projection/ #years)	Current Rate (mm/yr)	2050 (mm/yr)	2100 (mm/yr)
Moderate Scenario Rate RCP 8.5 50%	--	6.1	7.5
High Scenario Rate RCP 8.5 1%	--	10.7	17.0
NOAA Port Townsend	1.86	--	--

Table 6. Current and future erosion rates using Equation 1.

Erosion Rates	Current Rate (FT/YR)	2050 (FT/YR)	2100 (FT/YR)
Moderate Scenario Rate RCP 8.5 50%	--	0.36	0.40
High Scenario Rate RCP 8.5 1%	--	0.48	0.60
Oak Harbor RBC Historic	0.16	--	--

Erosion rates resulting from shore change analysis and SLR rates were used to calculate accelerated erosion rates and measured bluff recession distances for each SLR scenario and planning horizon. SLR rates were calculated at 10-year intervals by applying a linear assumption from the results in Table 6. Table 7 displays the decadal iterations of bluff recession for both the moderate and high SLR scenarios. It also displays the final estimated bluff recession predicted by each scenario out to 100 years, or 2120.

Table 7. Current and future erosion rates and total lateral erosion for 2020 to 2120 using a linear assumption with the moderate and high scenario values from Table 5.

Years	Moderate Scenario Erosion Rate (FT/YR)	Lateral Erosion (FT)	High Scenario Erosion Rate (FT/YR)	Lateral Erosion (FT)
2020-2030	0.28	2.82	0.31	3.08
2030-2040	0.31	3.10	0.36	3.60
2040-2050	0.34	3.38	0.41	4.12
2050-2060	0.37	3.66	0.46	4.64
2060-2070	0.39	3.94	0.52	5.16
2070-2080	0.42	4.22	0.57	5.68
2080-2090	0.45	4.50	0.62	6.20
2090-2100	0.48	4.78	0.67	6.72
2100-2110	0.51	5.06	0.72	7.24
2110-2120	0.53	5.34	0.78	7.76
Total Lateral Recession (FT)	**--**	**40.48**	**--**	**54.20**

Based on this analysis, by the year 2100 the lateral recession of the bluff will amount to approximately 30 FT for the moderate scenario and 39 FT for the high scenario. Forecasting a full century to 2120, the total lateral recession is estimated at approximately 40.5 FT for the moderate scenario and 54 FT for the high scenario (Table 7). Alternatively, estimating shoreline retreat using the Bruun Rule (another shoreline retreat model) yields similar, relatively smaller estimated magnitudes of recession (Bruun, 1962). Using a simplified Bruun Rule, with 5 FT of SLR and an average beach slope of 0.125, the recession due to SLR is estimated at 40 FT. By adding this to the background rate of 0.16 FT/YR, the total lateral recession equates to approximately 53 FT by 2100.

Watershed and Drainage Assessment

The RBC has a primary watershed that extends approximately 0.95 miles west of the bluff (shown in Figure 12, using mapping from Island County). The watershed extends only approximately 0.5 miles north to south, generally from SW 24th Ave. to W Waterloo Rd. This main watershed drains into the center of the RBC and is further discussed relative to drainage improvements immediately below.

The northern portion of the RBC is part of a very small coastal watershed that extends only approximately three rows of properties inland from the bluff. The southern end of the RBC is also part of a small coastal watershed without a clear channel or valley (Figure 12).

In 2006 the City of Oak Harbor identified that approximately 172.3 acres of main watershed contributed to the existing Scenic Heights drainage outfall located in the central reach of the RBC (Tetra Tech, 2006). This outfall was identified as a maintenance and erosion problem by the City of Oak Harbor and was subsequently replaced. We believe (though are not certain) that replacement efforts consisted of:

- Realigning 52 LF of existing 14-inch Polyvinyl Chloride (PVC) pipe
- Installation of 250 LF of 15-inch Corrugated Polyethylene (CPEP) pipe
- 204 LF of 18-inch High Density Polyethylene (HDPE) SDR 26 pipe
- 2 Type-1 catch basins
- 48-inch diameter Type-2 catch basin
- Structural anchor block (Type 'B')
- Bluff pillow
- Vertical bend and 18-inch HDPE diffuser tee

Davido Consulting Group, Inc. designed the replacement outfall system and modeled conditions for the 100-year 24-hour event, which equates to 2.7 inches and a peak flow of 10.92 cubic feet per second (cfs) (Davido Consulting Group, Inc., 2018). The contributing drainage area was modeled with Win-TR-55, a modeling software program developed by the United States Department of Agriculture (USDA). The major inputs to the model include contributing basin area, land coverage, soil group, and time of concentration. For more details on inputs see Davido Consulting Group, Inc. (2018).

Model results showed that the 18-inch HDPE outfall pipe would provide a flow capacity of 24.36 cfs, approximately 2.23 times the 100-year flow rate of the contributing basin. A summary of the outfall system pipe capacities is summarized below at the 100-year flow rate:

- 100YR = 10.92 cfs
- 15" CPEP @ 8.05% = 59%
- 15" CPEP @ 10.07% = 45% capacity

- 18” HSPE @ 8.42% = 45% capacity
- 18” HSPE @ down bluff

Based on their results, the system would reach slightly over half capacity for the 100-year flow scenario. Davido Consulting Group, Inc. (2018) also modeled the outfall system a second time with a basin that was 40% impervious in order to model a full buildout (development) scenario condition for the drainage basin. Under the 100-year flow event, a larger outfall system was necessary including 24-inch HDPE, which reached up to 79% capacity for certain segments of the outfall system. Field reconnaissance revealed that the system was conveying water under SW Scenic Heights St. and that there was no water flowing over the ground in the bottom of the valley in the Hillside area. Flow was observed at the base of the large drainage tightline in this area above the beach.

Geologic and Coastal Processes Summary

The Oak Harbor RBC constitutes 22 parcels with just over 2,300 FT of east-facing waterfront on Oak Harbor. The entire reach has a bluff elevation of approximately 38 to 50 FT (relative to MLLW). The bluff is subject to moderate energy in Puget Sound terms and appears to have correspondingly moderate to low bluff recession rates.

The marine bluff within the RBC is composed of erodible deposits subjected to wave attack and the influences of surface and ground water. From a geologic perspective the till and dominant Whidbey formation deposits are somewhat compacted and erode less easily than loose deposits such as Vashon advance outwash deposits, as outlined in the *Geology and Bluff* section above. The advance outwash sequence is dominated by coarse sand and is prevalent in many areas of the west and south shore of Whidbey Island. Deposits in the RBC are not as easily eroded as this advance outwash.

The composition of the bluff crest (glacial till) makes it fairly resistant to erosion and typically not subjected to deep-seated landslides. It is also because of the dense and relatively high strength of the glacial till here that results in the very steep slopes.

Overall, there is a moderate amount of seepage present in the mid bluff elevations in many parts of the study area. Seepage is minor in other parts. Seepage results in a slightly higher occurrence of bluff landslides. The RBC contains several larger bluff drainage lines, termed tightlines. There are also a significant number of small drainage tightlines from residential properties. The excessive vegetation and shore armor structures made identification of many of these tightlines incomplete.

Watershed characteristics landward of the RBC were outlined in the *Watershed and Drainage Assessment* section above. Much of the surface water flow from impervious surfaces and roadside ditches upslope of the RBC bluff appears to be already collected and conveyed. Several new developments are underway which will also have surface water drainage control systems put in place. Overall drainage collection from larger developments is strongly recommended. It is sufficient at single family residential development to rely on upland water dispersal along with vegetation maintenance or establishment, or through the use of existing or replaced bluff tightlines.

Bluff face vegetation is dominated by invasive exotic species in the RBC, particularly the north half. Deciduous tree species including red alder and willow are fairly common in the southern half of the reach. The exotic species present have no useful erosion control properties while the deciduous trees present have a small erosion control benefit. The bluff is too steep overall and not stable enough for more beneficial erosion control species in general.

Bluff crest vegetation is limited to lawn and small ornamental plants in almost all locations in the RBC. The general absence of shrubs and trees, augmented with ground covers, that are beneficial for erosion control above the bluff crest does contribute a small amount to slope stability problems, however this is not a driving force of processes in the study area.

Bluff Recession Rates for the RBC

Past recession rates for the bluff crest at the RBC were measured at 0 FT/YR - 0.43 FT/YR as documented above. This historical rate can be put into context for the Island County region. Bluff recession rates here have ranged from very minimal from approximately 0.1 FT/YR to an extreme high amount of 1.05 FT/YR just north of Fort Ebey (Coastal Geologic Services, 2018; Keuler, 1988), the westernmost point exposed to the Strait of Juan de Fuca with a rapidly receding beach and bluff.

Wave attack at the toe of the bluff is one of the long-term drivers of both toe erosion and eventually bluff face landslides and bluff recession. However, with waves approaching at a highly oblique angle and the presence of a very broad low tide terrace/sand flat causes wave energy to be moderate and not excessive. The current unarmored bluff recession rate was estimated to be 0.2 FT/YR or less. Based on our analysis of SLR at the RBC, bluff toe erosion will likely accelerate in the future.

Using an average bluff recession rate of 0.16 FT/YR, projected bluff crest locations were mapped for 2050 and 2100 including the estimated impacts of SLR (Figure 11). By 2050 the bluff crest could move east and landward by approximately 30 FT to 39 FT by 2100. These are preliminary estimates using a worst-case idealized scenario and can be revisited if desired. The real-life behavior of the bluff crest will be much less uniform, with areas of more- and less-pronounced erosion.

Sea Level Rise and Climate Change Impacts

Global sea levels are projected to increase at an accelerating rate through this century (IPCC, 2014). Additionally, the region appears to be experiencing an increase in intense precipitation events and winter storm wind and storm wave intensity (The Nature Conservancy and the Climate Impacts Group, 2016). All of these factors will cause an increase in the bluff toe erosion rate and overall recession rate, and possibly with slightly increased rate of landslide events triggered by heavy or prolonged precipitation as well. Overall, the sea level and wave impacts will be the most important.

Current and future water level estimates were developed for this project site using a variety of scenarios and the best available science. Current water levels assessment show that tidal flooding alone does not reach the bluff toe, but in combination with storm surge and waves, this does occur and has caused limited bluff toe erosion. By 2070 in the more conservative emissions scenario (RCP 8.5), MHHW will intersect with the current average bluff toe elevation. Projecting out to 2100, MHHW is predicted to rise to approximately 2 FT above the bluff toe. Coupled with storm surge and waves, water levels are estimated to reach well above the current bluff toe in both scenarios.

Bear in mind that the mid probability (50%) SLR projection by Miller et al. (2018) may be exceeded, and these projections are subject to change. In fact, most previous projections have been exceeded to date. In particular, the consequences of accelerated melting of ice sheets in Antarctica and Greenland have increased in recent years. To put the best available science projections presented above in perspective, the State of California is guided by SLR projections ranging between 3 and 7 FT for the year 2100. Other projections vary a lot, and generally range up to 2 m (6.6 FT; Sweet et al., 2017) by 2100.

With projected SLR, the beach profile and bluff toe elevation and configuration are expected to transgress landward, meaning these forms will move landward as they shift upwards at the same time (Bray and Hooke, 1997). Along unarmored shores, the response is generally a self-regulating process, as additional (eroded) sediment from the backshore or bluffs allows for down-drift shores to become higher and move landward, thereby maintaining the beach profile.

Shore armor along this RBC will likely be less effective at preventing erosion with SLR, and structures will likely incur damage due to increased water depths and greater wave energy and runup. As a result, allowing bank natural recession is the ecologically preferred course of action when possible. This may require houses to be moved landward or more commonly, when redevelopment occurs, the house be constructed in a more landward position. This approach is commonly referred to as “managed retreat” (Cooper, 2003).

As explained in this section there are a wide variety of factors that influence bluff recession. No single factor drives this process by itself and no single management approach is sufficient for preventing excessive erosion or bluff recession. Existing policy relative to this topic is outlined below along with recommendations for improvement relative to these physical processes and resources.

Past Work & Data Gaps

CGS completed a review of relevant data and documents prior to and after the field visit. Documents reviewed are compiled in Table 10 (attached).

Policy Discussion & Recommendations

Existing Policy Review

The existing Oak Harbor Shoreline Master Program (SMP) and the Oak Harbor Municipal Code (MC) were reviewed in detail for potential deficiencies and areas where improvements could be made in terms of benefiting slope stability in the RBC. At the direction of the City, protecting bluff safety, bluff ecology, and protecting private property rights were all held under consideration while identifying potential regulatory deficiencies and developing recommendations. Tables 8 and 9 contain specific references to key code numbers and existing language that are the subject of suggested revisions. Key elements and reasoning behind these recommended policy revisions are outlined in the third column. The tables also contain columns that briefly summarize the anticipated burden of implementing recommendations with respect to cost, enforcement practicality, and regulatory burden. Regulatory burden is broken down into anticipated burden for homeowners, consultants, and developers. Finally, the relative priority of each of these recommendations is characterized as low, moderate, high, and highest in the last column in these two tables. The tables are detailed and are designed to stand alone from this report.

Policy and Regulatory Priorities

Building and improvement setback is the most effective means of preserving natural processes and safe use of upland properties above an unstable bluff. These bluffs are inherently unstable and are subjected to forces of wave attack at the toe along with deep groundwater that cannot effectively be removed from bluff soils. Therefore, avoidance of developing the area nearest the bluff slopes is the most effective management measure. Minimum setbacks for building and other infrastructure siting controls the development of the properties and influences all other elements of property development and management. Maintaining adequate setback distances also allows for avoidance of costly construction and maintenance of engineered structures and drainage conveyance systems.

Drainage management is generally of moderate importance and is particularly important where legacy building setbacks are low and where natural low areas collect drainage or extensive vegetation clearing has occurred. Drainage management will avoid exacerbating bluff instability and prevent point discharge sources from causing surface erosion and landslides.

An important part of drainage management is to ensure that all drainage systems near the bluffs or tightline pipes running over the bluff edge are installed with sufficiently engineered designs and durable construction materials and installation methods. Many older drainage systems in the RBC and elsewhere in the region are composed of single-wall, corrugated 4-inch or larger diameter pipe. This material is subject to failures from a wide variety of causes including: ultraviolet damage, debris breaking the pipes, abrasion against bluff face, irregular installation and water freezing, and landslides. This type of pipe material should be avoided whenever possible and is never recommended by engineers for these applications. The advice of a civil engineer or geotechnical engineer specializing in drainage management is recommended for drainage system design in order to avoid flaws in drainage system design that could lead to failure. Alternatively, the City could provide detailed minimum standards for drainage system installation. However, it may be difficult to make such minimum standards applicable for the diversity of properties within the SMP jurisdiction.

Vegetation management is important for bluff stability in the RBC. However, vegetation is more critical for bluff stability at sites where Vashon advance outwash deposits are common. As the bluff in the RBC contains dense to moderate density bluff deposits, vegetation is not as critical within this site as it may be on other unstable bluffs on Whidbey Island and elsewhere. As such, with respect to policy recommendations for the Oak Harbor SMP and Oak Harbor Municipal Code, vegetation management and enhancement are generally designated as lower priority than setbacks and drainage management.

Table 8. Summary table detailing existing code contained in the Oak Harbor Shoreline Master Program (SMP) for which revisions or reconsiderations are recommended. Anticipated regulatory burden and cost-benefit analyses are also briefly described herein for each recommended revision.

Anticipated Burden key: AC = Anticipated Costs; EP = Enforcement Practicality; RB = Regulatory Burden for:; H = Homeowners; C = Consultants; D = Developers

City of Oak Harbor – Shoreline Master Program				
Code	Existing Language	Suggested Revision(s)	Anticipated Burden	Priority
2.B.4.d.2	[…] development should be sited to avoid the potential for slope erosion and failure over the useable life of the structure, and designed to prevent bluff erosion, including adequate provisions for stormwater.	Specify planning horizon for "usable life of the structure" for consistency, consideration of future conditions of erosion with sea level rise. Specify requirement: place development in a location that avoids need for future shoreline stabilization over the usable life of the structure, as these structures are expected to be less effective and more damaging to nearshore processes with anticipated sea level rise and potential increased storminess. Specify requirement for drainage management design and implementation by a qualified engineering professional. In association with steep marine slopes, drainage conveyance systems should be maintained in good repair, and should be constructed of materials of sufficient quality to avoid failure under normal environmental stressors (erosion/slope failure, freezing, etc.). <u>Example: Island County SMP –</u> 17.05A.090.A.5: *Surface drainage systems or substantial earth modifications shall be professionally designed to prevent maintenance problems or adverse impacts on shoreline features.* 17.05A.090.E.5: *The proposed structure will not require shoreline stabilization for the life of the single-family residence, typically 100 years.*	*AC:* Moderate *EP:* High *RB-H:* Moderate *RB-C:* Moderate *RB-D:* Moderate-High	High
2.B.4.d.3	Upland development should be located, sited, and designed to avoid clearing of vegetation or other alterations of steep slopes and buffer areas. Pruning of vegetation in accordance with accepted arboricultural standards to maintain and enhance views should be allowed. Trees should not be topped. Enhancement of shoreline bluff areas with native vegetation to prevent shoreline erosion should be encouraged.	Augment vegetation management criteria to prioritize/promote practices that preserve existing vegetation in accordance with ecological and critical areas objectives (most effective approach). Encourage or require replacement of vegetation when cleared. Consider conditioning approval of new upland development or redevelopment of existing structures on vegetation maintenance and/or mitigation for anticipated vegetation clearing. <u>Example: Island County SMP –</u> 17.05A.090.A.5: *Land clearing, grading, filling, or alteration of natural drainage features and landforms shall be limited to the minimum necessary for development. Surfaces cleared of vegetation and not developed shall be replanted and maintained in perpetuity. Surface drainage systems or substantial earth modifications shall be professionally designed to prevent maintenance problems or adverse impacts on shoreline features.* 17.05A.090.K: *Shoreline vegetation conservation* *2. Removal of native vegetation shall be avoided, where feasible. Where removal of native vegetation cannot be avoided, it shall be minimized to protect ecological functions. If non-native vegetation is to be removed, then it shall be replaced with native vegetation within the shoreline jurisdiction.*	*AC: Low*-Moderate *EP:* Low-Moderate *RB-H:* Low-Moderate *RB-C:* Low-Moderate *RB-D:* Low-Moderate	Low-Moderate

City of Oak Harbor – Shoreline Master Program				
Code	Existing Language	Suggested Revision(s)	Anticipated Burden	Priority
		3. Native plant materials that are equivalent to those which would typically occur with respect to size, structure, and diversity at maturation shall be used in restoration, rehabilitation, or enhancement projects. *5. Proponents of all new shoreline uses or developments shall demonstrate that site designs and layouts are consistent with the policies of this section to ensure shoreline functions, values, and processes are maintained and preserved. A shoreline permit or written statement of exemption shall not mandate, nor guarantee, unobstructed horizontal or lateral visibility of the water, shoreline, or any specific feature near or far.* *8. The Shoreline Administrator may deny a request or condition approval of vegetation management or removal proposals for view maintenance if it is determined the action will result in an adverse effect to slope stability, habitat value, health of surrounding vegetation, risk of wind damage to surrounding vegetation, nearby surface or ground water, or water quality of a nearby water body.* 17.05A.090.D.8: *When development is proposed on a site where the shoreline buffer area does not have native vegetation throughout, the buffer shall be required to be enhanced with native trees and shrubs that contribute to habitat quality and ecological functions, proportionate to the impacts of the proposed development as determined by the Shoreline Administrator. If the site will not support trees and shrubs, the Shoreline Administrator may allow use of native herbaceous plants. As a general guideline, for development outside of any required setback or buffer, the percentage of the buffer to be enhanced should equal the percentage increase in impervious lot coverage on the site. Any enhancement required pursuant to setback or buffer modification provisions of this Program would be in addition to this general guideline.* 17.05A.090.G.1: *In cases where new, expanded (greater than 200 square feet), or replaced residential structures (including principal structures and all associated impervious surfaces) are permitted in the shoreline building setback or buffer, buffer enhancement shall be provided as follows:* *a. If the expansion or modification is greater than 200 square feet and adds impervious surface to the building setback, including the primary structure and all accessory structures and appurtenances, the proponent shall be required to enhance an equal area of the shoreline buffer with native vegetation;* *b. If the expansion or modification is greater than 200 square feet and adds any new impervious surface within the shoreline buffer, including the primary structure and all accessory structures and appurtenances, the proponent shall be required to enhance an equal area of the shoreline buffer with native vegetation; and* *2. Buffer enhancement shall meet the requirements of section 17.05A.090.H.* *3. Requirements for vegetation enhancement associated with development in the building setback or buffer shall apply to the total of all new building area added on a project site after the effective date of this Program.* *4. If the proponent removes impervious surface from within the shoreline buffer or building setback, the horizontal area (square feet) of removed impervious surface may be deducted from the total of new impervious surface area for which enhancement of the buffer is required.*		
2.B.4.d.4	Shoreline access structures, such as trails, walkways, and stairs, should be located, designed, and maintained to	Specify that, particularly in sensitive critical areas such as steep slopes associated with RBC, some properties may have view-only access of beach areas. Direct beach access from bluff crest should not be construed as a guaranteed element of enjoyment of the property. The applicant bears the burden	*AC:* Low *EP:* High *RB-H:* Moderate	Moderate

Anticipated Burden: AC = Anticipated Costs; EP = Enforcement Practicality; RB = Regulatory Burden for: H = Homeowners; C = Consultants; D = Developers

City of Oak Harbor – Shoreline Master Program				
Code	Existing Language	Suggested Revision(s)	Anticipated Burden	Priority
	minimize alteration of shoreline bluffs and clearing of vegetation. Where feasible, shoreline access from multiple properties should be coordinated and consolidated to reduce the number of access structures.	of proof regarding safety and minimization of impacts from new or rebuilt shore access structures. Decision to permit new/rebuilt access should be based on application and geotechnical analysis from a qualified professional. Require documentation of shared beach access structure, where relevant. Language may be borrowed or adapted from Oak Harbor SMP: 5.C.4.c.2.b.	*RB-C:* Low *RB-D:* Low	
3.B.4.a.4.g	Within the shoreline jurisdiction, incentive-based buffer reductions shall not exceed a total of 25%. Provisions for buffer averaging contained in OHMC 20.25.040(4) shall apply within the shoreline jurisdiction, except that no buffer shall be reduced to less than the required setback for the environment designation as listed in Chapter 4, Table 2 of this document, or as otherwise allowed under averaging provisions in footnotes 4 and 5 of Table 2. [Chapter 4, table 2: "In no case shall primary structures be located closer than 25 FT from the top of steep slope areas and bluffs," contingent on geotechnical analysis and critical areas report.]	With a projected 30+ FT of bluff recession by 2100 (based on current moderate models of emissions scenarios and sea level rise), the minimum 25 FT setback is insufficient and should be expanded. Expand minimum setback distance to at least 50 FT for new construction or additions, and condition setback reduction on maintenance/enhancement of native vegetation, structure placement that will not necessitate a need for future shore protection structure. Maintain requirement for geotechnical analysis and critical areas report for buffer reduction. May also consider implementation of an expanded critical area (hazard slopes, shoreline) buffer and additional building setback, as applied by Island and Jefferson County (see examples). These policies are more-restrictive than current Oak Harbor SMP and MC standards, but allow for more flexibility on the part of the City with respect to regulating safe development in shore- and steep bluff-adjacent areas: <u>Example: Island County SMP</u> – 17.05A.090.D.2: *Residential development, including principal structures and all associated impervious surfaces, shall be located landward of the shoreline buffer plus building setback except as specified in this SMP or with the approval of a shoreline variance.* 17.05A.090.D.3: *In all shoreline environment designations, a building setback shall be maintained from the landward edge of the required buffer. The minimum required building setbacks for each shoreline environment designation are shown in Table 3. No permanent structure or impervious surface may extend within the building setback, except as follows:* *a. Impervious surfaces may not cover more than twenty (20) percent of the building setback area;* *b. Structures less than thirty (30) inches in height may be allowed; and* *c. A single garden or storage structure over thirty (30) inches in height may be allowed as accessory to a single-family residence. Such structures shall be limited to 200 square feet and shall be subject to a maximum height of twelve (12) feet.* 17.05A.090.D. Table 3: (Summary of setbacks and buffers; vary by designation) *Marine Buffer (from OHWM): 30 – 125 FT* *Steep Slope Buffer (from top of marine bluff with slope > 40%): 30 – 50 FT* *Building Setback (from most-landward marine or slope buffer): 25 – 45 FT* 17.05A.090.E.1: *On lots where the area of the lot outside of the standard shoreline buffer and building setback as indicated in Table 3, the required side setbacks in chapter 17.03, and any required critical*	*AC:* Moderate-High *EP:* Moderate-High *RB-H:* Low-Moderate *RB-C:* Moderate *RB-D:* Moderate	High

Anticipated Burden: AC = Anticipated Costs; EP = Enforcement Practicality; RB = Regulatory Burden for: H = Homeowners; C = Consultants; D = Developers

City of Oak Harbor – Shoreline Master Program				
Code	Existing Language	Suggested Revision(s)	Anticipated Burden	Priority
		area buffer is less than 2,200 square feet, development may extend into the building setback provided: *a. The maximum building footprint (including principal structures and all associated impervious surfaces) shall be no larger than 2,200 square feet;* *b. There is no opportunity to consolidate lots under common ownership that will alleviate the nonconformity;* *c. The proposed development has utilized the maximum portion of the lot outside of the shoreline buffer, building setback, critical areas, and critical area buffers before extending into the building setback; and* *d. Buffer enhancement is provided consistent with section 17.05A.090.G.* Example: Jefferson County CAO – 18.22.530.12: *The administrator may reduce geologically hazardous area buffers as follows:* *(a) Buffers may be reduced by up to 25 percent with a geotechnical report prepared by a geotechnical professional with a state stamp; provided, the geotechnical report identifies recommendations for preventing or minimizing risks post-development.* *(b) All buffer reductions 25 percent or greater and all development within a high or moderate geologically hazardous area shall require a geotechnical report prepared by a geotechnical professional. The administrator may require a third-party review based on JCC 18.22.930 or the applicant enters into an indemnity and hold harmless agreement with the county that is approved by the county's risk manager and the prosecuting attorney. If the administrator requires a third-party review of the geotechnical report, the administrator shall be responsible for identifying and transmitting the geotechnical report to the third-party reviewer.*		
3.B.8.c.6	Setback Zone 1 - Vegetation Management Zone (VMZ) established. The first thirty (30) feet of shoreline setback area landward of the OHWM shall be established as a VMZ, except in the Conservancy environment where the VMZ shall include the entire required setback area, and in the Residential Bluff Conservancy environment, where the VMZ shall include the entire shoreline setback and all steep or unstable slopes and required slope setbacks. Vegetation preservation shall be the highest priority within the VMZ, and the purpose of this zone shall be to protect and enhance shoreline ecological	Recommend additional text regarding protection of mature vegetation and prioritization of vegetation integrity within VMZ. See recommendations for 2.B.4.d.3. Consider encouraging, through appropriate mechanisms available to the City, voluntary replanting of buffer area on properties where native vegetation in the VMZ is limited or absent. Where little/no native vegetation is present in in the shoreline buffer, consider requiring vegetation planting in the shoreline buffer as a condition of new development and/or site redevelopment with expanded footprint.	*AC:* Low *EP:* Moderate *RB-H:* Low *RB-C:* Low *RB-D:* Low	Low-Moderate

City of Oak Harbor – Shoreline Master Program				
Code	Existing Language	Suggested Revision(s)	Anticipated Burden	Priority
	function and slope stability associated with native vegetation.			
3.B.8.c.6.b	Existing lawns and other non-native landscaping and improvements are allowed in the VMZ and may be maintained without a permit, provided existing native vegetation is to be preserved and new non-native vegetation is not permitted	Restrict or discourage placement of large landscaping features (especially water features), fill material (including substantial soil for planting beds), or other similar within bluff setback zone within RBC, as these can contribute additional weight and/or moisture which can, in turn, contribute to bluff instability. Consider incentivization of residents to convert existing lawn to native vegetation within the VMZ, whether as matter of public education or code with incentives.	*AC:* Low *EP:* Moderate *RB-H:* Low *RB-C:* Low *RB-D:* Low	Moderate
3.B.8.c.10	Tree Pruning and Hazard Tree Removal: Selective pruning of trees for safety or view protection is allowed in shoreline jurisdiction if consistent with the provisions of OHMC 19.46 – Landscaping and Screening. Non-hazard trees located in steep slope and bluff areas shall be retained, and pruning shall not include topping, pollarding or stripping; no more than 40% of the crown shall be removed.	Reduce permissible crown pruning and tree limbing/pruning to preserve habitat value. Example: Island County SMP – 17.05A.090.K(7): *Selective pruning or thinning of trees for safety or view protection or maintenance may be allowed when it is limited to:* *a. Removal of no more than twenty-five (25) percent of the canopy of any tree or group of trees (calculated based on the area of the crown, or upper portion(s) comprised of branches and leaves or as determined by a certified arborist) in any given five-year period; or* *b. Pruning of trees that does not affect ecological functions. No more than twenty (20) percent of the limbs on any single tree may be removed and no more than twenty (20) percent of the canopy cover in any single stand of trees may be removed in a given five-year period. Pruning shall comply with the National Arborist Association pruning standards, unless the tree is a hazard tree as certified by an arborist and approved by the Shoreline Administrator.*	*AC:* Low *EP:* Moderate *RB-H:* Low *RB-C:* Low *RB-D:* Low	Low
3.B.8.c.11	Unauthorized vegetation removal. Vegetation removal conducted without the appropriate review and approvals anywhere within shoreline jurisdiction also requires the submittal and approval of a shoreline landscaping plan as outlined in Regulation 4 above. The landscaping plan must utilize only native vegetation, and should be designed to compensate for temporal loss of function and address the specific functions adversely impacted by the unauthorized vegetation removal.	Enhance existing policy requiring compensatory mitigation through vegetation re-planting or other appropriate action in response to unpermitted vegetation removal, particularly for extensive, unpermitted clearing action, and unpermitted clearing within the VMZ. Extent of enforcement/penalty may be at the discretion of appropriate departments but should allow for enforcement that is sufficiently severe as to deter unauthorized vegetation removal. Required re-planting should prioritize dense re-planting with appropriate native vegetation within the VMZ, possibly with guidance of qualified professional. May also require monitoring of re-planted area to ensure success of reintroduced vegetation, with additional planting if introduced coverage fails to establish. <u>Example: Island County Zoning Code –</u> 17.03.260.I: *Restoration shall be required for any unauthorized alteration of a critical area or critical area buffer. The purpose of restoration is to return the critical area or critical area buffer to the condition that predated the unauthorized alteration.* *1. Restoration plan. Except in those circumstances described below in subsection I.1.a., restoration shall be based on a specific plan.* *a. In the event that the Planning Director determines that an unauthorized alteration is unintentional, temporary in nature and that restoration will occur through natural revegetation within two (2) years from the date of the disturbance, the Planning Director shall establish restoration requirements including monitoring in a compliance letter.*	*AC:* Moderate *EP:* Low-Moderate *RB-H:* Low-High *RB-C:* Low-High *RB-D:* Low-High (anticipated burden may vary depending on the extent of the unauthorized vegetation clearing and the degree of regulatory or compensatory action sought by the City).	Moderate

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City of Oak Harbor – Shoreline Master Program				
Code	Existing Language	Suggested Revision(s)	Anticipated Burden	Priority
		b. When a restoration plan is required, the plan shall be prepared by a qualified professional and shall include the following: (i) A description of the unauthorized alteration and the condition of the critical area or critical area buffer before alteration; and (ii) Measures necessary to restore the critical area or critical area buffer including grading and planting plans showing proposed post-construction topography, hydrologic patterns, spacing and distribution of plants species, actions to provide or improve habitat, size and type of proposed plant stock, irrigation and other information that is relevant to the proposed restoration; and (iii) A management plan that includes restoration goals, benchmarks and review criteria; site treatment measures for maintenance of the restoration, including but not limited to supplemental watering schedules and non-native/invasive vegetation management; and (iv) A monitoring plan that specifies the standards, photo points, time period and frequency of reports that will be used to determine whether the restoration is successful; and (v) A contingency plan that establishes the actions that will be taken should monitoring identify that the restoration is not successfully achieving the established benchmarks and standards within the established time periods. *c. In preparing and approving the restoration plan, the applicant and the county may consult with the Department of Fish and Wildlife and the Department of Natural Resources and the Department of Ecology.* *d. The restoration plan shall be prepared at the violator's cost and shall be reviewed under the process set forth for Type II decisions in chapter 16.19. All restoration shall be consistent with the approved restoration plan.* 17.05A.090.D(10):*The applicant shall monitor and report annually for a period of five (5) years on the condition of any buffer enhancement required by this Program. Monitoring shall include photographs of the plantings and an inventory of plant survival and cover expressed as a percent of the planting area. Buffer enhancement plantings shall have targets for vegetative cover that must be met within or by the fifth growing season. At that time, if the vegetative cover does not meet the target, additional planting or other action may be required and the monitoring period extended. The target for vegetative cover shall be ninety (90) percent unless the Shoreline Administrator modifies the required target after determination that environmental conditions indicate less vegetative cover more nearly matches what a naturally occurring plant community would achieve at the particular location.* 17.05A.090.K(3): *Native plant materials that are equivalent to those which would typically occur with respect to size, structure, and diversity at maturation shall be used in restoration, rehabilitation, or enhancement projects.*		
5.C.1.b.3	Structures should be located and designed to avoid the need for future shoreline stabilization where feasible. Land subdivisions should be designed to assure that future development of the created lots will not require shoreline stabilization for development to occur	See recommendation for 2.B.4.d.2; define "expected life of structure" for consideration of planning horizon with respect to structure placement and subdivision boundaries. Consider impact of fully built-out conditions on shoreline and bluff processes when permitting densified subdivisions. <u>Island County SMP</u> – 17.05A.090.E.5: *The following provisions shall apply to any development proposed within a shoreline buffer or building setback:*	*AC:* Low-Moderate *EP:* High *RB-H:* Low *RB-C:* Low-Moderate *RB-D:* Moderate	Highest

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City of Oak Harbor – Shoreline Master Program				
Code	Existing Language	Suggested Revision(s)	Anticipated Burden	Priority
		c. A geologic analysis indicates that with the reduced setback or buffer, the proposed structure will not require shoreline stabilization for the life of the single-family residence, typically 100 years; 17.05A.090.E.1 - *On lots where the area of the lot outside of the standard shoreline buffer and building setback as indicated in Table 3, the required side setbacks in chapter 17.03, and any required critical area buffer is less than 2,200 square feet, development may extend into the building setback provided:* *a. The maximum building footprint (including principal structures and all associated impervious surfaces) shall be no larger than 2,200 square feet;* *b. There is no opportunity to consolidate lots under common ownership that will alleviate the nonconformity;* *c. The proposed development has utilized the maximum portion of the lot outside of the shoreline buffer, building setback, critical areas, and critical area buffers before extending into the building setback; and* *d. Buffer enhancement is provided consistent with section 17.05A.090.G.* 17.05A.090.K(11) - *Subdivision of property shall be in a configuration that will not require significant vegetation removal or shoreline modification and that will not adversely impact ecological functions. Each new parcel must be able to support its intended development without significant ecological impacts to the shoreline ecological functions.* <u>Jefferson County SMP</u> – *18.25.500.1(h): Creation of new residential lots through land division should be designed, configured and developed to ensure that no net loss of ecological functions and processes occurs from the plat or subdivision, even when all lots are fully built-out*		
5.C.1.c.2.b.iii	For hard and soft stabilization measures, the applicant must demonstrate that any on-site drainage issues have been directed away from the shoreline edge prior to considering structural stabilization.	Within the RBC, it may be appropriate for drainage conveyance systems to be directed over the bluff face to the beach rather than directing water away from shoreline edge. Specify language for drainage management within RBC in association with coastal bluffs, and consider including the requirement for an engineered drainage design when drainage water is planned to be routed over the bluff face. See recommendation for 2.B.4.d.2.	*AC:* Moderate *EP:* Moderate *RB-H:* Moderate *RB-C:* Moderate *RB-D:* Moderate	Moderate
Table 2: Shoreline Development Standards: Shoreline setback	Setbacks shall be measured from the ordinary high water mark (OHWM). All new or expanded development in the Shoreline Residential Bluff Conservancy environment proposed within 100 feet of a designated steep slope or bluff shall be required to submit a critical areas report as part of development permit application, pursuant to Ordinance 1440 § 5, 2005, including a geotechnical analysis by a	Increase minimum building setback to allow for safe construction and sufficient bluff protection for RBC lots (should be greater than current 25 FT minimum setback). See recommendations for 2.B.4.d.2 and 3.B.4.a.4.g <u>Example: Is County SMP</u> – 17.05A.090.E.1: *On lots where the area of the lot outside of the standard shoreline buffer and building setback as indicated in Table 3, the required side setbacks in chapter 17.03, and any required critical area buffer is less than 2,200 square feet, development may extend into the building setback provided:* *a. principal structures and all associated impervious surfaces) shall be no larger than 2,200 square feet;*	*AC:* Low *EP:* High *RB-H:* Low-Moderate *RB-C:* Low *RB-D:* Low-Moderate	Highest

Anticipated Burden: AC = Anticipated Costs; EP = Enforcement Practicality; RB = Regulatory Burden for: H = Homeowners; C = Consultants; D = Developers

City of Oak Harbor – Shoreline Master Program				
Code	Existing Language	Suggested Revision(s)	Anticipated Burden	Priority
	qualified professional. New development on steep slopes or bluffs shall be set back sufficiently to ensure that shoreline stabilization is unlikely to be necessary during the life of the structure, as demonstrated by the geotechnical analysis. Please see additional geotechnical report requirements in Chapter 5, Section C.1.c and critical area report requirements in OHMC 20.28. In no case shall primary structures be located closer than 25 feet from the top of steep slope areas and bluffs. If application of the 50-foot standard shoreline setback would allow the construction of a structure within 25 feet of a steep slope area or top of bluff or within the setback recommended by geotechnical analysis, the more restrictive standard shall apply	*b. There is no opportunity to consolidate lots under common ownership that will alleviate the nonconformity;* *c. The proposed development has utilized the maximum portion of the lot outside of the shoreline buffer, building setback, critical areas, and critical area buffers before extending into the building setback; and* *d. Buffer enhancement is provided consistent with section 17.05A.090.G.* 17.05A.090.C.12*: Geologically hazardous areas shall be regulated pursuant to the following:* *e. New development that, during the life of the development, would cause foreseeable risk to the structure or the safety of its inhabitants from geological conditions or would require shoreline stabilization is prohibited, except where there is no alternative location for an allowed use and the development would not cause a net loss of ecological functions.* 17.05A.090.E.5: *The following provisions shall apply to any development proposed within a shoreline buffer or building setback:* *c. A geologic analysis indicates that with the reduced setback or buffer, the proposed structure will not require shoreline stabilization for the life of the single-family residence, typically 100 years;* 17.05A.090.F.1 - *The common line setback and shoreline buffer reduction procedures described in this section shall not be used to reduce a steep slope buffer.*		
Table 3: Shoreline Modification Provisions: Soil bio-engineering and other non-structural	Permitted in RBC (not conditional)	Provide a definition of soil bioengineering for consistency. Condition soil bioengineering in the RBC on professional design to avoid potential undesirable impacts to bluff stability. Different interpretations of this term exist in the region.	*AC:* Low *EP:* Moderate *RB-H:* Moderate *RB-C:* Moderate *RB-D:* Moderate	Low
Table 3: Shoreline Modification Provisions: Fill upland of OHWM	Permitted in RBC (not conditional)	Condition fill placement upland of OHWM and on top of bluff within RBC on professional/geotechnical investigation. Unregulated additions of fill to bluff top could exacerbate erosion.	*AC:* Low *EP:* Low-Moderate *RB-H:* Moderate *RB-C:* Moderate *RB-D:* Moderate	Moderate

Table 9. Summary table detailing existing code contained in the Oak Harbor Municipal Code (OHMC) for which revisions or reconsiderations are recommended. This review encompasses code pertaining to storm water (Chapter 12), critical areas (Chapter 20), and subdivisions (Chapter 21). Anticipated regulatory burden and relative implementation priority are also briefly described herein for each recommended revision.

City of Oak Harbor – Municipal Code				
Code	Existing Language	Suggested Revision(s)	Anticipated Burden	Priority
12.30.210	Consistent with the nine minimum requirements as identified in Chapter 2, Volume I of the manual, the director shall approve or disapprove the following activities, unless exempted in OHMC 12.30.220: (1) New Development. (a) Land-disturbing activities, […]; (b) Structural development, including construction or installation of a building or other structure; (c) Creation of hard surfaces; (d) Subdivision, short subdivision and binding site plans, as defined and applied in RCW 58.17.020. (2) Redevelopment. On an already substantially developed site (i.e., has 35 percent or more of existing hard surface coverage), the creation or addition of hard surfaces, the expansion of a building footprint or addition or replacement of a structure, structural development including construction, installation or expansion of a building or other structure, land-disturbing activity, replacement of hard surface that is not part of a routine maintenance activity, and land-disturbing activities associated with structural or impervious redevelopment.	Revisit limitations on subdivision or development density based on stormwater or other pertinent codes. Ensure stormwater and drainage conveyance systems associated with critical areas are professionally-engineered, maintained in good repair, and are of sufficient durability to manage drainage near critical bluff areas. Example: Island County SMP – 11.03.100(C): C. *In the case of small residential development proposed within a* ***designated critical drainage area****, the applicant may either submit a drainage narrative for review/approval or may accept, as conditions of permit approval, the attachment of conditions which fulfill either, as applicable, the low-impact development surface water rate control best management practices (BMPs) or conventional rate control BMPs, and which also fulfill the temporary erosion and sedimentation control requirements (BMPs) of this chapter, unless otherwise exempted below. Small residential development activities that discharge surface water into a designated water quality sensitive area shall have additional water quality BMPs attached as conditions of approval.* 17.05A.090.A.5: *Land clearing, grading, filling, or alteration of natural drainage features and landforms shall be limited to the minimum necessary for development. Surfaces cleared of vegetation and not developed shall be replanted and maintained in perpetuity. Surface drainage systems or substantial earth modifications shall be professionally designed to prevent maintenance problems or adverse impacts on shoreline features.*	*AC:* Moderate-High *EP:* Moderate *RB-H:* Moderate *RB-C:* Moderate *RB-D:* Moderate	Moderate
20.12.080	(1) Where development is partly prohibited due to the presence of critical areas, as defined in this title, an applicant may be permitted to transfer the density attributable to the undevelopable area of the property to	Revise density transfer allowances. Consider: "Where development is partly prohibited due to the presence of critical areas, as defined in this title, an applicant may be permitted to transfer the density attribute of the critical area and a portion of the associated buffer (consider 40-60%) of the property to another noncritical portion of the same site or property, subject to the limitations of this section. This density transfer allowance may not be used to transfer density from portions of the site or property that could not be reasonably construed	*AC:* Moderate *EP:* High *RB-H:* Moderate *RB-C:* Moderate *RB-D:* Moderate-High	Highest

Anticipated Burden: AC = Anticipated Costs; EP = Enforcement Practicality; RB = Regulatory Burden for: H = Homeowners; C = Consultants; D = Developers

City of Oak Harbor – Municipal Code				
Code	Existing Language	Suggested Revision(s)	Anticipated Burden	Priority
	another noncritical portion of the same site or property subject to the limitations of this section. Up to 100 percent of the density that could be achieved on the unbuildable portion of the site can be transferred to the noncritical area portion of the property, subject to: (a) The density limitation of the underlying zoning district; (b) The minimum lot size of the underlying zoning district may be reduced by up to 25 percent; and (c) Applicable setbacks may be reduced to 15 feet, and the lot coverage standards of underlying zoning regulations may be increased to 60 percent. (Ord. 1440 § 2, 2005).	as developable in the absence of extensive fill and structural stabilization, including tidelands (land seaward of the ordinary high water line) and steep bluff faces. (The allowable density transfer in the existing code regarding tidelands in highly unusual.) Consider reducing the percent of allowable density transfer, and/or requiring applicant to provide evidence that density transfer will not, under fully developed conditions, result in adverse impacts to shoreline areas and critical areas. Determine whether the density limitation for the RBC is appropriate for achieving goals of protecting bluff safety and ecology while allowing enjoyment of property, accounting for a 25% reduction in allowable lot size. If this is not appropriate for the bluff area, consider omitting or reducing this density transfer allowance, or placing at Administrator discretion. Example: Island County SMP – 17.03.040: *Definitions; Lot area/lot size means the total land area within the lot lines. Gross lot area shall include any land area required to be dedicated for public right-of-way or public open space, and/or donated for such purposes.* ***Tidelands (land seaward of the ordinary high tide line), whether privately or publicly owned, shall not be included in the calculation of lot area.*** *However, privately owned shorelands (non-tidal) should be included in such calculation.* 17.05A.090.C.11: *Land that is constrained by critical areas or buffers* ***shall not be subdivided to create parcels that do not contain a buildable site*** *outside of critical areas and their required buffers, unless the parcel is an open space tract created for the purposes of protecting and managing a critical area, and a conservation easement indicating that the parcel cannot be built upon is recorded with the County Auditor.* 17.05A.100.J(10): *Residential structures shall only be located upon geologically hazardous areas (as defined in chapter 17.02A) if in compliance with the bluff setback standards and conditions contained in chapter 11.02 or set back fifty (50) feet from the top of a bank greater than 100 feet in height, whichever is more restrictive.* 117.05A.100.J (11): *The following shoreline setbacks shall be applied to residential development:* *a. All residential development shall comply with the buffer requirements of section 17.05A.090 and the critical areas buffers established in chapters 17.02 and 17.02A.* *b. A greater setback may be required if necessary to comply with the grading, geologically hazardous area, erosion control and drainage requirements of chapter 11.02 and chapter 11.03 and the critical areas regulations contained in chapters 17.02 and 17.02A.* 17.05A.100.J(13): *New residential development shall be designed and built in a manner that avoids the need for structural shore armoring and flood hazard reduction over the life of the development in accordance with section 17.05A. 090.L, flood control structures, and section 17.05A.110.A, shoreline stabilization, of this Shoreline Master Program and other applicable plans and laws.*		

Anticipated Burden: AC = Anticipated Costs; EP = Enforcement Practicality; RB = Regulatory Burden for: H = Homeowners; C = Consultants; D = Developers

City of Oak Harbor – Municipal Code				
Code	Existing Language	Suggested Revision(s)	Anticipated Burden	Priority
		17.05A.100.J(15): *Creation of new residential lots through land division shall be designed, configured, and developed to ensure that no net loss of ecological functions and processes occurs from the plat or subdivision, even when all lots are fully built out.* (Identical text applied in Jefferson County SMP: 18.25.500.1) 17.05A.100.J(17). *Building buffers and setbacks from shorelines consistent with the requirements of this Shoreline Master Program and chapters 17.03 and 17.02 shall be established as conditions of preliminary plat approval in all new waterfront subdivisions. A plat restriction shall specify the required setbacks and all building buffers and setbacks shall be shown on the face of the plat.* 18.15.505(3a): *The dimensions and area of each proposed lot, tract or parcel (including any reserve tract(s)) to accurately show that the property proposed for the [planned rural residential development] contains sufficient area to allow the number of lots, tracts or parcels proposed without exceeding the average density allowed in the underlying zoning district. Where a density bonus is requested under JCC 18.15.520, the average density allowed in the underlying district may be exceeded by up to 20 percent of the allowed density for that district and an additional 20 percent for the area in the reserve tract that are designated critical areas. An additional bonus may be granted for the buffer area(s) associated with critical areas that are included within the reserve tract, the bonus shall not exceed 20 percent of the allowed density in the buffer area; and provided further, that the area of land contained in access easements, access panhandles or pipestem configurations shall not be included in the area computations;* <u>Jefferson County SMP</u> – 18.25.500.2 *(2) Uses and Activities Prohibited Outright.* *(b) Residential development that can be reasonably expected to require structural shore armoring during the useful life of the structure or within 100 years, whichever is greater, is prohibited.* *(d) Land division and boundary line adjustments in shoreline jurisdiction are prohibited when such actions will result in lot configurations that are likely to require:* *(i) Significant vegetation removal;* *(ii) Structural shore armoring;* *(iii) Shoreline modification for erosion control;* *(iv) Flood hazard protection; or* *(v) Result in a net loss of shoreline ecological functions and processes at the time of development of the subdivision and/or during the useful life of the development or within 100 years, whichever is greater.* 18.35.030. *(5) Pursuant to Chapters 79.125 and 58.17 RCW, tidelands may not be altered in any fashion under this section. Tideland acreage may not be included or given other consideration in any land division, plat alteration, or boundary line adjustment. The authority to alter platted tidelands lies with the department of natural resources. [Ord. 8-06 § 1]*		

Anticipated Burden: AC = Anticipated Costs; EP = Enforcement Practicality; RB = Regulatory Burden for: H = Homeowners; C = Consultants; D = Developers

City of Oak Harbor – Municipal Code				
Code	Existing Language	Suggested Revision(s)	Anticipated Burden	Priority
20.28.030(1)	New structures and additions to existing structures within or adjacent to a geologically hazardous area shall be set back a minimum of 25 feet from the top of a steep or unstable slope unless a larger setback is recommended in a geotechnical analysis or by the International Building Code. In no case shall the setback be less than 25 feet from a steep or unstable slope unless allowed through the "reasonable use" provisions of OHMC 20.12.060 and supported by a geotechnical report and approved by the director. Decks which add no substantial loading weight to the hazardous area and accessory buildings 120 square feet or less may extend into the setback area to within 10 feet of the top or toe of a steep or unstable slope, unless a larger setback is recommended by the geotechnical analysis or by the International Building Code.	Increase minimum allowable setback from top of steep or unstable slope for marine bluffs. See recommendations for OH SMP 3.B.4.a.4.g.	*AC:* Low *EP:* High *RB-H:* Moderate *RB-C:* Moderate *RB-D:* Moderate	Highest
20.28.035	Storm water impacts shall be addressed in compliance with geotechnical recommendations, city code, and the Washington State Department of Ecology's 2012 Stormwater Management Manual for Western Washington (as amended December 2014) (Publication No. 14-10-055), or future updated publications, and other applicable regulations. Storm water drainage in areas of steep or unstable slopes shall be designed in such a manner that storm water does not create stability or erosion impacts. Surface drainage shall be directed away from landslide and erosion hazard areas.	Require that stormwater and drainage conveyance systems associated with sensitive or steep slopes are professionally-engineered, maintained in good repair, and are of sufficient durability to withstand disturbance events and many seasons of exposure to the elements. See recommendations for OHMC 12.30.210	*AC:* Moderate *EP:* Moderate *RB-H:* Moderate *RB-C:* Moderate *RB-D:* Moderate	High

Anticipated Burden: AC = Anticipated Costs; EP = Enforcement Practicality; RB = Regulatory Burden for: H = Homeowners; C = Consultants; D = Developers

City of Oak Harbor – Municipal Code				
Code	Existing Language	Suggested Revision(s)	Anticipated Burden	Priority
	When no other solution is feasible, surface drainage piping may be located on the face of a geologically hazardous area when contained in a pipe slope drain (closed, nonleaking pipe) in such a way that erosion will not be exacerbated. At no time shall concentrated storm water runoff be allowed to flow uncontained over a steep or unstable slope or impact a neighbor-ing property. (Ord. 1801 § 43, 2018).			

Conclusions

The unique geologic and environmental setting of the RBC necessitates the application of tailored, regionally appropriate policies that allow for full and safe use and enjoyment of coastal properties by landowners, while also meeting the City's mandate for protecting critical and sensitive ecological areas. As outlined in the *Existing Policy Review* section, establishing and maintaining adequate upland building setbacks, managing drainage with materials and drainage designs of sufficient quality, and promoting vegetation management are priority policy areas that will allow for improved co-occurrence of natural processes with use and enjoyment of the upland properties by landowners.

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ATTACHMENTS:

Figure 1. Net shore-drift and location map for the Oak Harbor Residential Bluff Conservancy. Direction of net shore-drift reported from the perspective of the water facing the shore.

City of Oak Harbor Residential Bluff Conservancy Policy/Regulation

COASTAL GEOLOGIC SERVICES

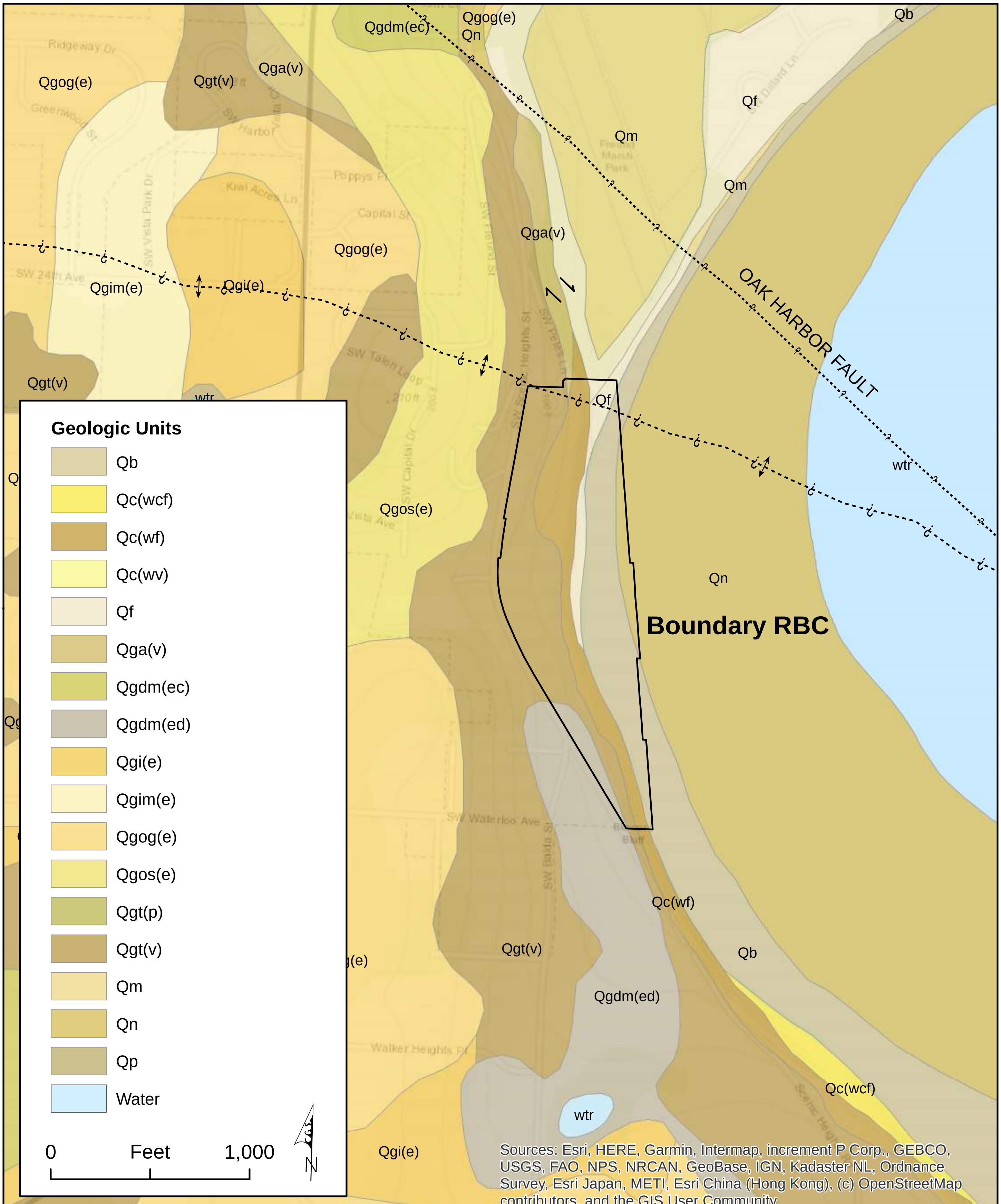

Figure 2. Surficial geology in the vacinity of the Oak Harbor Residential Bluff Conservancy.
Data from Dragovich et al. 2005

City of Oak Harbor Residential Bluff Conservancy Policy/Regulation Review

COASTAL GEOLOGIC SERVICES

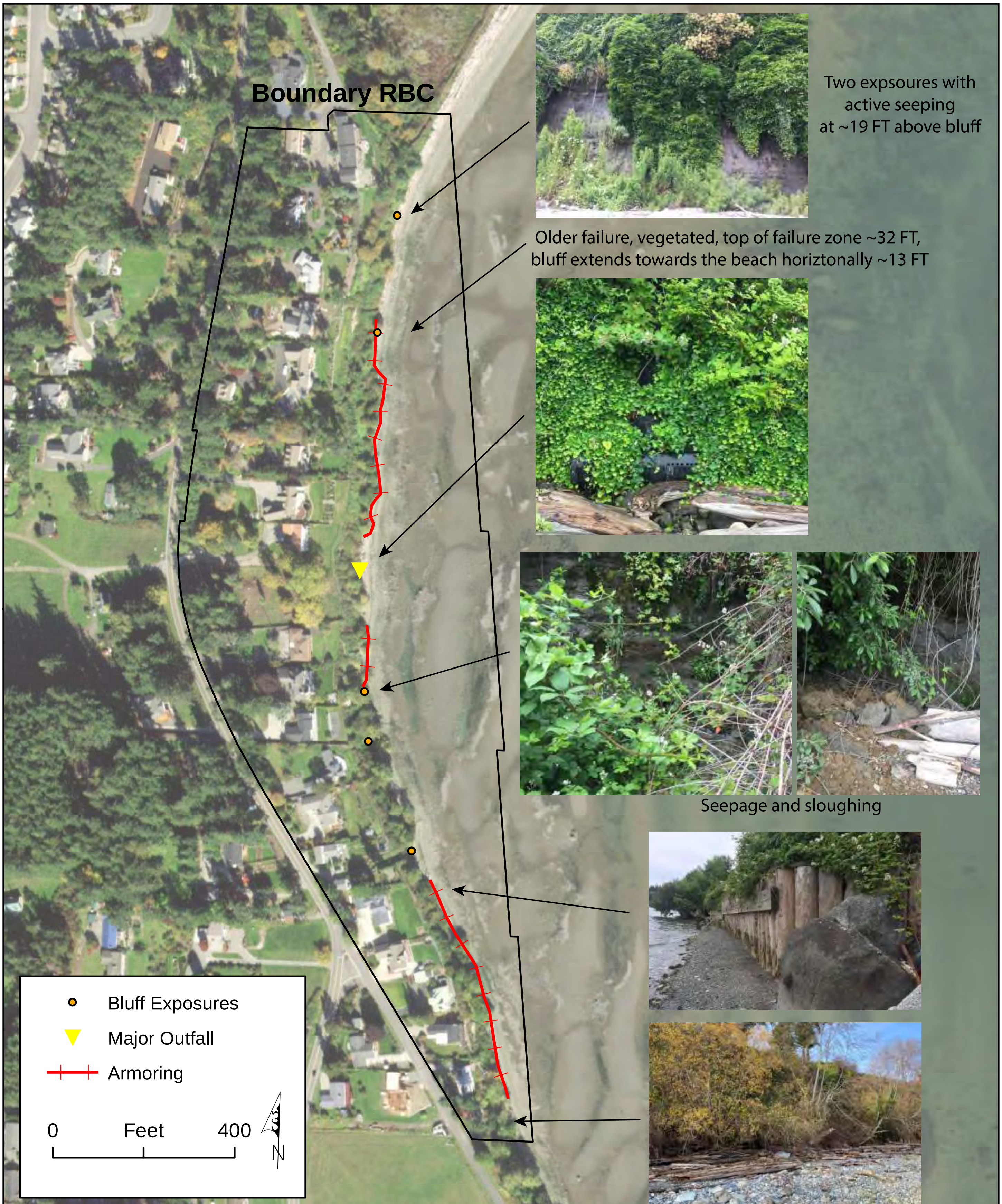

Figure 3. Bluff exposures, major outfalls, and armoring along the Oak Harbor Residential Bluff Conservancy shoreline.

City of Oak Harbor Residential Bluff Conservancy Policy/Regulation

COASTAL GEOLOGIC SERVICES

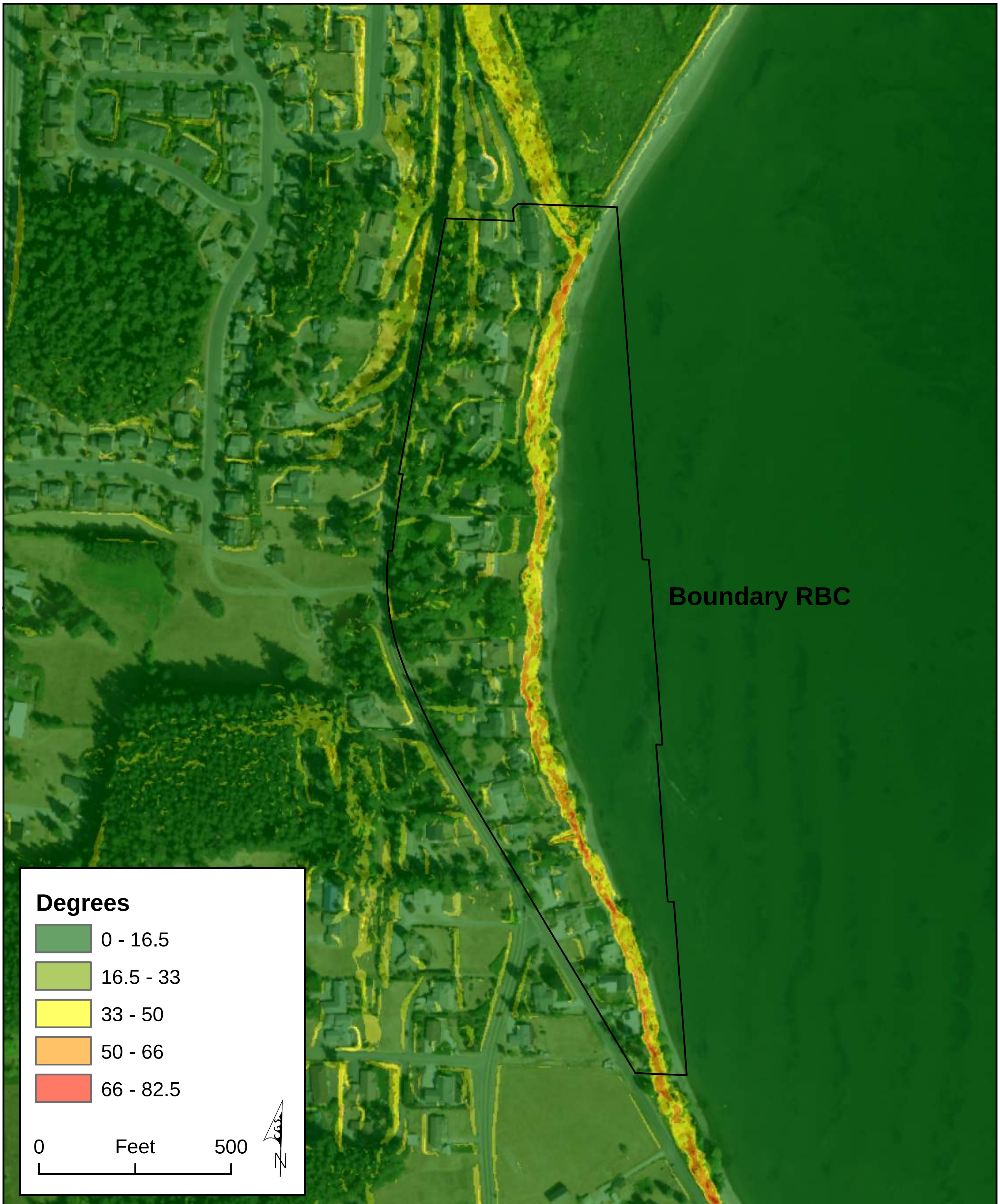

Figure 4. Slope map of Oak Harbor RBC.
Data from 2014 Island County LiDAR.
City of Oak Harbor Residential Bluff Conservancy Policy/Regulation Review

COASTAL GEOLOGIC SERVICES

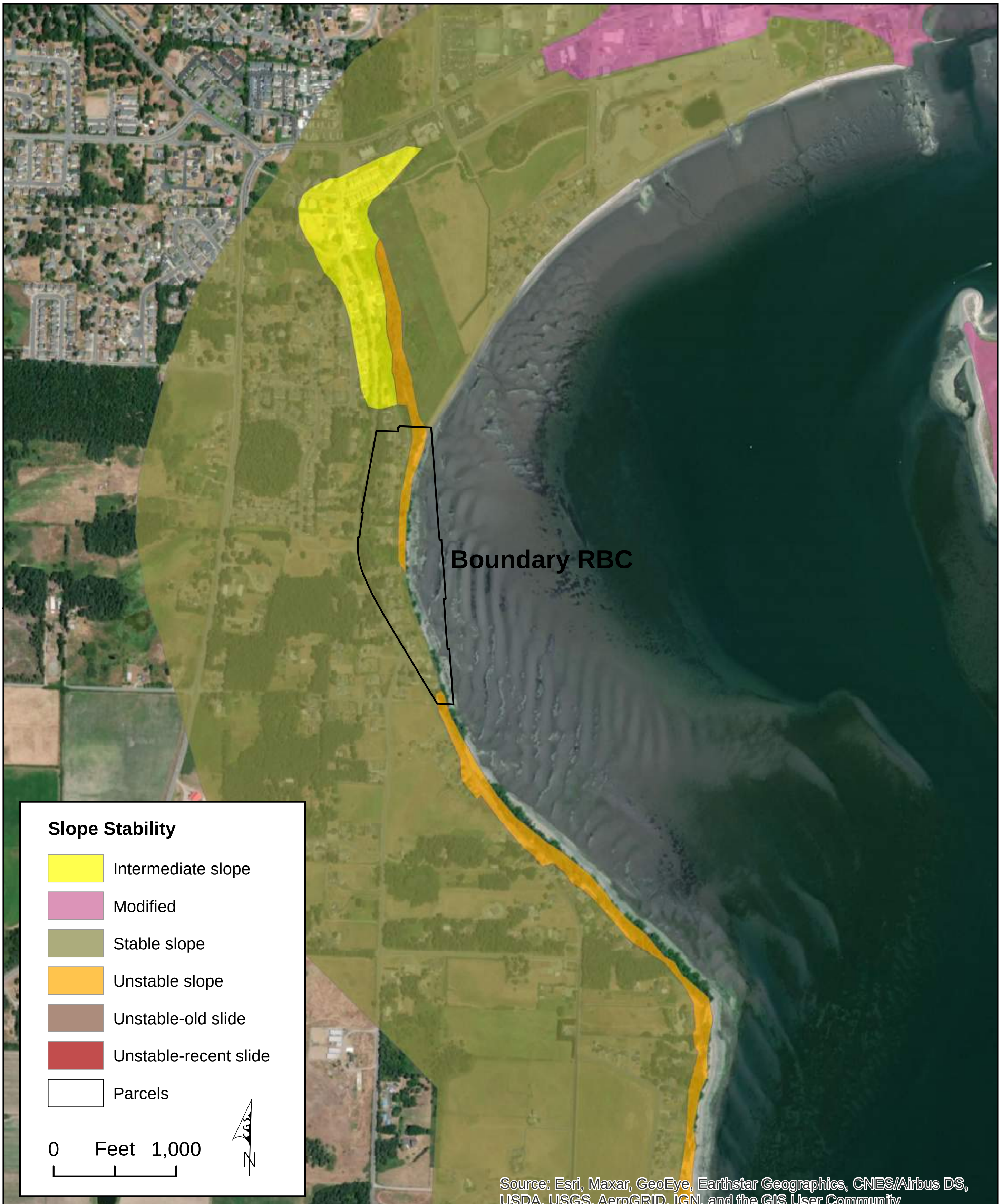

Figure 5. Slope stability in the vacinity of the Oak Harbor Residential Bluff Conservancy. Data from the Coastal Zone Atlas of WA (DOE 1979).

City of Oak Harbor Residential Bluff Conservancy Policy/Regulation Review

COASTAL GEOLOGIC SERVICES

Figure 6. Mapped landslides, observed sluffing, and bluff exposures.
Data collected in the field and from Johannessen & Chase 2005.
City of Oak Harbor Residential Bluff Conservancy Policy/Regulation Review

COASTAL GEOLOGIC SERVICES

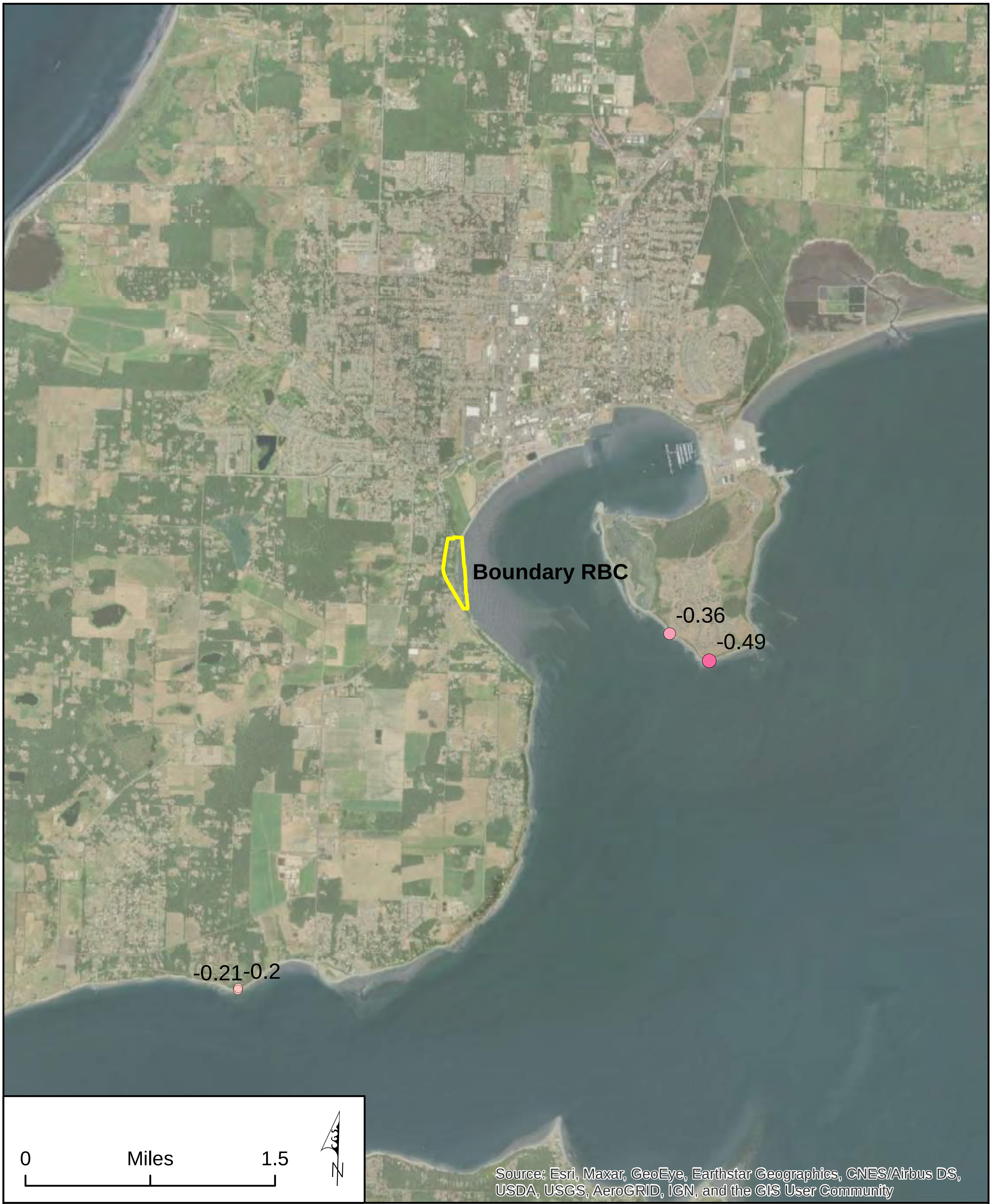

Figure 9. Bluff measures bluff recession rate site map. Negative numbers represent bluff recession in FT/YR. Data from Coastal Geologic Services (2018).

City of Oak Harbor Residential Bluff Conservancy Policy/Regulation

COASTAL GEOLOGIC SERVICES

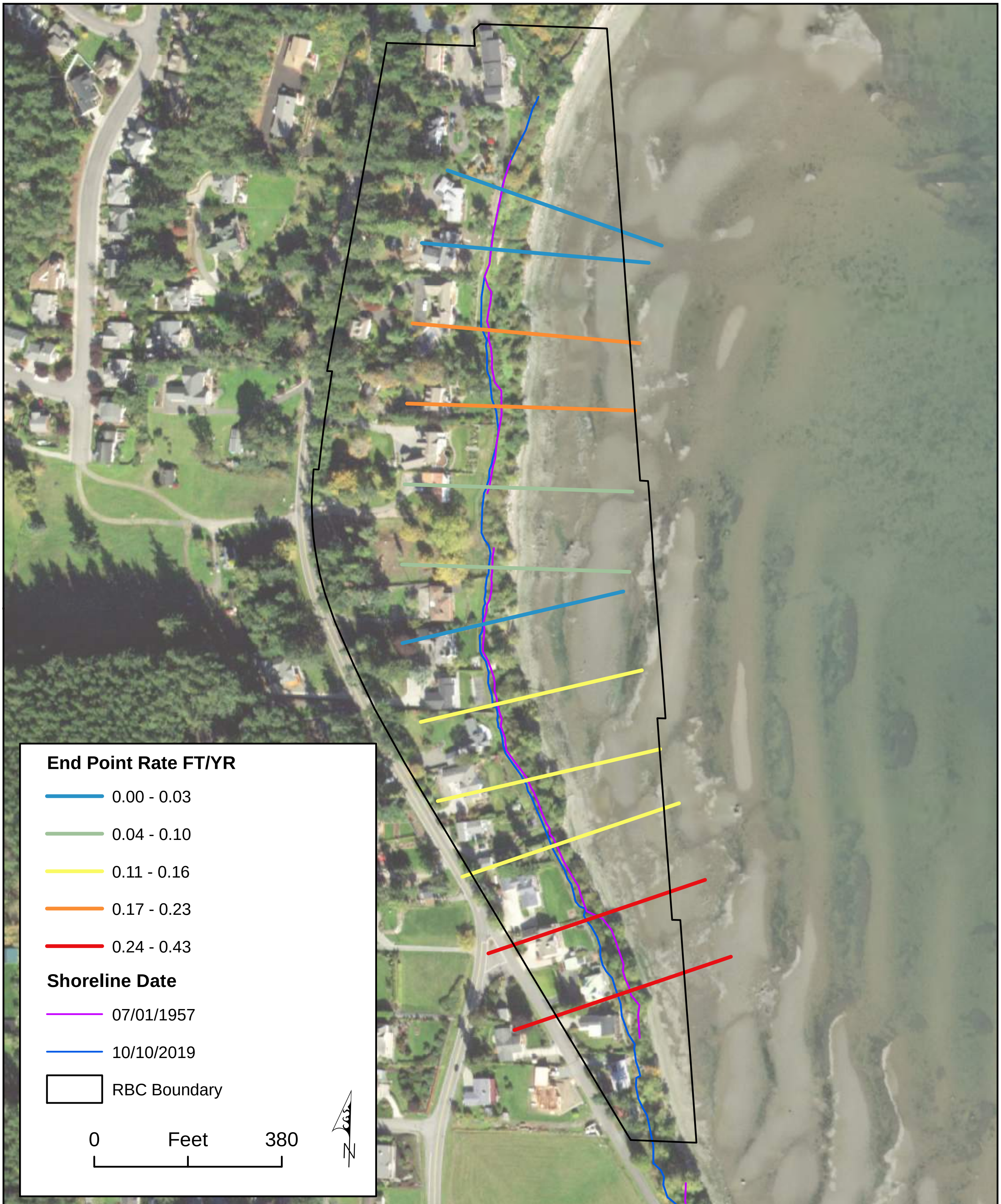

Figure 10. Erosion rates (FT/YR) along the Oak Harbor Residential Bluff Conservancy between 1957 and 2019 based on aerial image analysis with DSAS.

City of Oak Harbor Residential Bluff Conservancy Policy/Regulation

COASTAL GEOLOGIC SERVICES

Figure 11. Bluff crest locations for 2019, 2050, and 2100 based on an estimated recession rate of -0.16 FT/YR, not accounting for accelerated recession due to SLR.

COASTAL GEOLOGIC SERVICES

City of Oak Harbor Residential Bluff Conservancy Policy/Regulation

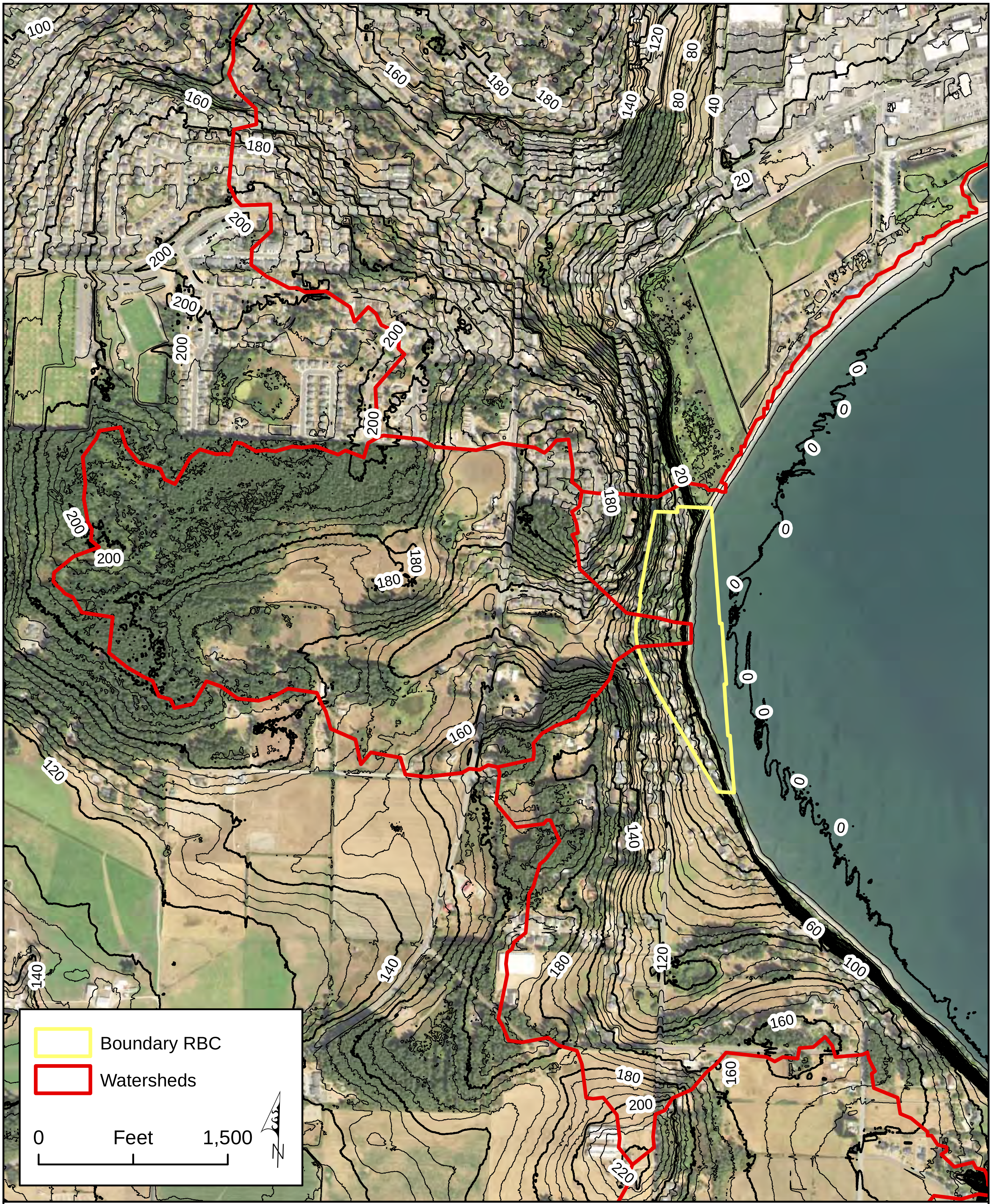

Figure 12. Oak Harbor RBC watershed basin.

Data from Island County.

City of Oak Harbor Residential Bluff Conservancy Policy/Regulation Review

COASTAL GEOLOGIC SERVICES

1a. 2016 aerial oblique taken 7/25/2016 of the northern portion of the Oak Harbor RBC.

1b. 2016 aerial oblique taken 7/25/2016 of the central and southern portions of the Oak Harbor RBC.

1c. 2006 aerial oblique taken 6/29/2006 of the northern portion of the Oak Harbor RBC.

1d. 2006 aerial oblique taken 6/26/2006 of the central portion of the Oak Harbor RBC.

1e. 2006 aerial oblique taken 6/29/2006 of the southern portion of the Oak Harbor RBC.

1f. 2001 aerial oblique taken 4/22/2001 of the north portion of the Oak Harbor RBC.

1g. 2001 aerial oblique taken 4/22/2001 of the central portion of the Oak Harbor RBC.

1h. 2001 aerial oblique taken 4/22/2001 of the southern portion of the Oak Harbor RBC.

1i. 1993 aerial oblique taken 5/5/1993 of the northern portion of the Oak Harbor RBC.

1j. 1993 aerial oblique taken 5/5/1993 of the southern portion of the Oak Harbor RBC.

Photo Pages. Historical aerial oblique compilation of the site (Washington Department of Ecology).