4. Mitigation Options

4.1 Introduction

The broad options for mitigating the flooding hazards at the Ocean Boulevard Pump Station site are listed in Table 4-1 below. The probability of the flood hazard occurring for various time periods is also provided in the table for reference.

Table 4-1: Broad Flood Hazard Mitigation Options

Flood Hazard	Probability	Broad Mitigation Options	Relative Cost
Storm Wave Flooding	Flooding to 2.45 m CGVD currently expected to occur every 5 years on average, will become an annual occurrence by the end of the station's expected life (2065) and increase in severity.	Berm (concrete, riprap or bio-engineered) to reduce wave overtopping	$
		Flood-proofing the building, kiosk and wet well	$
		Move the pump station	$$$$
"Blue Water" Flooding	Flooding to 2.45 m CGVD currently not probable (greater than 1 in 1000 year return period). There is a 37% chance flooding to this level will occur before the end of the station's expected life.	Raise the pump station	$$$
		Flood-proofing	$
		Diking	$$
		Move the pump station	$$$$
Tsunami Wave Flooding	9% chance that the pump station will be impacted by a CSZ tsunami before the service life of the pump station is reached	Emergency planning	$
		Construct a tsunami barrier (wall)	$$$$
		Reconstruct the pump station to withstand tsunami	$$$$
		Move the pump station	$$$$

When reviewing the broad flood hazard mitigation options and probabilities of occurrence in Table 4-1, the following conclusions are drawn:

- The storm wave flooding hazard is high and will become higher in the future. Immediate mitigation is required. **Construction of a berm and flood-proofing** are viable, relatively inexpensive, options at the Ocean Boulevard Pump Station site and could be constructed in a phased approach. **Moving the pump station** is also an option which would completely eliminate the flooding risk but is considerably more expensive.
- There is a 37% chance that the wet well hatches and ventilation/odour control kiosk will be impacted by "blue water" flooding before the end of the service life of the pump station is reached. **Flood-proofing** vulnerable equipment is a relatively inexpensive near-term mitigation strategy. **Moving the pump station** would completely eliminate the flooding risk and for this reason is generally preferred to investing considerable amounts of money in the current location by raising the pump station or constructing a perimeter dyke.
- The tsunami flooding hazard is significant, but flooding by tsunami (with associated station damage) is not probable during the remaining service life of the station. **Development of an emergency**

plan is a relatively inexpensive mitigation strategy. **Moving the pump station** is a safe location would eliminate the tsunami hazard. Constructing a tsunami barrier or reconstructing the pump station to withstand a tsunami would involve investing large amounts of money in its' current location and would not completely eliminate the risk and are therefore not recommended.

The mitigation strategies are described in detail in the following sections.

4.2 Mitigation Strategies

Protection Berm and Flood-Proofing

The storm wave flooding hazard can be mitigated by constructing a protection berm between the pump station and the sea. This berm would be high enough such that the waves run-up the berm, but only a limited amount of water "overtops" the berm and floods the pump station.

A berm has already been constructed on the seaward side of the pump station. The existing berm has a lock block rear face and is fronted by riprap. Some vegetation (mostly grasses) has colonized the slope; it is unknown if the vegetation has self-colonized or was planted. The berm has an elevation of about 3.3 m CGVD and is 25 m long and extends roughly the length of the station (wet well and building). The effectiveness of this berm is greatly limited by trails at each end which allow "white water" unto the site.

There are several options for constructing the new berm:

Riprap: A riprap berm designed for the 2065 water level (i.e. the end of the station's service life) would have a crest elevation of approximately 4.8 m CGVD. This means the crest would be just below the existing roofline of the station. Assuming that the berm has a 2H:1V seaward slope and stepped lock-block rear slope (similar to the existing construction), it would be 10.5 m wide versus the existing width of approximately 3.5 m.

Figure 4-1: Riprap Slope Protection

Figure 4-2: Concrete Seawall

Concrete Seawall: A concrete seawall could have a steeper seaward slope than riprap, thereby reducing its footprint. However, the wave run-up on a concrete seawall would be higher than a riprap berm and therefore a concrete seawall would need to have a higher crest elevation. Given that the height of the riprap berm is probably the maximum that would be considered acceptable for the site (obstruction of views by the public being a consideration) a concrete seawall is not considered to be a viable option. Furthermore, a concrete seawall has low habitat value and an "urban" appearance which is not considered to be appropriate for the site.

Bioengineered Slope Protection: Bioengineered slope protection is constructed by combining vegetation, rocks, wood structures and geotextiles into a resilient shore protection. It has a natural appearance and the highest habitat value of the options considered. Bioengineered slope protection works well in low wave energy environments. In higher wave energy environments, more rock and "structure" needs to be integrated into the slope protection. For the Ocean Boulevard Pump Station site, a bioengineered slope protection is considered to be a viable option for the near term because the toe of the berm is at relatively high elevation (about 2 m CGVD). However, as the sea level rises, the slope protection will be under increasingly severe wave attack, and a bioengineered slope protection may be damaged. In our experience, bio-engineered slope protection is more expensive than riprap by a factor of approximately 2.

Figure 4-3: Bioengineered Slope Protection

Based on the foregoing, construction of a riprap berm has been assumed for the purposes of conceptual design. It is recommended that options to integrate bioengineered slope protection elements into the berm be investigated during detailed design. The factors which must be considered include cost, habitat value, aesthetics and the potential need to reconstruct the berm as the sea level rises.

Given that the toe of the riprap berm is at relatively high elevation (about 1.5 m CGVD which is equal to HHWLT), it is not expected to have adverse geomorphological impacts on the beach. However, geomorphological impacts will need to be monitored as the sea level rises and the Coburg Peninsula continues to erode as it transitions to a new equilibrium condition (more on this in the following section).

It should be noted that beach nourishment (placing sand and gravel on the beach fronting the pump station) has not been considered as an option because the existing natural beach is already highly effective at reducing wave run-up. Furthermore, beach nourishment cannot be effectively implemented on a small, pump station site level scale. Similarly, construction of an offshore reef to reduce wave heights at the site is not considered to be an attractive option due to environmental impacts, cost and potential geomorphological impacts (formation of a tombolo with sediment accretion of the south side and exacerbated erosion of the Coburg Peninsula on the north side).

A plan and cross-section for the proposed berm are provided in Figure 4-4. As previously discussed, the ultimate crest elevation berm is estimated to be 4.8 m CGVD. This crest elevation has been set based on the 1:50 year return period storm event. Two-percent of the waves in this storm event are expected to go over the top of the berm and therefore drainage though the berm (with check valves) will need to be provided or the site will need to be graded to the west to provide drainage into Esquimalt Lagoon. A freeboard allowance of 0.3 m has been included in the crest elevation.

The length of the berm is 50 m, and it would extend from the grass hill to the south to roughly the crosswalk at the north. The existing pathways to the beach on the south and north sides of the station would be blocked by the berm, and therefore access to the beach/road would be reduced. By the year

2065, “white water” flooding to the 2.45 m CGVD elevation is expected to occur multiple times per year, therefore during winter storms the station will frequently be the only dry location on the Coburg Peninsula and access will only be possible because it is located at the end of Lagoon Road.

The berm can be constructed in phases. If a phased construction approach is adopted, an initial crest elevation of 4.2 m CGVD is recommended (i.e. 0.9 m above the existing elevation). This is expected to provide protection until 2025; if the rate of sea level rise is less than expected (i.e. less than 0.25 m), raising the berm can be postponed.

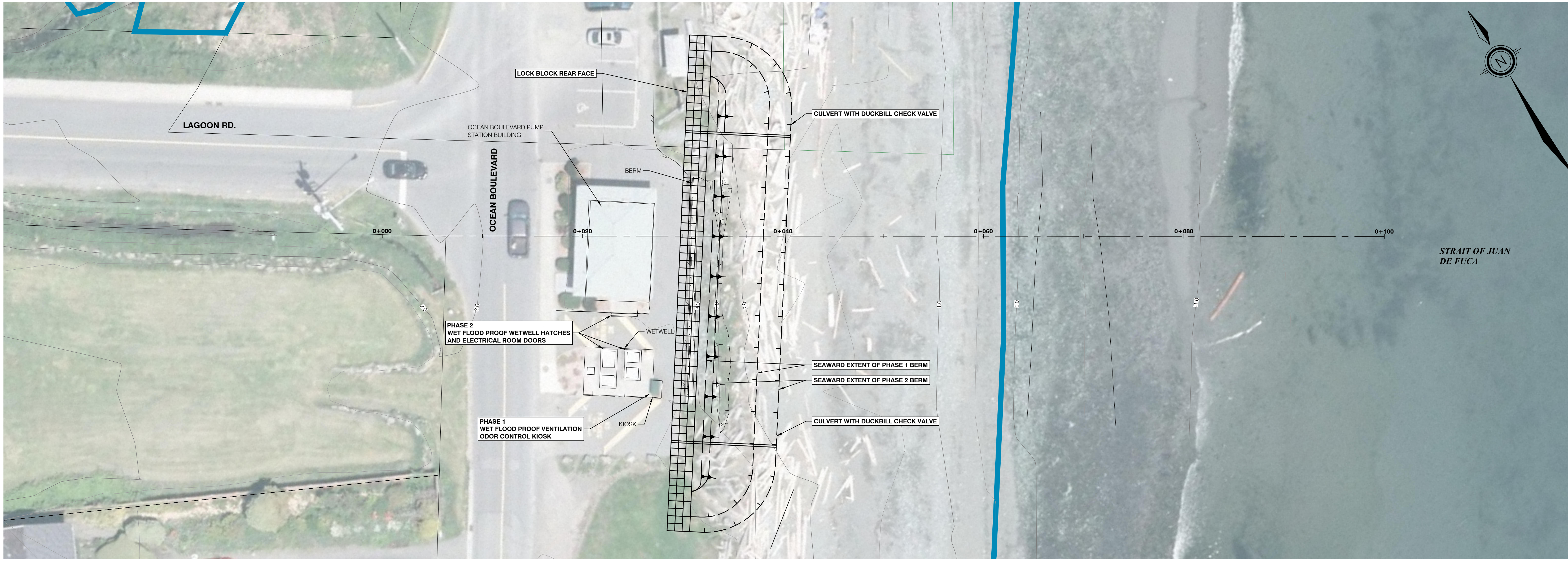
The Phase 1 berm has a width of approximately 9 m versus the current berm width of approximately 4 m. The Phase 2 berm has a width of 11 m. The toe of the berms will be at an elevation of approximately 1.5 m CGVD, which is approximately the elevation of high tide. As a result, it will not be possible to walk past the berm at the highest of tides and when there is significant storm surge.

The Class D, indicative cost for raising the berm to 4.8 m CGVD is $464,000 including 20% engineering and 30% contingency. The estimated cost of construction for Phase 1 (to 4.2 m CGVD) is estimated as $198,000 including 20% engineering and 30% contingency. The cost estimate does not include potential site regrading or culverts.

A detailed topographic survey of the road should be performed to confirm that water that overtops the beach north and south of the berm will not flood the station.

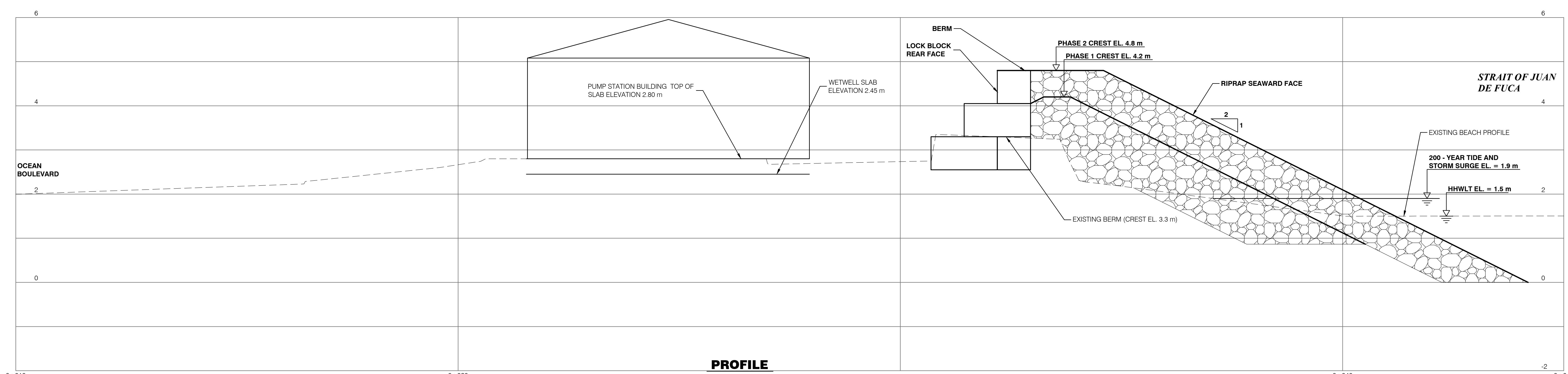
Flood-proofing the wet well hatch, ventilation/odour control kiosk and electrical room doors is required if the berm is constructed. The ventilation/odour control kiosk would need to be raised in Phase 1 and the wet well hatches and electrical room doors would need to be sealed in Phase 2. The rationale for this is that the ventilation/odour control kiosk is very low and contains electrical equipment and is therefore vulnerable to splashing whereas a station overflow due to water entering the wet well is most probable during “blue water” flooding which is not expected to a probable occurrence until later in the life of the station. Furthermore, the electrical room doors are at a higher elevation and should be flood-proofed as a precaution as water levels rise.

The Class D, indicative cost for the Phase 1 wet flood-proofing is $12,000 including 20% engineering and 30% contingency. The estimated cost of the Phase 2 wet flood-proofing is estimated as $89,000 including 20% engineering and 30% contingency.



PLAN
Scale: 1:200

0 2 (1:200) 10m



PROFILE
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NOTE:
1) ALL ELEVATIONS ARE TO CANADIAN GEODETIC VERTICAL DATUM

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consulting engineers

Seal:

Rev	Date	Des	Dwn	Chk	Description of Revision	Rev	Date	Des	Dwn	Chk	Description of Revision

CITY OF COLWOOD

OCEAN BOULEVARD PUMP STATION PROTECTION PLAN MITIGATION OPTIONS PROTECTION BERM

Project No. 2417.006
Group GENERAL
Drawing No. **FIGURE 4-4**
Rev.

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At Full Size, this border measures 520 mm x 800 mm

O:\2400-2499\2417-006\501-Drawings\b_Figures\FIGURE 4-4.dwg

Emergency Planning

Emergency planning is a potential method to mitigate the tsunami hazard. An emergency plan would outline the nature of the hazard being mitigated and the emergency response actions which must be undertaken in the short and longer term. A typical emergency response plan would outline actions to be taken in the first 24 hours after the disaster, the week following the disaster, the following month and so on as appropriate. Preparation of a detailed emergency plan for tsunami at the Ocean Boulevard pump station is outside the scope of this assignment; however a potential plan could be as follows:

First 24 hours: assess the damage at the pump station and modify the plan if needed;

First Week: install temporary pump, control kiosk and standby generator set;

First Month: bring a larger fuel tank for the generator set so the tank doesn't need to be filled as often and install fencing around the equipment for security. Clear debris from the site. Start making arrangements to bring in an electrical service connection so the standby generator set can be removed.

First Year: Begin design of a replacement pump station outside the sea level rise and tsunami flood hazard zones to be constructed as soon as possible.

The emergency response plan above is predicated on the assumption that the building will be completely destroyed but the wet well and connecting gravity sewers and forcemain will be intact. Some of the equipment that will be required to be on hand for the emergency plan are a temporary pump, diesel generator set and control kiosk. Consideration should also be given to facilitating the connection of the temporary pump to the forcemain.

The emergency plan should be integrated into municipal and regional emergency plans for other facilities.

The estimated cost to prepare an emergency plan is $20,000. Assuming that the emergency plan components consist of pumps, a control kiosk and generator set, the Class D indicative cost including 15% Engineering and 30% contingency is $157,000 which is a small fraction of the cost of moving the pump station as discussed in the next section. It should be noted that there would be an environmental impact if the station was destroyed by a tsunami, primarily due to sewage overflows prior to implementation of the emergency plan. As long as the emergency plan is carried out in a timely manner, this environmental impact will be of a short duration and relatively small compared to the widespread damage that the CSZ earthquake and tsunami can be expected to cause.

Moving the Pump Station

The least-risk mitigation strategy for the Ocean Boulevard Pump Station is moving the station outside the sea level rise and tsunami flood hazard areas. Based on the flood hazard assessment conducted as part of this project, moving the station is not expected to be required before its service life is reached (2065). However, if sea level rise progresses faster than projected, the station is destroyed by tsunami or erosion of the Coburg Peninsula threatens the pump station and cannot be economically mitigated (see below), relocating the station inland may be required. Moving the pump station may also be the preferred option if construction of a berm and flood-proofing is considered to be not feasible due to associated aesthetic impacts and potential environmental impacts (to be assessed during design).

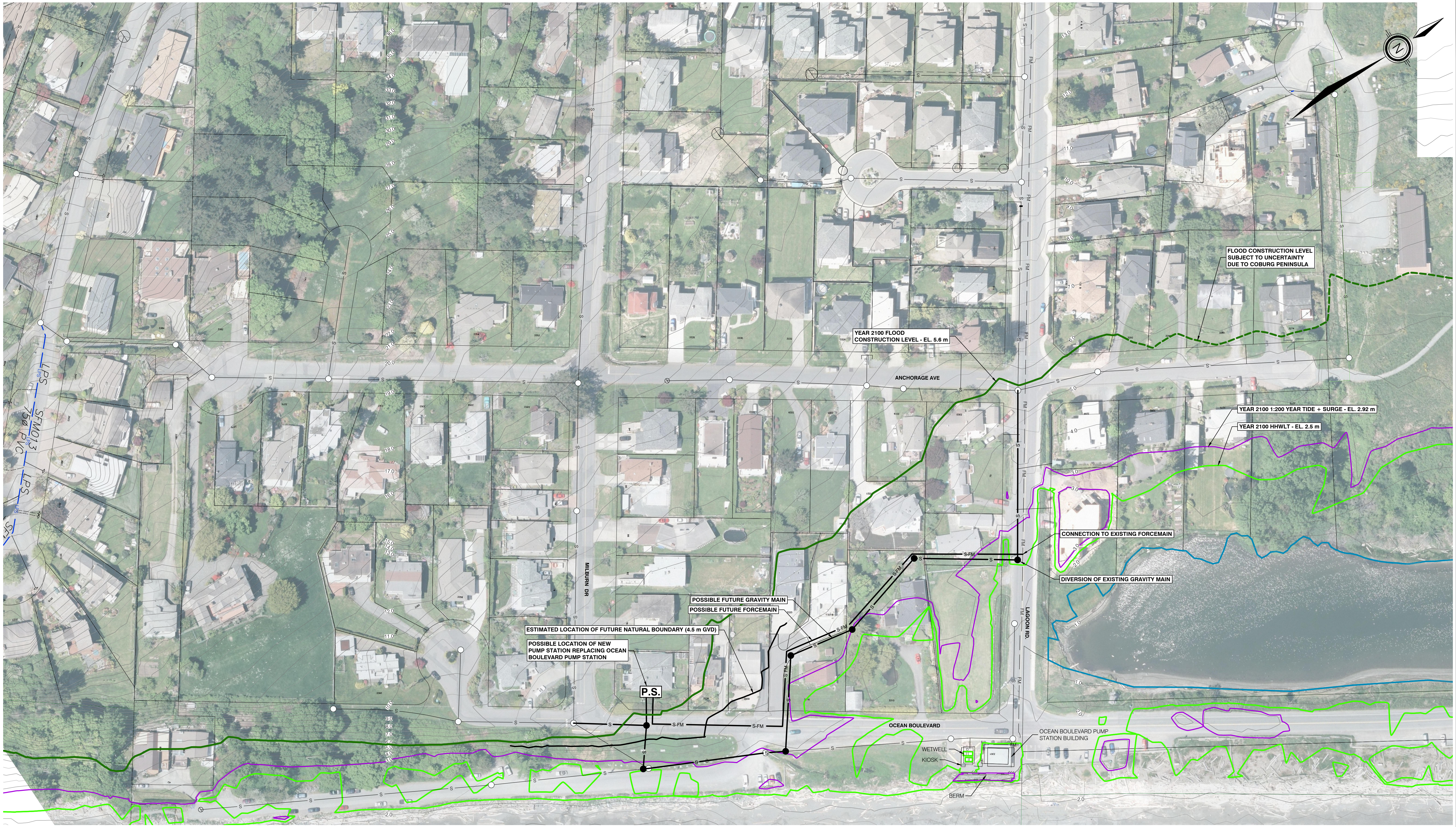
The station should be located outside both the sea level rise and the tsunami flood hazard areas. Flood construction levels (FCLs), calculated according to the requirements of the latest version of the draft amendment to the BC Provincial Flood Hazard Area Land Use Management Guidelines [1] are provided in Table 4-2 below. The flood hazard area associated with the governing elevation (year 2100 sea level rise- 5.6 m CGVD) is shown in Figure 4-6. The reconstructed pump station must be constructed landward of this area. It should be noted that the FCLs are based on the wave exposure and shoreline conditions in the area of the pump station site only and should not be considered indicative of the FCLs outside of this area. The FCLs shown outside of the pump station site on Figure 4-5 have been used for the purpose of this assessment only to determine potential areas for the relocation of the pump station and should not be used for other purposes. In particular, the FCLs in the area protected by the Coburg Peninsular are subject to uncertainty due to the different wave exposure in this area.

Table 4-2: Flood Construction Levels

Scenario	Flood Construction Level (m, CGVD)	Components Included
Storm + Sea Level Rise	5.6	• 1:200 Year Water Level (Tide + Storm Surge) • Allowance for Sea Level Rise to 2100 • Allowance for Regional Uplift • Estimated Wave Effects in the 1:200 Year Storm • Freeboard of 0.6 m
Tsunami	5.1	• CSZ Tsunami Wave • Allowance for Sea Level Rise to 2100 • Ground Subsidence • Factor for Public Safety

A potential location for the reconstructed pump station is shown in Figure 4-5; also shown on this figure are relocated sewers and the year 2100 estimated location of HHWLT (2.5 m CGVD) and the 1:200 year tide plus storm surge (2.92 m CGVD). Gravity flow to the relocated pump station is feasible and the wet well would be approximately 8 m deep. The alignment of the relocated sewer has been selected to keep the infrastructure above future high tide.

A Class D, indicative cost estimate for moving the pump station and reconfiguring the associated sewer infrastructure is $2.6 million including 20% engineering and 30% contingency. It should be noted that these costs do not include land acquisition.



NOTE:
1) ALL ELEVATIONS ARE TO CANADIAN GEODETIC VERTICAL DATUM

PLAN
Scale: 1:750

0 10 (1:750) 40m

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consulting engineers

Seal:

Rev	Date	Des	Dwn	Chk	Description of Revision	Rev	Date	Des	Dwn	Chk	Description of Revision

CITY OF COLWOOD

OCEAN BOULEVARD PUMP STATION PROTECTION PLAN MITIGATION OPTIONS MOVING THE PUMP STATION

Project No. 2417.006
Group GENERAL
Drawing No. FIGURE 4-5
Rev.

4.3 Additional Considerations

Erosion of the Coburg Peninsula

The Coburg Peninsula is a natural spit formed by wave-induced longshore sediment transport from south to north. The spit is breached at its' northern end by a channel that connects to Esquimalt Lagoon.

Figure 4-6: Sand and Gravel Escarpment South of the Coburg Peninsula

The geomorphology of the spit has been shaped by historical changes in the availability of sediment in the littoral zone. One the largest sources of sediment is a gravel and sand escarpment located approximately 1 km south of the peninsula (Figure 4-6). The erosion of this escarpment adds sediment to the littoral zone which is then carried north by wave-induced currents and deposited on the Coburg Peninsula. The land inshore of the escarpment was used for a gravel mining operation for much of the 20th Century. The amount of sand in the littoral zone increased from about 1910 to 1970 likely due to dumping of waste sand on the foreshore as a result of the gravel mining operations. This additional sand appears to have deposited on the Coburg Peninsula, thereby growing the beach.

Since the dumping of sand from the gravel pit ceased in the 1970s, progressive erosion of the Coburg Peninsula has occurred. This is evidenced by reported erosion at the abutment of the Ocean Boulevard Bridge and erosion at the DND property at the north end of the peninsula. This erosion can be expected to continue until a new equilibrium condition is reached, which will likely include continued erosion of the peninsula and "coarsening" of the beach materials (sand gradually replaced by gravel and cobbles) due to the reduction of sand in the littoral zone. The extent of erosion of the peninsula could be increased due to reductions in the availability of sediment due to shoreline hardening in areas south of the pump station.

Several studies have been undertaken related to the erosion of the peninsula. Some of the erosion mitigation strategies that have been proposed include riprapping the entire peninsula or a portion of the peninsula, construction of a series of groynes or offshore breakwaters and ongoing beach nourishment. Several pilot projects involving vegetation of the spit with native species in order to stabilize the peninsula and improve habitat have been performed. Each of these proposed options has varying levels of effectiveness and advantages and disadvantages.

Given the enormous cost of preventing the erosion of the entire peninsula and the fact that construction of shore protection works can have unintended and undesirable consequences (e.g. erosion elsewhere), the City has adopted a “watch and wait” strategy with regard to the management of erosion at the peninsula. Spot repairs have been made to the Ocean Boulevard bridge abutments and localized storm damage to Ocean Boulevard have been performed but in general the Coburg Peninsula is being left to revert to a new morphology that is in equilibrium with its environment.

Impact on the Pump Station

Based on the foregoing, the rate of erosion of the Coburg Peninsula and the extent to which it affects the Ocean Boulevard Pump Station must be considered in the mitigation strategy. Erosion at the pump station site, which cannot be mitigated economically or without unacceptable consequences may necessitate that the station be moved in advance of our projections based on flooding hazards.