4.2.2 – HYDRAULIC PROCESS AND ALTERATION REPORT

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Memorandum

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Subject	CP Track Expansion – Viterra Cascadia - Hydraulic Process and Alteration Report
Date	14 June 2019
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Document Ref:	103396-02-MEM-001

1.1 Introduction

Canadian Pacific Railway (CP) is proposing to conduct rail track extension activities near the Viterra Cascadia Terminal on Burrard Inlet, Vancouver, BC, to facilitate movement of additional grain product to this terminal. The proposed track extension involves widening of the existing CP rail embankment with the placement of clean, engineered, fill material extending in to the Burrard Inlet. Furthermore, to offset the potential loss of intertidal and subtidal fish habitat in the marine environment twenty-one (21) artificial reef habitats are proposed seaward of the embankment.

As part of the Project & Environmental Review Application to Port of Vancouver (VFPA) there is a requirement to investigate the impacts of the proposed placement of material in the Burrard Inlet on local hydraulics. This memorandum provides a review and summary of the available information and assessment of the local hydraulics to support the application submission. The proposed Works occur within the Second Narrows Traffic Control Zone (TCZ-2).

1.2 Site Information

The tidal range at the Second Narrows Bridge is approximately 5.0 m with mean water level at approximately +3.0 m CD. The tides are summarised in Table 1 based on the values presented in the AECOM design drawings and supplemented with additional information from the Canada Hydrographic Service chart.

Table 1 Tidal information applicable to the proposed site (Source: AECOM Drawing 60587181-C-302 unless noted†)

Description	Height above Chart Datum (m CD)	Height above Geodetic Datum (m GD)
Higher High Water Large Tide (HHWLT)	+5.070	+2.095
Higher High Water Mean Tide (HHWMT)	+4.370	+1.395
Mean Water Level (MWL)	+3.020	-0.045
Lower Low Water Mean Tide (LLWMT) †	+1.1	-1.875
Lower Low Water Large Tide (LLWLT) †	+0.0	-2.975

† Chart 3494 Vancouver Harbour Central Portion, Canada Hydrographic Service

Based on publicly available data the depth of the Burrard Inlet adjacent to the proposed embankment is up to 33 m deep at low tide (LLWLT) and is approximately 510 m wide.

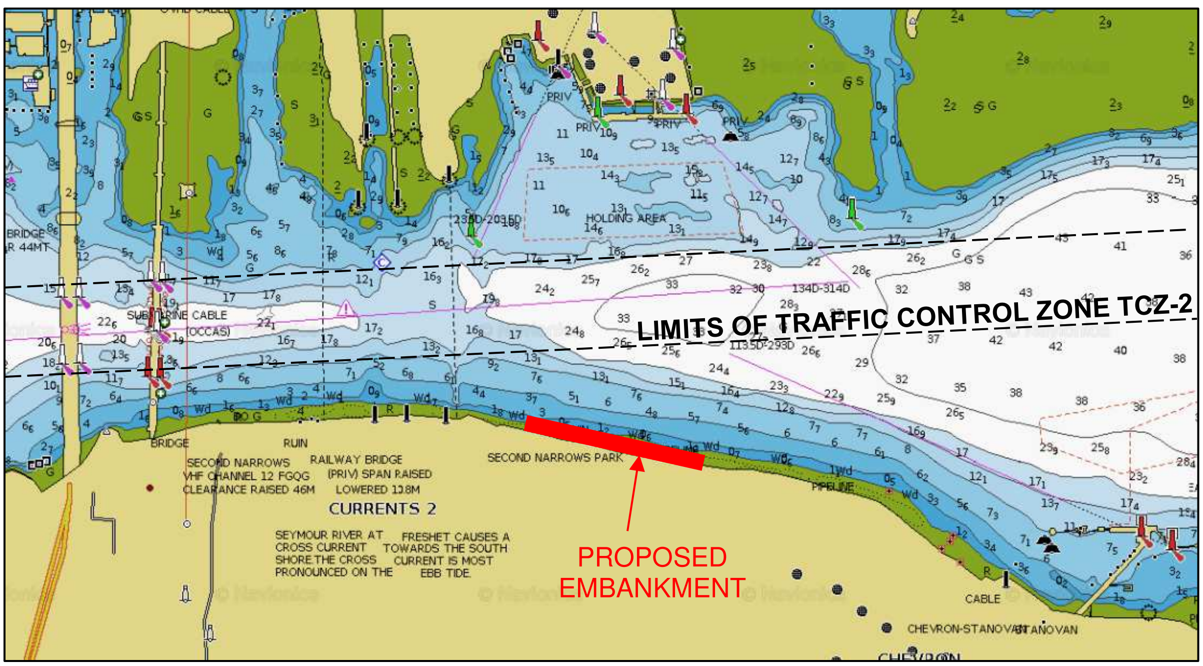

Figure 1 Hydrographic chart (Source: Navionics.com) showing Burrard Inlet east of Second Narrows Bridge and Traffic Control Zone (TCZ-2)

1.3 Method

To investigate the impact on the hydrodynamics through the Burrard Inlet consideration is given to the following equation for open channel flow:

$$Q = \overline{V}A$$

Where Q = flow rate (m^3/s), $\overline{V}$ = average velocity (m/s) through the channel cross section, and A = cross sectional area (m^2).

For this assessment, it is assumed that the flow rate, Q, through the channel is unchanged by the construction of the road as the hydraulic head upstream and downstream of the affected section, which is driven by the tides, will remain unaffected. Flows in all areas of interest for this study are expected to be subcritical for all stages of the tide.

1.4 Hydraulic Assessment

1.4.1 Existing Channel

The section of the channel with the smallest cross-sectional area will have the highest velocity which is the key parameter when considering the susceptibility of the channel to erosion and geomorphological changes. Spot levels and distances have been obtained from Canadian Hydrographic Services (CHS) Chart 3494 Vancouver Harbour Central Portion for the two alignments shown in Figure 2. By observation the channel is shallower towards the western end of the proposed embankment and therefore will have a smaller overall cross-sectional area. Alignment 1 is perpendicular to the flow which is primarily east-west and Alignment 2 is perpendicular to the shoreline at the work site.

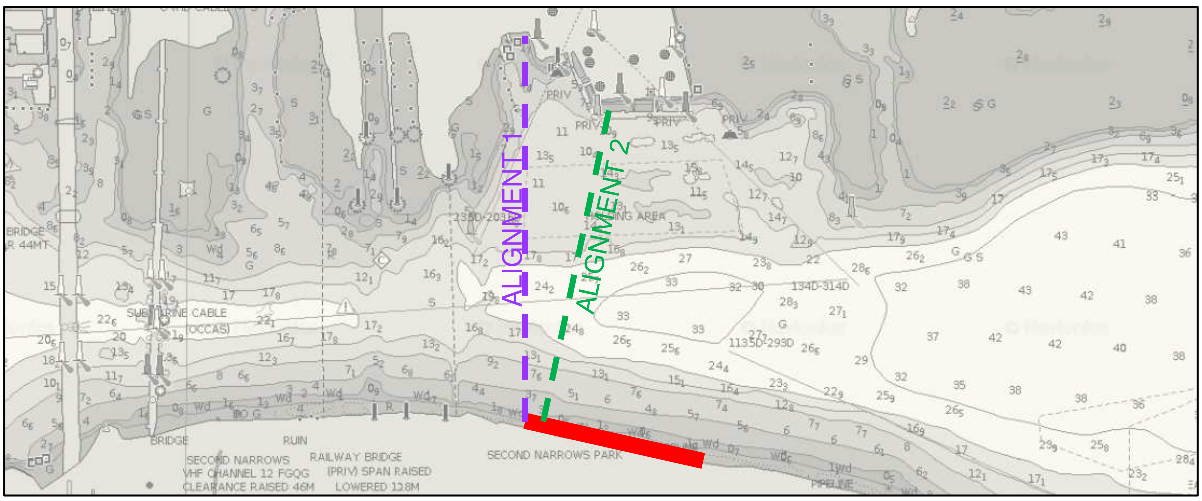

Figure 2 Alignments selected to assess impacts on the hydraulics of the channel

The channel cross sections (looking west) are shown in **Error! Reference source not found.**.

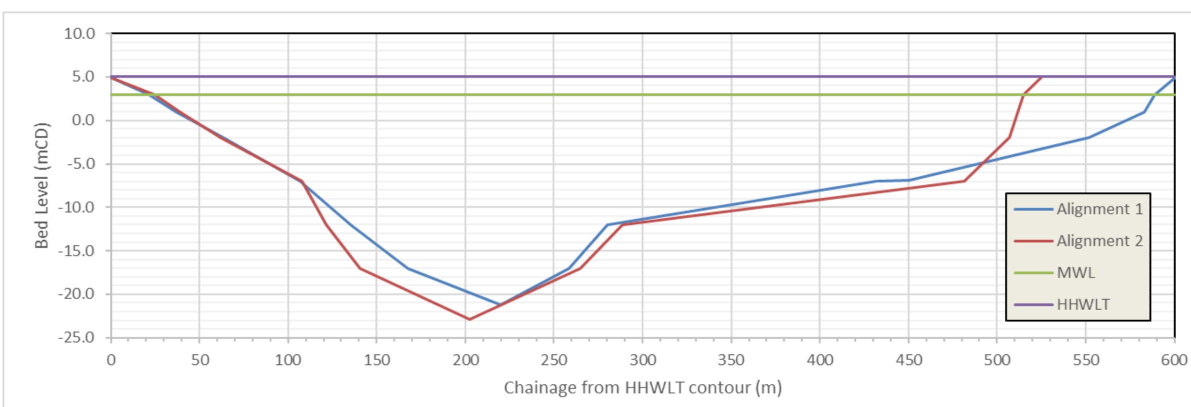

Figure 3 Typical channel cross section at Alignment 1 and Alignment 2

The calculated flow areas at LLWLT (Lower Low Water Large Tide), Mean Water Level (MWL) and HHWLT (Higher High Water Large Tide) for both alignments of the existing channel are summarised in Table 2.

Table 2 Flow cross-sectional areas of existing channel for Alignment 1 and 2 at MWL and HHWLT

Reference Alignment	Cross-Sectional Area of Flow at LLWLT	Cross-Sectional Area of Flow at MWL	Cross-Sectional Area of Flow at HHWLT
Alignment 1	5,070 m^2	6,700 m^2	7,870 m^2
Alignment 2	5,415 m^2	6,830 m^2	7,850 m^2

As can be seen from Table 2, Alignment 1 has the smallest flow area of the two sections at LLWLT and MWL, but at HHWLT Alignment 2 has a marginally smaller flow area.

1.4.2 Proposed Embankment Fill

The typical track fill section provided on AECOM drawing 60587181-C-302 indicates that the existing channel bed will be initially excavated below MWL and then backfilled by the embankment and riprap protection. This will allow the toe of the embankment protection to be keyed in for stability, however, it is expected that the excavated area in front of the toe will infill naturally over time. As shown by the blue trapezoid in Figure 4 there will be a small increase (<3 m^2) in the cross-sectional area at or below MWL post construction.

Placement of the embankment fill above MWL will reduce the flow area accordingly, up to a maximum reduction at the highest water level. At HHWLT it is estimated that the typical reduction in cross-sectional area will be approximately **77.4 m^2**. This area is indicated in red in Figure 4.

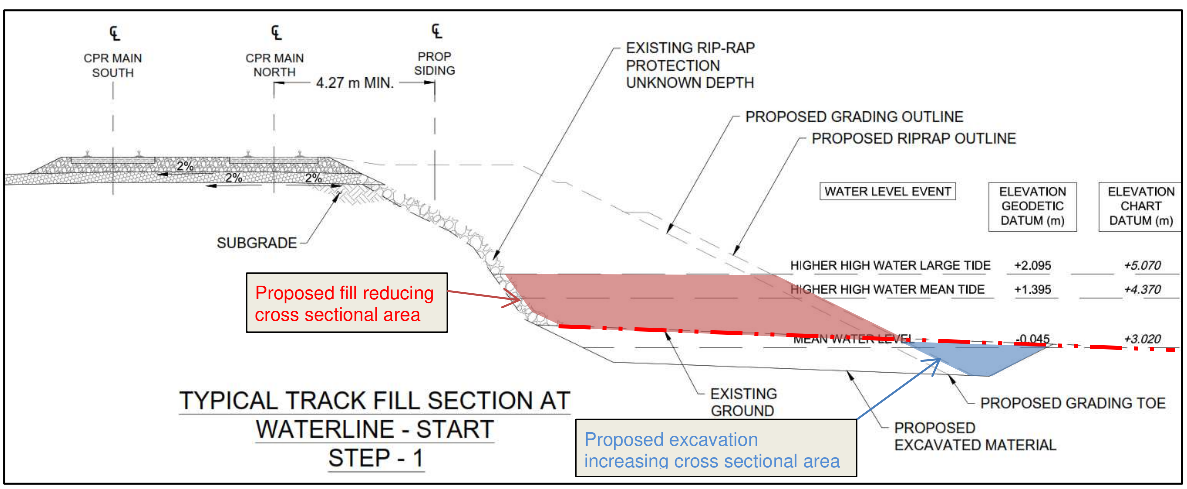

Figure 4 Typical design cross-section (AECOM Drawing 60587181-C-302)

1.4.3 Shallow Rock Reefs

In addition to the embankment, the placement of shallow rock reefs also has potential to reduce the cross-sectional area. The reefs comprise of approximately 1 m diameter boulders placed in clusters of 23 in a pattern of 3 x 5 boulders in the bottom layer with 2 x 4 boulders in the upper layer potentially placed on a cobble blanket to prevent scour. The reefs will be placed such that they are submerged at MWL but some may be partially dry at LLWMT.

The proposed layout, configuration and profile of the proposed reefs is shown in Figure 5.

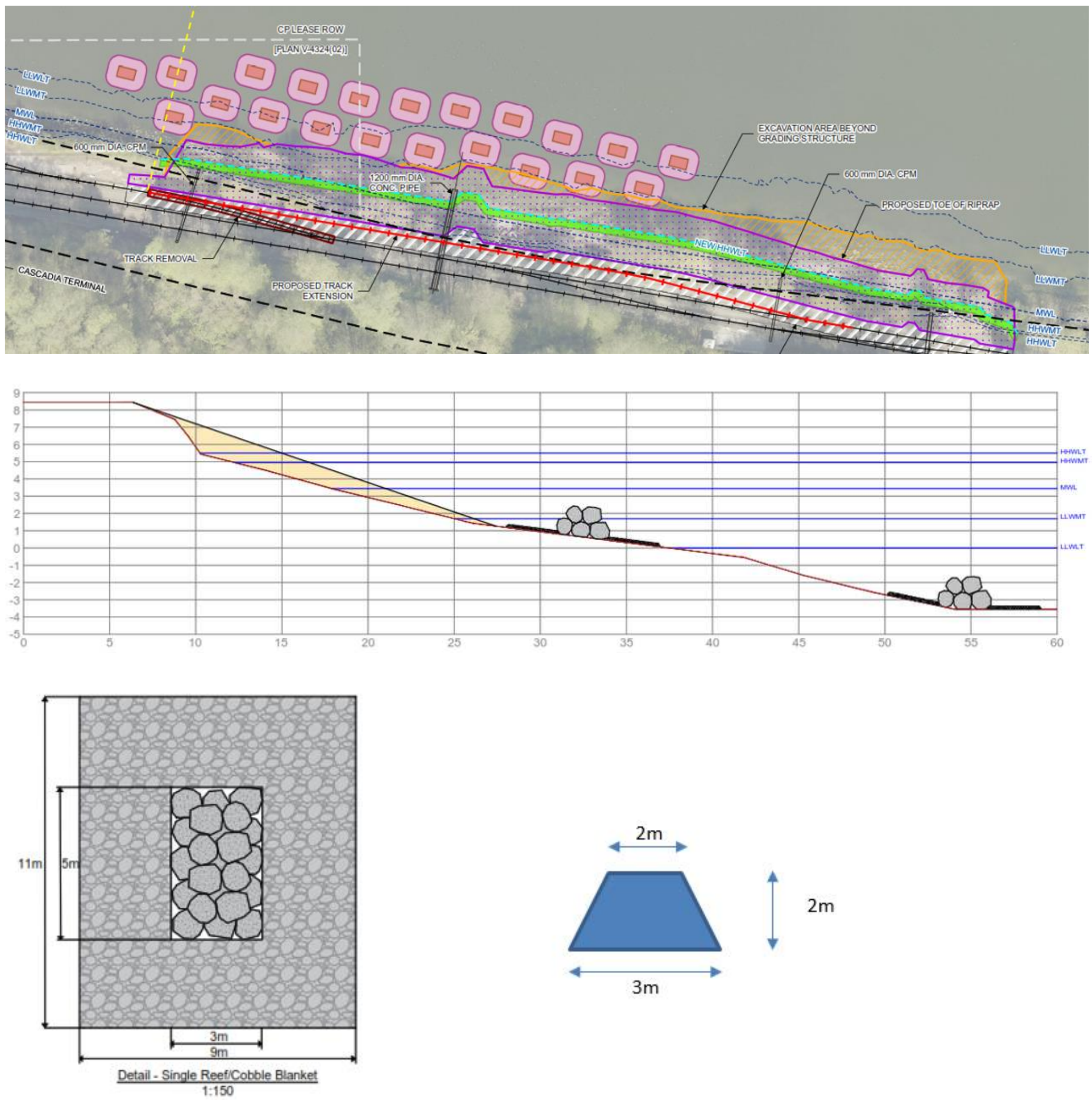

Figure 5 Layout and configuration of offsetting reefs

The most impact to the flow cross-sectional area will be when there are 2 reefs present within the profile. As a conservative estimate of the impact area the voids within the reefs are ignored and the total area per unit metre of the reefs, including the cobble blanket, is **13.6 m^2**. By observation, at LLWLT there would be only one reef cluster reducing the flow area, which is **6.8 m^2**.

1.4.4 Flow Area Reduction and Effect on Average Velocity

The expected maximum cross-sectional area of the proposed embankment and reefs combined is calculated to be **91.0 m^2**. This excludes the excavated material at the toe of the revetment as it is expected that this area would infill reasonably quickly after construction.

- At LLWLT the percentage reduction in cross-sectional area, due to a single reef, is **0.13%**.
- At MWL the percentage reduction in cross-sectional area, due to the reefs only, is **0.20%**.
- At HHWLT the percentage reduction in cross-sectional area, due to the reefs and embankment is approximately **1.15%** for both Alignment 1 and Alignment 2.

As the average velocity of the flow is inversely proportional to the cross-sectional area for the same flow rate, the average velocity increases as the area decreases. The relative increase in average velocity through the channel is therefore estimated to be 0.13% at LLWLT, 0.2% at MWL and increasing up to 1.15% at HHWLT.

It is noted that the flow disturbance due to the reefs and embankment would be stronger in the immediate vicinity of the embankment and reduce towards the channel centre and north bank. Consequently, the change in current velocity at distances greater than approximately 3x embankment width from the boulder reef is expected to be negligible. Local bed scour at the toe of the embankment and around the reef boulders will be mitigated by design.

1.5 Discussion

Consideration has been given to two channel cross sections to determine a realistic but conservative estimate of the potential impacts on hydraulics within the Burrard Inlet due to the construction of the widened embankment and placement of shallow water rock reefs near the Viterra Cascadia Terminal. It is expected that the average velocity of the hydraulic flow through the channel section at the embankment could increase by just over 1% during HHWLT and approximately 0.2% at MWL. Further, the flow disturbance is expected to be primarily confined to the areas adjacent to the embankment and the boulder reefs. These are designed to resist scour as a result of their interaction with the flow.

A 1% change in average velocity of the tidal flow in the channel adjacent to the proposed embankment for a relatively small duration in the tidal cycle is not expected to result in a measurable impact on the overall morphology of the Inlet. Furthermore, the channel flow velocity will revert to existing velocities both upstream and downstream of the project area.

Based on the assessment, at water levels of MWL and lower (i.e. approximately 50% of the time) there will be negligible change to the channel hydraulics due to the construction of the proposed embankment. At water levels above MWL the percentage increase in average velocity through the section of interest varies gradually increasing to approximately 1% at HHWLT. As noted, it is expected that the increased velocity will be localised near the embankment and so the average velocity change within the central area of the channel will be less than 1%. The effect on flow hydraulics, if any, within TCZ-2 is therefore expected to be unnoticeable for navigational purposes.