Appendix IR2020-2.1-A

Hemmera Memo: RBT2 – Potential project footprint reduction and reduced effects to fish and fish habitat

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Re: **RBT2 – Potential Project Footprint Reduction and Reduced Effects to Fish and Fish Habitat**

1.0 INTRODUCTION

The Roberts Bank Terminal 2 Project (RBT2 or project) is a proposed new container terminal located in Delta, B.C. The project consists of three main components: (1) a new multi-berth marine container terminal, (2) a widened causeway, and (3) an expanded tug basin.

In response to an information request (IR) from the minister of Environment and Climate Change Canada dated August 24, 2020[1], to describe any technically feasible project design options that would reduce effects to fish and fish habitat[2], the Vancouver Fraser Port Authority (port authority) evaluated further potential project design options. Based on this additional work, a potential reduction was identified in the size of the current proposed project footprint (assessed in the project's Environmental Impact Statement (EIS)[3] and in the project construction update[4]). A potential reduction in the current proposed project footprint would avoid the permanent destruction[5] of habitats within the potential footprint reduction area. This in turn

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[1] CIAR Document #2067 From the Minister of Environment and Climate Change to the Vancouver Fraser Port Authority re: Information Request. Available at https://www.ceaa-acee.gc.ca/050/documents/p80054/135827E.pdf.

[2] Fish are defined "as in Section 2 of the *Fisheries Act* and include shellfish, crustaceans, and other marine animals." Fish habitat is defined "as in Section 34(1) of the *Fisheries Act* and includes spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes (i.e., food and forage)."

[3] CIAR Document #181 Roberts Bank Terminal 2 Project – Environmental Impact Statement, Volume 1, Sections 4 (Project Description) and 5 (Alternative Means of Carrying out the Project). https://www.ceaa-acee.gc.ca/050/documents/p80054/101388E.pdf.

[4] CIAR Document #1210 From the Vancouver Fraser Port Authority to the Review Panel re: Project Construction Update. https://www.ceaa-acee.gc.ca/050/documents/p80054/122934E.pdf.

[5] Fisheries and Oceans Canada interprets destruction of fish habitat as any permanent change to fish habitat that completely eliminates its capacity to support one or more life processes of fish.

would leadto a reduction in the overall direct (footprint-related) effects on primary[6] and secondary[7] productivity due to loss of fish and fish habitat at Roberts Bank and a reduction in the indirect effects to fish species or groups comprising the food web of each habitat type within the potential footprint reduction area. Hemmera Envirochem Inc. (Hemmera) was tasked with describing the effects to fish and fish habitat that would be reduced with a potential reduction in the current proposed project footprint. This report summarizes our findings.

2.0 POTENTIAL PROJECT FOOTPRINT REDUCTION

Following evaluation of project design options to reduce effects to fish and fish habitat, a potential reduction was identified in the current proposed project footprint, including the marine terminal and widened causeway project components, by up to a total of 14.4 hectares (ha; **Table 2-1**). For the purposes of this assessment, we assumed the maximum possible project footprint reduction of 14.4 ha (**Table 2-1**).

Table 2-1 Potential footprint reduction (in hectares; ha) by project component

Project component	Potential footprint reduction (ha)	Optimizations
Marine terminal	10.3	Focused on the north side of the marine terminal
Causeway (seaward end)	2.3	Focused on reduction related to re-design of rail infrastructure
Causeway (shoreward end)	1.8	
Total	**14.4**	-

3.0 METHODS

We evaluated using a semi-quantitative approach the effects to fish and fish habitat that would be reduced with the maximum possible footprint reduction of 14.4 ha. Direct (footprint-related) effects to fish habitat that would be reduced were described quantitatively (**Section 3.1**). Potential reduction in indirect effects to fish that comprise the food webs of the habitat types within the footprint reduction area were described qualitatively (**Section 3.2**). In this report, direct and indirect effects that would be reduced focused on marine vegetation, fish, and invertebrate representative species or groups that were selected to structure the marine biophysical effects assessment presented in the project's EIS.

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[6] Primary productivity refers to the rate of organic carbon production by marine vegetation (e.g., eelgrass, marsh) using sunlight through photosynthesis.

[7] Secondary productivity refers to the rate of biomass generation by consumer organisms via ingestion and assimilation of organic matter.

3.1 Potential reduction in direct effects to fish habitats

We quantified the potential reduction in the direct (footprint-related) effects to fish habitats by quantifying the primary (i.e., vegetative biomass) and secondary (i.e., biomass of sessile infaunal invertebrate communities) productivity associated with marine habitat types[8] within the potential footprint reduction area. First, we determined the extent (ha) of these marine habitat types (**Section 3.1.1**). Then, we calculated the primary and secondary productivity (in tonnes (t)) associated with each habitat type within the potential footprint reduction area (**Section 3.1.2**). Direct effects that would be reduced were described on an areal (ha) and productivity (t) basis.

3.1.1 Extent of fish habitats within the potential footprint reduction area

We quantified the areal extent of marine habitat types within the current proposed project footprint and the potential reduced footprint by overlaying these footprints on the 2019 Roberts Bank habitat map and exporting the resulting polygons using ArcGIS 10.5. The 2019 Roberts Bank habitat map depicts vegetative and bare habitats at Roberts Bank that were mapped in 2019 during empirical surveys undertaken to provide current (2019) estimates of biomass at Roberts Bank in support of the development of the project's application for a *Species at Risk Act* (*SARA*)-compliant *Fisheries Act* Authorization (FAA). The extent (ha) of each habitat type within the potential footprint reduction area was calculated as the difference between the overlap with the current proposed project footprint and the overlap with the potential reduced footprint.

Using the same method for marine habitat types detailed above, we also calculated the extent (ha) of existing orange sea pen (*Ptilosarcus gurneyi*) beds within the potential footprint reduction area. The distribution of orange sea pens was surveyed during empirical surveys undertaken to provide current (2019) estimates of biomass at Roberts Bank in support of the project's SARA-compliant FAA application.

We also calculated the extent (ha) of habitat within the potential footprint reduction area predicted to be suitable for Pacific sand lance (*Ammodytes hexapterus*) burying and Dungeness crab (*Metacarcinus magister*) life stages (i.e., juvenile, adult, gravid[9]). Habitat suitability for Pacific sand lance and Dungeness crab life stages was based on outputs of a habitat suitability modelling study undertaken by Hemmera (2014a) to support the biophysical effects assessment presented in the project's EIS. Similar to methods described above for marine habitat types, we overlaid the polygons of predicted habitat suitability for Pacific sand lance and Dungeness crab life stages (Hemmera 2014a) above the current proposed and potential reduced project footprints and calculated the resulting difference.

3.1.2 Productivity of fish habitats within the potential footprint reduction area

We calculated using a quantitative approach the potential reduction in the loss of primary and secondary productivity associated with each of the marine habitat types within the potential footprint reduction area. For primary productivity (t), we multiplied the areal extent (ha) of each of the habitat types within the potential footprint reduction area by the empirical biomass input (t/ha; calculated from literature and field surveys undertaken for the project in 2012 and 2013; Hemmera 2014b) for each vegetative habitat type. Bare habitats (i.e., sand/mud, cobble/gravel) do not have associated primary productivity values as they are classified by the lack of vegetation and are characterized by the dominant substrate type. Where biomass inputs were not available for sparse habitat types (e.g., sparse eelgrass), we multiplied the

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[8] Marine habitat types include marine vegetative (i.e., intertidal marsh, native and non-native eelgrass) and bare habitats (i.e., sand/mud, rock, gravel/cobble) and not terrestrial grass or unclassified upland areas.

[9] Gravid life stage refers to carrying eggs or developing young.

biomass of the equivalent dense habitat (e.g., dense eelgrass) by 0.3 as a correction factor, since sparse habitat types were classified as less than 30% cover (Hemmera 2014c). Since primary productivity is not even throughout the year and varies by species, we multiplied the primary productivity of each habitat type by a correction factor to account for seasonality and to yield an annualized estimate of primary productivity of habitats within the potential footprint reduction area. These correction factors for growing season were previously determined for parameterizing the Roberts Bank ecosystem model and are based on the percent of the year that the vegetation has seasonal growth at Roberts Bank: native eelgrass (*Zostera marina*) 0.75 or 75% of the growing season, non-native eelgrass (*Zostera japonica*) 0.4 or 40% of the growing season, intertidal marsh 0.6 or 60% of the growing season (Hemmera 2014b). The seasonal correction factor for the habitat type consisting of a mix of native and non-native eelgrass was calculated as the mean of both individual habitat types, 0.58 or 58% of the growing season. Productivity was also calculated to be proportional to the biophysical local assessment area (LAA; Figures 11-1, 12-1, and 13-1 in the EIS) by dividing the annualized productivity values by the size of the biophysical LAA (i.e., 5,468.05 ha).

For secondary productivity (t), we multiplied the areal extent (ha) of each habitat type within the potential footprint reduction area by the biomass input (t/ha) of the following sessile representative species or groups: macrofauna, meiofauna, infaunal bivalves, and orange sea pens. Empirical biomass inputs were calculated from additional empirical surveys undertaken to provide current (2019) estimates of biomass at Roberts Bank in support of the development of the project's *SARA*-compliant FAA application. Secondary productivity was also calculated to be proportional to the biophysical LAA by dividing the annualized productivity values by 5,468.05 ha.

3.2 Potential reduction in indirect effects to fish

A potential project footprint reduction would also result in a reduction in indirect effects to fish. The fish habitat within the footprint reduction are would no longer be destroyed and would be available to fish to perform important life functions (e.g., rearing, spawning). Additionally, reduction in the loss of secondary productivity would make prey, such as macrofauna, meiofauna, and bivalves, available to fish. We described these indirect effects qualitatively by habitat type, based on information drawn from literature and empirical surveys undertaken at Roberts Bank in support of the project (e.g., Archipelago 2014a,b).

4.0 RESULTS

A potential decrease in the current proposed project footprint would avoid the permanent destruction of up to 14.4 ha of habitat within the potential footprint reduction area. This would in turn lead to a reduction in direct (footprint-related) effects on primary and secondary productivity at Roberts Bank as well as a reduction in indirect effects on representative fish species or groups comprising the food web of each habitat type within the potential footprint reduction area. The effects on fish and fish habitat that would be reduced are described in detail below.

4.1 Potential reduction in direct effects to fish habitats

The extent of marine habitat types within the potential footprint reduction area is shown in **Table 4-1** and in **Figures 1** to **3**. A reduction in primary and secondary productivity by habitat type that would be achieved with the maximum possible footprint reduction is shown in **Table 4-1** and **Table 4-2**, respectively, and summarized in Table 4-3. The extent of habitat predicted to be suitable for Pacific sand lance and Dungeness crab life stages within the potential footprint reduction area is summarized in **Table 4-4** and shown in **Figures 4** to **7**.

4.1.1 Potential reduction in direct effects to primary and secondary productivity of fish habitats

Overall, a potential reduction in the project footprint of up to 14.4 ha would avoid the permanent destruction of up to 4.67 ha of vegetative habitat (i.e., non-native eelgrass: 2.42 ha; intertidal marsh: 1.52 ha; native eelgrass: 0.73 ha) and 9.71 ha of bare habitat (i.e., sand/mud: 9.69 ha; rock: 0.02 ha; **Table 4-3**). The overall direct effect on primary productivity would be reduced by 25.40 t (0.84 t of primary productivity and 24.56 t of secondary productivity; **Table 4-3**). The largest reduction in overall direct effects to productivity that could be achieved with a potential project footprint reduction of up to 14.4 ha is tied to the habitat types with the largest reduction in areal extent: subtidal bare sand/mud (9.43 t), followed by intertidal non-native eelgrass (7.86 t) and intertidal marsh (5.29 t; **Table 4-3**).

Intertidal marsh at Roberts Bank consists of both salt and brackish marsh, with the distribution and plant community structure largely influenced by elevation, and by correlation inundation time, salinity, and sediment composition (Hutchinson 1982). Direct effects to the primary productivity of intertidal marsh that would be reduced were quantified based on marsh elevation (i.e., high and low) and density (i.e., sparse or dense) as categorized for the 2019 Roberts Bank habitat map (**Table 4-1**). Very little high marsh runs along the current proposed project footprint; thus, a potential project footprint reduction would avoid the permanent destruction of only 0.04 ha of dense high marsh along the shoreward end of the causeway, or an annualized primary productivity of 0.34 t (**Table 4-1**, **Figure 1**). There is no sparse high marsh present within the potential footprint reduction area. The potential project footprint reduction would also avoid the permanent destruction of 1.49 ha of low marsh (0.14 ha of dense low marsh at the shoreward end of the causeway and 1.35 ha of sparse low marsh between the shoreward and seaward ends of the causeway), which would equate to an annualized primary productivity of 0.04 t (0.01 t dense and 0.03 t sparse marsh; **Table 4-1**, **Figure 1** and **Figure 2**). The secondary productivity associated with a potential reduction of 1.52 ha of intertidal marsh would be 4.91 t (macrofauna: 1.15 t, meiofauna: 0.60 t, and infaunal bivalves: 3.17 t; **Table 4-2**).

The distribution of native eelgrass at Roberts Bank ranges from intertidal to shallow subtidal (i.e., below 0 metres (m) Chart Datum (CD)); therefore, the direct effects to primary productivity were quantified based on habitat zone (i.e., intertidal and subtidal) and density (i.e., sparse and dense) as characterized for the 2019 Roberts Bank habitat map (**Table 4-1**). In the intertidal zone, a potential project footprint reduction would avoid the permanent destruction of 0.48 ha of sparse native eelgrass, or an annualized primary productivity of 0.15 t of sparse eelgrass (**Table 4-1**, **Figure 3**). There is no dense native eelgrass within the intertidal portion of the potential footprint reduction area. The secondary productivity associated with a potential reduction of 0.48 ha of intertidal native eelgrass would be 1.55 t (macrofauna: 0.36 t, meiofauna: 0.19 t, and infaunal bivalves: 1.00 t; **Table 4-2**). In the subtidal zone, a potential footprint reduction would avoid the permanent destruction of 0.24 ha of native eelgrass (0.24 ha of dense eelgrass and <0.01 ha of sparse native eelgrass), which would equate to an annualized primary productivity of 0.25 t (**Table 4-1**, **Figure 3**). The secondary productivity associated with a potential reduction of 0.24 ha of subtidal native eelgrass would be 0.24 t (macrofauna: 0.08 t, infaunal bivalves: 0.17 t; **Table 4-2**).

Non-native eelgrass grows at a tidal elevation slightly above native eelgrass with minimal overlap (Baldwin and Lovvorn 1994a,b); therefore, distribution at Roberts Bank is only in the intertidal zone and the direct effects to primary productivity were quantified based on density (i.e., sparse and dense; **Table 4-1**). A potential project footprint reduction would avoid the permanent destruction of 2.42 ha (0.77 ha dense and 1.65 ha sparse) non-native eelgrass along the shoreward and seaward ends of the causeway, equating to an annualized primary productivity of 0.06 t (0.04 t dense and 0.02 t sparse; **Table 4-1**, **Figures 1** and **2**).

The secondary productivity associated with a potential reduction of 2.42 ha of intertidal non-native eelgrass would be 7.80 t (macrofauna: 1.82 t, meiofauna: 0.95 t, and infaunal bivalves: 5.03 t; **Table 4-2**).

A small polygon of mixed native and non-native eelgrass was mapped near the division between the marine terminal and the seaward end of the widened causeway project components (**Figure 2**). A potential project footprint reduction would overlap slightly with this native/non-native eelgrass polygon and would avoid the permanent destruction of <0.001 ha along the seaward end of the causeway or of <0.001 t of annualized primary productivity (**Table 4-1**, **Figure 2**). The secondary productivity associated with this mixed eelgrass polygon would be <0.001 t of macrofauna, meiofauna, and infaunal bivalves (**Table 4-2**).

Bare habitats at Roberts Bank do not have associated primary productivity values as they are classified by the lack of vegetation and are characterized by the dominant substrate type. A potential project footprint reduction would avoid the permanent destruction of 0.19 ha of intertidal bare sand/mud at the seaward end of the causeway (**Figure 2**) and of 9.50 ha of subtidal bare sand/mud under the marine terminal (**Figure 3**), with no associated primary productivity values (**Table 4-1**). Despite the lack of marine vegetation, bare sand/mud habitats sustain marine invertebrate communities that contribute secondary productivity. In the intertidal zone, the secondary productivity associated with a potential reduction of 0.19 ha of bare sand/mud would be 0.62 t (macrofauna: 0.15 t, meiofauna: 0.08 t, infaunal bivalves: 0.40 t; **Table 4-2**). In the subtidal zone, the potential footprint reduction area would overlap with 1.80 ha of sparse orange sea pen. The secondary productivity associated with a potential reduction of 9.50 ha of subtidal bare sand/mud would equate to 9.43 t (macrofauna: 2.97 t, infauna bivalves: 6.46 t, orange sea pen: <0.01 t; **Table 4-2**).

Table 4-1 Potential reduction of primary productivity loss: areal extent (in hectares; ha) of marine habitat types under the current proposed project footprint, under the potential reduced project footprint, and the difference; habitat productivity (in tonnes per hectare; t/ha), potential reduction in annualized productivity loss, and potential reduction in annualized productivity loss proportional to the biophysical local assessment area (LAA)

Marine habitat type		Habitat zone	Areal extent of habitat (ha)			Productivity (t/ha)	Correction factor for seasonality	Potential reduction of primary productivity loss (t)	
			Current proposed project footprint	Potential reduced project footprint	Potential project footprint reduction			Annualized productivity	Annualized productivity proportional to the biophysical LAA
High marsh	Dense	Intertidal	1.198	1.161	0.037	15.290	0.600	0.343	<0.001
	Sparse	Intertidal	0.199	0.199					
Low marsh	Dense	Intertidal	2.393	2.252	0.141	0.102	0.600	0.009	<0.001
	Sparse	Intertidal	9.304	7.958	1.346	0.034	0.600	0.027	<0.001
Native eelgrass	Dense	Intertidal	2.473	2.473					
		Subtidal	0.590	0.353	0.238	1.388	0.750	0.247	<0.001
Native eelgrass	Sparse	Intertidal	1.548	1.067	0.482	0.416	0.750	0.150	<0.001
		Subtidal	0.065	0.059	0.006	0.416	0.750	0.002	<0.001
Non-native eelgrass	Dense	Intertidal	4.168	3.396	0.772	0.120	0.400	0.037	<0.001
	Sparse	Intertidal	16.347	14.699	1.648	0.036	0.400	0.024	<0.001
Native eelgrass/non-native eelgrass		Intertidal	<0.001	0.000	<0.001	0.754	0.575	<0.001	<0.001
Kelp		Intertidal	0.012	0.012					
		Subtidal	0.017	0.017					
Sand/mud		Intertidal	2.625	2.433	0.192	0.000	-	0.000	0.000
		Subtidal	125.594	116.096	9.497	0.000	-	0.000	0.000
Gravel/cobble		Intertidal	5.868	5.868					
Rock		Intertidal	2.205	2.184	0.021	0.000	-	0.000	0.000
		Subtidal	0.009	0.009					
Total			**174.615**	**160.234**	**14.381**	**18.557**	**-**	**0.840**	**<0.001**

Note: Grey cells indicate that the habitat type is not influenced by the potential project footprint reduction

Table 4-2 Potential reduction of secondary productivity loss: Areal extent (in hectares; ha) of marine habitat types, habitat productivity (in tonnes per hectare; t/ha), potential reduction in annualized productivity loss and potential reduction of annualized productivity loss proportional to the biophysical local assessment area (LAA).

Marine habitat type	Habitat zone	Representative species or group of secondary producers	Potential project footprint reduction (ha)	Secondary productivity (t/ha)	Potential reduction in secondary productivity loss (t)	
					Productivity	Productivity proportional to the LAA
Intertidal marsh	Intertidal	Macrofauna	1.524	0.753	1.148	<0.001
		Meiofauna		0.391	0.596	<0.001
		Infaunal bivalves		2.080	3.170	0.001
Native eelgrass	Intertidal	Macrofauna	0.482	0.753	0.363	<0.001
		Meiofauna		0.391	0.188	<0.001
		Infaunal bivalves		2.080	1.002	<0.001
	Subtidal	Macrofauna	0.244	0.313	0.076	<0.001
		Meiofauna				
		Infaunal bivalves		0.680	0.166	<0.001
Non-native eelgrass	Intertidal	Macrofauna	2.420	0.753	1.822	<0.001
		Meiofauna		0.391	0.946	<0.001
		Infaunal bivalves		2.080	5.034	0.001
Native eelgrass/Non-native eelgrass	Intertidal	Macrofauna	<0.001	0.753	<0.001	<0.001
		Meiofauna		0.391	<0.001	<0.001
		Infaunal bivalves		2.080	<0.001	<0.001
Sand/mud – bare	Intertidal	Macrofauna	0.192	0.753	0.145	<0.001
		Meiofauna		0.391	0.075	<0.001
		Infaunal bivalves		2.080	0.400	<0.001

Marine habitat type	Habitat zone	Representative species or group of secondary producers	Potential project footprint reduction (ha)	Secondary productivity (t/ha)	Potential reduction in secondary productivity loss (t)	
					Productivity	Productivity proportional to the LAA
Sand/mud – bare	Subtidal	Macrofauna	7.697	0.313	2.409	<0.001
		Meiofauna				
		Infaunal bivalves		0.680	5.234	0.001
Sand/mud – under orange sea pen	Subtidal	Macrofauna	1.800	0.313	0.563	<0.001
		Meiofauna				
		Infaunal bivalves		0.680	1.224	<0.001
		Orange sea pens		0.0012	0.002	<0.001
Rock – bare	Intertidal	Macrofauna	0.021			
		Meiofauna				
		Infaunal Bivalves				
		Total	**14.381**	-	**24.565**	**0.004**

Note: Grey cells indicate that no secondary productivity associated with infaunal invertebrate communities characterizes rock substrate. Meiofauna values were not available for subtidal bare sand/mud given the sampling method (i.e., sieve size) that was used during empirical surveys conducted for the project in 2019.

Table 4-3 Summary of potential reduction in productivity loss by habitat type: primary productivity, secondary productivity, and total productivity (in tonnes; t)

Marine habitat type	Habitat zone	Potential project footprint reduction (ha)	Potential reduction of productivity loss (t)					
			Primary productivity		Secondary productivity		Total productivity	
			Annualized under potential project footprint reduction	Annualized proportional to the biophysical LAA	Within potential project footprint reduction	Proportional to the biophysical LAA	Within potential project footprint reduction	Proportional to the biophysical LAA
Intertidal marsh	Intertidal	1.524	0.379	<0.001	4.914	0.001	5.293	0.001
Native eelgrass	Intertidal	0.482	0.150	<0.001	1.552	<0.001	1.702	<0.001
	Subtidal	0.244	0.249	<0.001	0.242	<0.001	0.491	<0.001
Non-native eelgrass	Intertidal	2.420	0.061	<0.001	7.802	0.001	7.863	0.001
Native eelgrass/Non-native eelgrass	Intertidal	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sand/mud	Intertidal	0.192	0.000	0.000	0.621	<0.001	0.620	<0.001
	Subtidal	9.497	0.000	0.000	9.433	0.002	9.434	0.002
Rock	Intertidal	0.021	0.000	0.000	0.000	0.000	0.000	0.000
	Total	**14.381**	**0.840**	**<0.001**	**24.564**	**0.004**	**25.404**	**0.005**

Note: LAA – local assessment area (Figures 11-1, 12-1, and 13-1 in the RBT2 EIS).

4.1.2 Potential reduction in direct effects to predicted suitable habitat for Pacific sand lance and Dungeness crab

Overall, a potential reduction in the current proposed project footprint by up to 14.4 ha would avoid the permanent destruction of 9.70 ha of habitat that is predicted to be moderately suitable for Pacific sand lance burying (**Table 4-4**, **Figure 4**). The potential footprint reduction area would also overlap with and would avoid 11.27 ha, 9.91 ha and 9.88 ha (**Table 4-4**) of habitat predicted to be suitable for, respectively, juvenile (moderate and high suitability; **Figure 5**), adult (high suitability; **Figure 6**) and gravid (moderate and high suitability; **Figure 7**) life stages of Dungeness crab.

Juvenile and adult Pacific sand lance use shallow intertidal and subtidal habitats during spring and summer, where they school and feed on zooplankton during daylight. When not feeding, Pacific sand lance remain close to the seafloor where they bury in sediments for prolonged time periods and over the winter during dormancy when food is scarce (Haynes et al. 2007, 2008). Burying sediments are coarse sand or mixed sand-gravel with low silt content from intertidal areas to depths of −80 m CD (Robinson et al. 2013, Greene et al. 2017). Based on results of habitat suitability modelling undertaken to support the project's EIS (Hemmera 2014a), the subtidal portion of the potential project footprint reduction would avoid the destruction of 9.70 ha of habitat predicted to be moderately suitable for Pacific sand lance burying (**Table 4-4**, **Figure 4**); this would represent a reduction by 1.1% of a direct effect assessed in the EIS. The potential footprint reduction area does not overlap with sediments predicted to be highly suitable for Pacific sand lance burying. Following project construction, a total of 768.1 ha of moderately suitable and 490.1 ha of highly suitable habitat would be available for Pacific sand lance burying (Hemmera 2014a).

Juvenile Dungeness crabs settle and rear in intertidal habitats at Roberts Bank where they grow rapidly by moulting (shedding their shells) (Rasmuson 2013). Densities of juvenile Dungeness crabs are higher in nearshore areas characterized by shallow depths, relatively high salinities, and lower temperatures (Rooper et al. 2002). At Roberts Bank, habitats that support eelgrass beds and green algae are highly used by juvenile crabs. Based on results of habitat suitability modelling undertaken to support the project's EIS (Hemmera 2014a), a potential project footprint reduction in the intertidal zone would avoid the destruction of 1.53 ha of habitat predicted to be moderately and highly suitable for juvenile crab life stages **Table 4-4, Figure 5**). In the subtidal zone, the potential footprint reduction area would overlap with and would avoid 9.74 ha of habitat predicted to be moderately suitable for juvenile crabs (**Table 4-4, Figure 5**); this would represent a reduction by 0.4% of a direct effect assessed in the EIS. Following project construction, a total of 1,058 ha of moderately suitable and 1,819 ha of highly suitable habitat would be available for juvenile Dungeness crabs (Hemmera 2014a).

Adult Dungeness crabs are most abundant on subtidal sand or mud bottoms and are frequently found inactive and buried in the soft sediment during the day (McGaw 2005). Adult crabs migrate daily to shallow intertidal flats to forage during nocturnal high tides (Holsman et al. 2006, Curtis and McGaw 2012). Based on results of habitat suitability modelling undertaken to support the project's EIS (Hemmera 2014a), a potential project footprint reduction would avoid the destruction of 9.88 ha (intertidal: 0.14 ha, subtidal: 9.74 ha; **Table 4-4, Figure 6**) of habitat predicted to be highly suitable for adult Dungeness crabs; this would represent a reduction by 0.9% of a direct effect assessed in the EIS. Following project construction, a total of 916 ha of moderately suitable and 909 ha of highly suitable habitat would be available for adult Dungeness crabs (Hemmera 2014a).

Gravid Dungeness crabs, each bearing about 2 million fertilized eggs, aggregate in shallow water habitat (Armstrong et al. 1988) during fall and winter (Shirley et al. 1987). Brooding habitats are characterized by homogeneous sandy substrates that are permeable and well oxygenated (Scheding et al. 2001, Stone and O'Clair 2002). During this time, brooding females are found partially or completely buried within the sediment to maintain attachment of the eggs on their underside (Scheding et al. 2001, Rasmuson 2013). Based on results of habitat suitability modelling undertaken to support the project's EIS (Hemmera 2014a), a potential project footprint reduction would avoid the destruction of 9.88 ha (intertidal: 0.14 ha, subtidal: 9.74 ha; **Table 4-4, Figure 7**) of habitat predicted to be moderately and highly suitable for gravid Dungeness crabs; this would represent a reduction by 0.8% of a direct effect assessed in the EIS. Following project construction, a total of 258 ha of moderately suitable and 471 ha of highly suitable habitat would be available for gravid Dungeness crabs (Hemmera 2014a).

Table 4-4 Extent (in hectares; ha) of suitable habitat for Pacific sand lance burying and Dungeness crab life stages (i.e., juvenile, adult, gravid) within the potential footprint reduction area

Species		Habitat suitability	Habitat zone	Areal extent of habitat (ha)		
				Current proposed project footprint	Potentially reduced project footprint	Potential project footprint reduction
Pacific sand lance		Moderate	Subtidal	123.766	114.070	9.696
		High	Subtidal	2.994	2.993	<0.001
Dungeness crab	Juvenile	Low	Intertidal	16.945	14.374	2.571
		Moderate	Intertidal	2.366	2.144	0.222
		Moderate	Subtidal	118.859	109.117	9.741
		High	Intertidal	9.266	7.957	1.309
	Adult	Low	Intertidal	9.066	8.013	1.053
		High	Intertidal	2.530	2.363	0.168
		High	Subtidal	126.221	116.480	9.741
	Gravid	Low	Intertidal	0.882	0.844	0.038
		Moderate	Intertidal	1.526	1.387	0.139
		Moderate	Subtidal	72.128	69.674	2.454
		High	Intertidal			
		High	Subtidal	54.093	46.806	7.287

Note: Grey cells indicate that the habitat predicted to be suitable would not be influenced by a potential project footprint reduction.

4.2 Potential reduction in indirect effects to fish

A potential reduction in direct effects to fish habitat (described in **Section 4.1**) would also benefit fish indirectly through the provision of food and refuge associated with fish habitats within the potential footprint reduction area. Habitats that would no longer be destroyed, if the project footprint reduction were to be implemented would be available to fish to perform critical life functions, such as spawning or rearing. Additionally, infaunal invertebrate communities (i.e., macrofauna, meiofauna, infaunal bivalves) associated with fish habitats that would be avoided from a potential footprint reduction would become available to fish as food. These potential indirect benefits to fish are described qualitatively below with a focus on those representative species or groups that were selected for the assessment presented in the project's EIS and comprise the food web that characterizes each habitat type that would be avoided with a potential reduction in the current proposed project footprint.

4.2.1 Representative species or groups comprising the food web of intertidal marsh habitat

As indicated in **Section 4.1**, a potential project footprint reduction would avoid the destruction of 1.52 ha of intertidal marsh habitat along the shoreward and seaward ends of the causeway (**Table 4-3**, **Figures 1** and **2**); associated reduction in direct productivity loss would amount to 5.29 t (**Table 4-3**). The extent of intertidal marsh within the potential footprint reduction area would be available within the Roberts Bank ecosystem, before, during and after project construction, as a source of food for juvenile and adult fish species that inhabit this habitat type and as refuge from predators.

Intertidal marshes at Roberts Bank, including low marsh within the potential footprint reduction area, sustain a detritus food web (Kistritz 1978, Levings 2016) and provide productive habitat for fish, including opportunities for rearing and estuarine growth, as well as refuge from predation (Levy and Northcote 1981, 1982, Levings and Nishimura 1997, Chalifour et al. 2019, 2020). Fish species that contribute to the food web of intertidal marshes at Roberts Bank include predominantly ocean-type[10] Chinook (*Oncorhynchus tshawytscha*) and chum (*Oncorhynchus keta*) salmon, as well as shiner perch (*Cymatogaster aggregata*), and to a lesser extent small demersal fish species such as threespine stickleback (*Gasterosteus aculeatus*) and sculpins (Cottidae).

Juvenile salmon that rear in the estuary benefit from intertidal marsh vegetation as it has been documented in the literature to provide refuge during flood tides and to increase food availability (Levy and Northcote 1981, 1982, Archipelago 2014a, Chalifour et al. 2019, 2020). Juvenile salmon have been documented to remain within tidal channels characteristic of intertidal marshes as the tide ebbs and maximize their encounters with drifting invertebrate prey exported from the marsh and concentrated in the marsh channel network during receding tides (Hering et al. 2010). Intertidal marsh also provides a rearing environment that is osmotically less stressful to juvenile Chinook salmon as they physiologically adapt to higher salinities (Chalifour et al. 2019, 2020). Chalifour et al. (2019) consistently caught salmon, including Chinook, in substantially higher numbers in marsh than eelgrass or sandflat at Roberts Bank during sampling in spring and summer 2016 and 2017. Higher numbers of juvenile salmon were also caught along the north shoreline of the Roberts Bank causeway, including within the potential footprint reduction area, during sampling in spring and summer 2020 as part of the project's follow-up program element for juvenile salmon. Of the non-salmonid species, shiner perch, and small demersal fish species have been recorded in high numbers within marsh habitat at Roberts Bank, including within the potential footprint reduction area (e.g., Archipelago 2014a). Adult shiner perch have been documented in the literature to enter marsh

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[10] Chinook salmon with ocean-type life history outmigrate to sea during their first year of life; they are also referred to as subyearlings.

channels as early as May, while juveniles remain through September (Cornwell et al. 2001). Threespine stickleback and Pacific staghorn sculpin (*Leptocottus armatus*) both spawn in marsh habitat at Roberts Bank (Wootton 1984, Taylor and McPhail 1986).

4.2.2 Representative species or groups comprising the food web of eelgrass habitat

As indicated in **Section 4.1**, a potential project footprint reduction would avoid the destruction of 2.90 ha of intertidal eelgrass habitat (0.48 ha of native eelgrass under the marine terminal and 2.42 ha of non-native eelgrass along the shoreward and seaward ends of the causeway footprint reduction areas; **Table 4-3**, **Figures 1** and **2**) and 0.24 ha of subtidal native eelgrass habitat under the marine terminal footprint reduction area (**Table 4-3**, **Figure 3**). Associated potential reduction in direct productivity loss would amount to 10.06 t for the intertidal and subtidal zones combined (**Table 4-3**). Although morphologically different from native eelgrass, non-native eelgrass has been found to sustain invertebrate abundance that is twice the abundance of neighbouring native eelgrass (albeit with differing community composition) and has been determined to provide habitat comparable to native eelgrass (e.g., Knight et al. 2015). For this reason, the food web characterizing non-native eelgrass was considered the same as for native eelgrass at Roberts Bank to describe the potential indirect effects to fish that would be reduced from a potential project footprint reduction.

Eelgrass provides habitat structure and complexity that attracts diverse assemblages of fish and invertebrates and has also been shown to lower mortality rates of juvenile fish and invertebrates (e.g., Orth and Heck 1980, Able and Sogard 1991, Johnson et al. 2003). Eelgrass habitat provides increased feeding opportunities, leading to greater biodiversity and increased abundance of fish and invertebrates (Sogard 1992, Baldwin and Lovvorn 1994a). The extent of eelgrass within the potential footprint reduction area would be available within the Roberts Bank ecosystem as a source of food for juvenile and adult fish and invertebrate species that inhabit this habitat type, as refuge from predators, as well as for spawning. Fish species that contribute to the eelgrass food web at Roberts Bank include juvenile and adult forage fish, such as Pacific herring (*Clupea pallassii*), surf smelt (*Hypomesus pretiosus*), Pacific sand lance, and shiner perch, juvenile salmon, juvenile and adult Dungeness crab, juvenile flatfish, and small demersal fish species.

Forage fish can be habitat-dependent on eelgrass for one or more life stages. Adult Pacific herring spawn on eelgrass (Penttila 2007); while Roberts Bank is not an important herring spawning area, eelgrass at Roberts Bank has been documented to support some spawn (VFPA 2017). Juvenile forage fish, such as herring, sand lance, surf smelt, and shiner perch, use eelgrass beds at Roberts Bank, including within the potential footprint reduction area (e.g., Archipelago 2014a,b), for prey and refuge (e.g., Kelly et al. 2008, Sisson and Baker 2017, Rubin et al. 2018). Eelgrass provides rearing opportunities for juvenile salmon as they transition from brackish environments to nearshore and coastal waters at Roberts Bank that are characterized by higher salinities (e.g., Archipelago 2014a,b). Rearing within eelgrass beds is also characteristic of species of flatfish and small demersal fish (e.g., Taylor and McPhail 1986, Rooper et al. 2003, Archipelago 2014a,b). Lastly, juvenile Dungeness crabs settle at Roberts Bank in areas with vegetative cover, including within eelgrass beds that offer three-dimensional complexity in which to hide from predators (e.g., Orth and Heck 1980, Holsman et al. 2006, Hemmera 2014d).

4.2.3 Representative species or groups comprising the food web of sand/mud habitat

As indicated in **Section 4.1**, a potential project footprint reduction would avoid the destruction of 9.69 ha of sand/mud habitat (0.19 ha in the intertidal and 9.50 ha in the subtidal zone; **Table 4-3**, **Figures 2** and **3**); associated reduction in direct productivity loss would amount to 10.05 t (**Table 4-3**). The extent of sand/mud within the potential footprint reduction area would be available within the Roberts Bank ecosystem as a source of food for juvenile and adult fish species that inhabit this habitat type as well as for performing critical life functions (e.g., spawning, rearing, burying).

Sand- and mudflats contribute to the structure and processes of the estuarine ecosystem at Roberts Bank. They accommodate in the intertidal zone microphytobenthos (e.g., diatoms), they serve as feeding grounds for fish and invertebrates, including flatfish and crabs (e.g., Levings 1982, 2016, Hemmera 2014d), and they provide low tide refugia, especially within tidal channels, for species like juvenile Chinook salmon when water levels are receding during ebb tides (Levings 1982, 2016). Sand/mud at Roberts Bank, including within the potential footprint reduction area, is used by juvenile flatfish, such as English sole and starry flounder (*Platichthys stellatus*) for rearing (Archipelago 2014a,b,c). Trawl surveys at Roberts Bank (down to depths of –25 m CD) in 2012 and 2013 documented nine species of flatfish, of which English sole and starry flounder were the most common (Archipelago 2014c). Most flatfish caught were juveniles, suggesting that sand/mud at Roberts Bank is important for rearing (Archipelago 2014c). In the potential footprint reduction area at the marine terminal, sediments are coarse and highly oxygenated, providing important sandy bottom habitats for orange sea pen aggregations, for Pacific sand lance that may bury when overwintering or when not feeding in the water column during daylight, and for adult Dungeness crab, including brooding females (Hemmera 2014a; see also **Section 4.1.2**). Tidal flats also physically connect and provide important sources of sediment for adjacent vegetated habitats, such as eelgrass beds and intertidal marshes (e.g., Chalifour et al. 2019).

5.0 SUMMARY

A potential reduction of the project footprint by up to 14.4 ha would avoid the permanent destruction of 4.67 ha of vegetated fish habitat (i.e., intertidal marsh, native and non-native eelgrass) and 9.71 ha of bare sand/mud (**Table 4-3**). Reduction in direct productivity losses associated with habitats within the potential footprint reduction area would amount to a total of 25.40 t (0.84 t of primary productivity and 24.56 t of secondary productivity; **Table 4-3**). The largest reduction in overall direct effects is tied to the habitat types with the largest reduction in areal extent: subtidal bare sand/mud (9.43 t), followed by intertidal non-native eelgrass (7.86 t) and intertidal marsh (5.29 t; **Table 4-3**).

A potential project footprint reduction would also result in the reduction of indirect effects to fish through the increased availability of fish habitat for important life functions and the provision of prey through the reduction in direct loss of secondary productivity. This would benefit both adult and juvenile life stages of fish, including Pacific salmon, who use these habitats for activities such as rearing, foraging, predator avoidance, and spawning.

6.0 CLOSURE

We have appreciated the opportunity of working with you on this project and trust that this report is satisfactory to your requirements. Please feel free to contact the undersigned by phone at 604.669.0424 regarding any questions or further information that you may require.

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APPENDIX A

Supporting Figures

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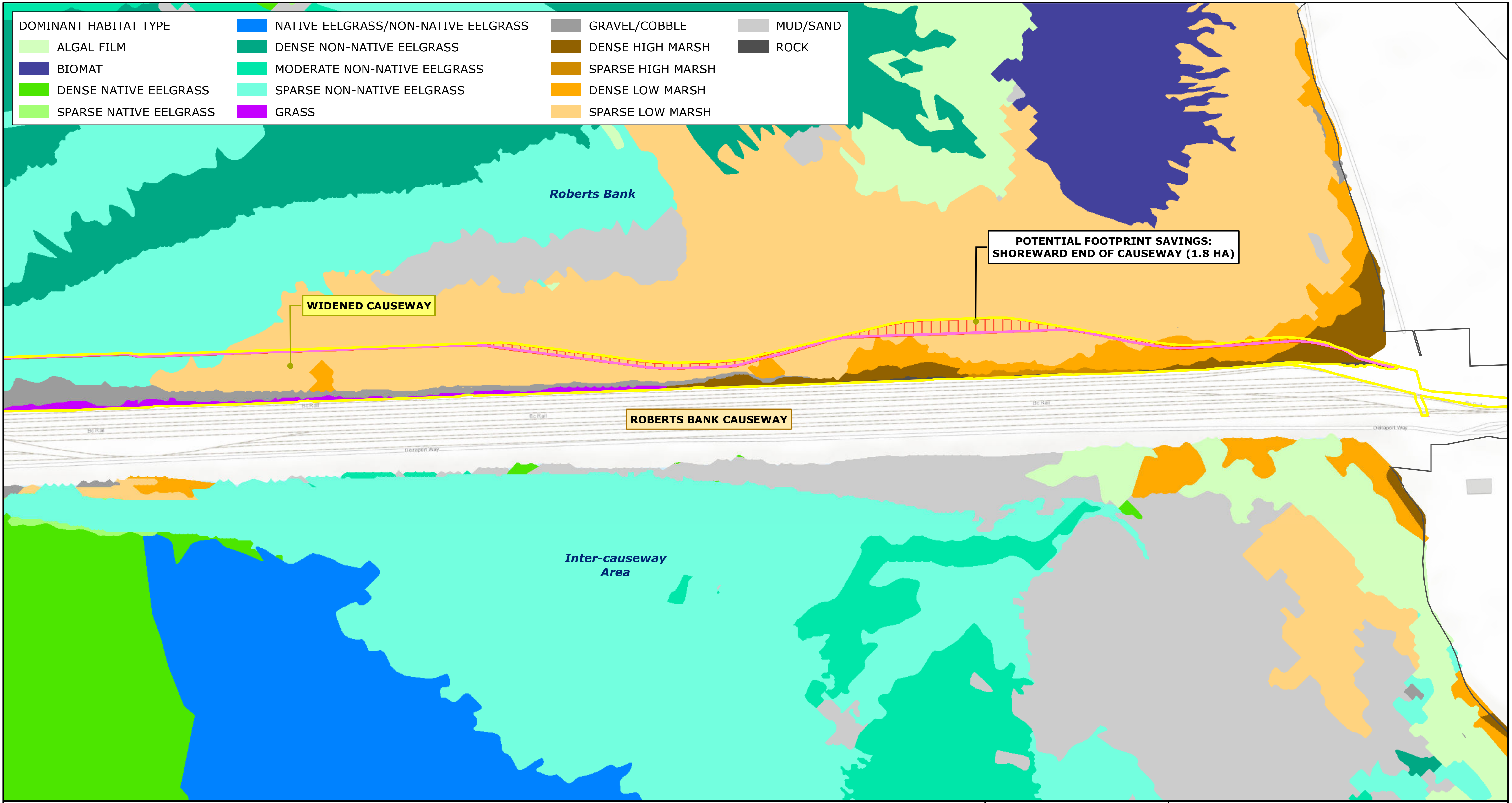


Legend

- ▭ BOUNDARY OF PROJECT AREA
- ▭ REDUCED FOOTPRINT
- ▨ FOOTPRINT REDUCTION AREA

PROJECT COMPONENT

EXISTING LANDMARK

0 125 250
Metres
1:6,000
NAD 1983 UTM Zone 10N

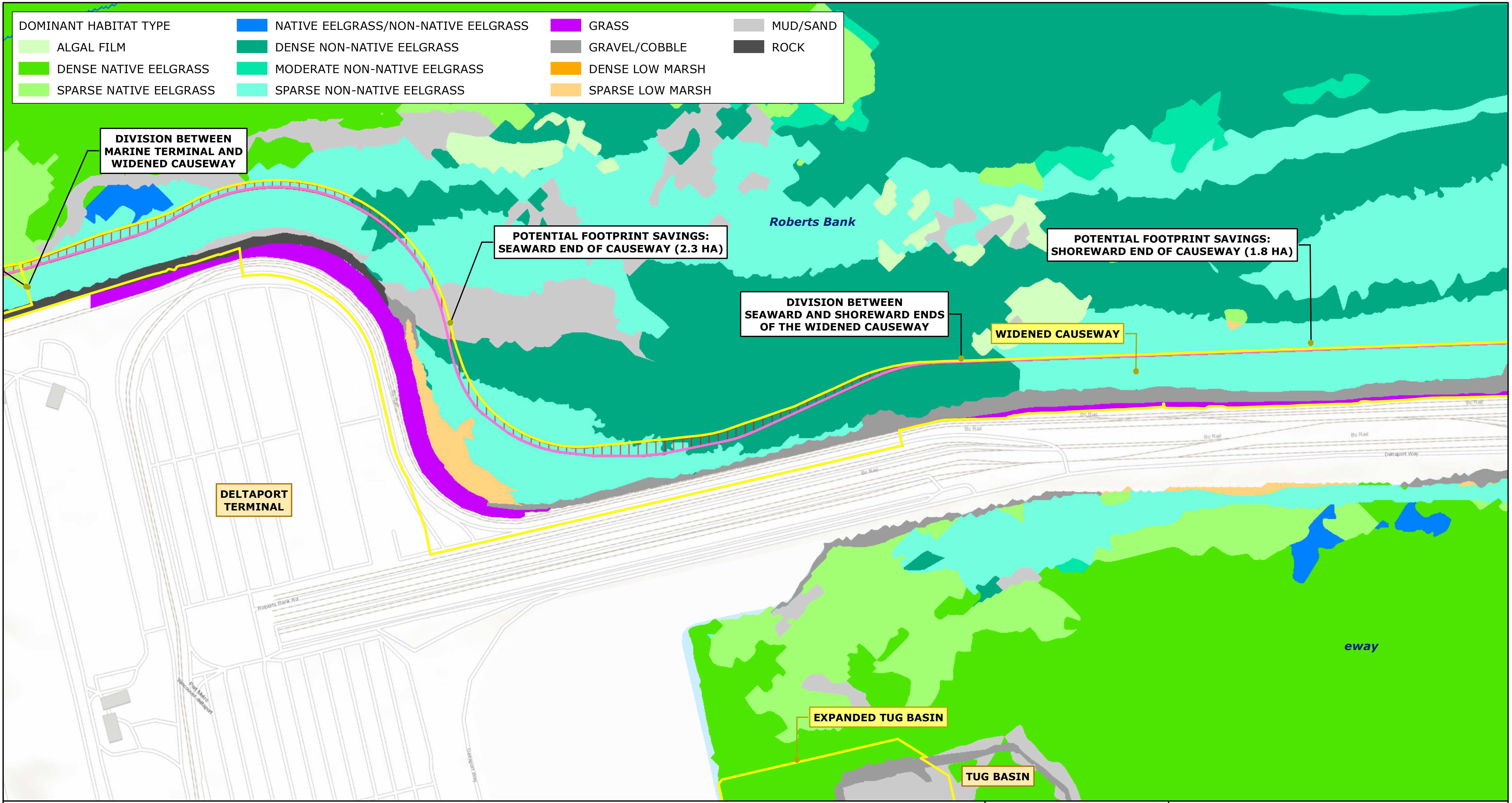
N

ROBERTS BANK TERMINAL 2

FOOTPRINT REDUCTION AREA OVERLAID ON 2019 HABITAT MAP

DATE:	FIG No.
17/02/2021	1

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community



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Legend

- BOUNDARY OF PROJECT AREA
- REDUCED FOOTPRINT
- FOOTPRINT REDUCTION AREA
- 0 m (CHART DATUM)

PROJECT COMPONENT

EXISTING LANDMARK

0 125 250
Metres
1:6,000
NAD 1983 UTM Zone 10N

PORT of vancouver

ROBERTS BANK TERMINAL 2

FOOTPRINT REDUCTION AREA OVERLAID ON 2019 HABITAT MAP

DATE:	FIG No.
17/02/2021	2

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

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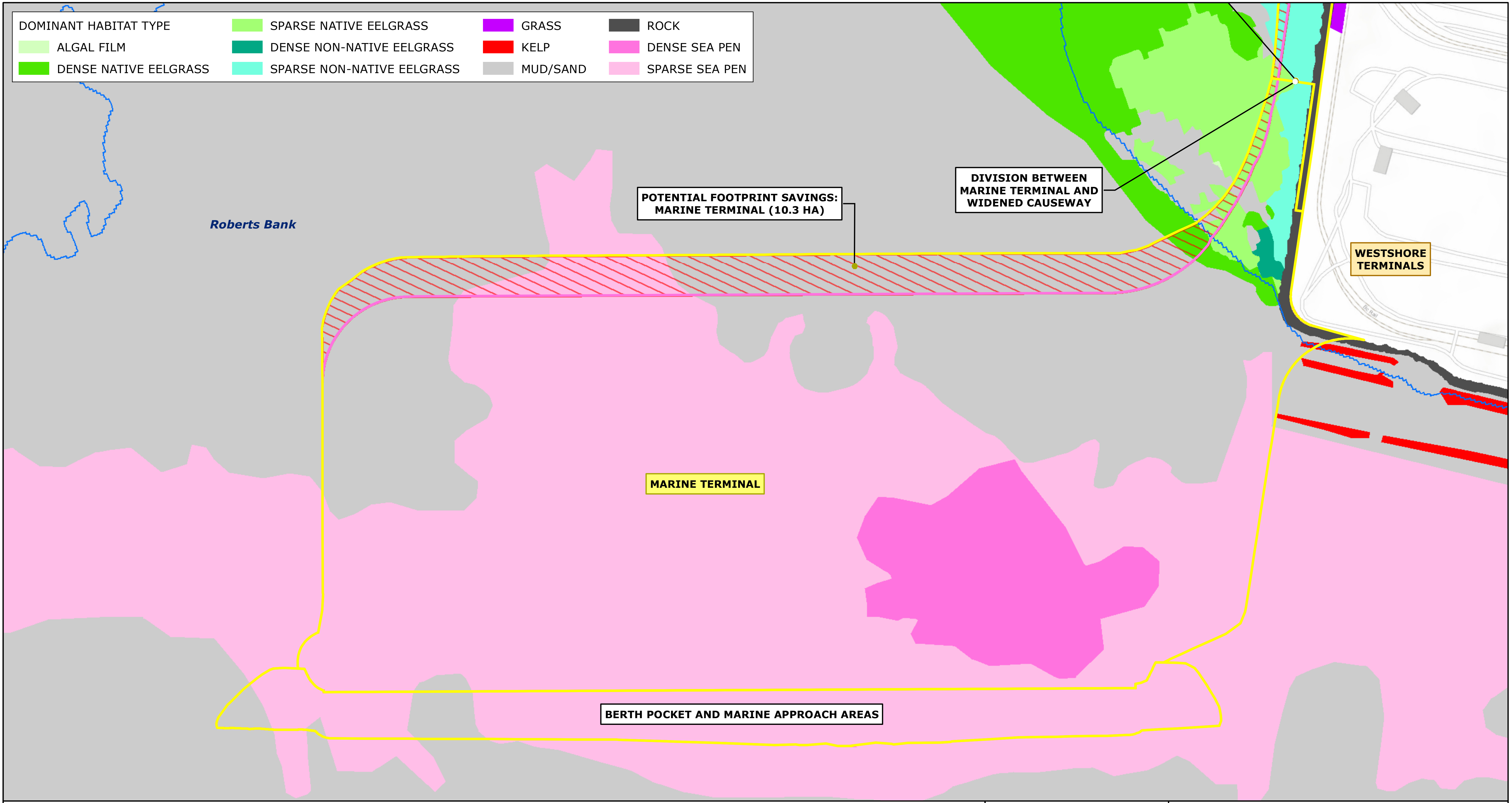


Legend

- BOUNDARY OF PROJECT AREA
- REDUCED FOOTPRINT
- ▨ FOOTPRINT REDUCTION AREA
- 0 m (CHART DATUM)

PROJECT COMPONENT

EXISTING LANDMARK

0 125 250
Metres
1:6,000
NAD 1983 UTM Zone 10N

N

PORT of vancouver

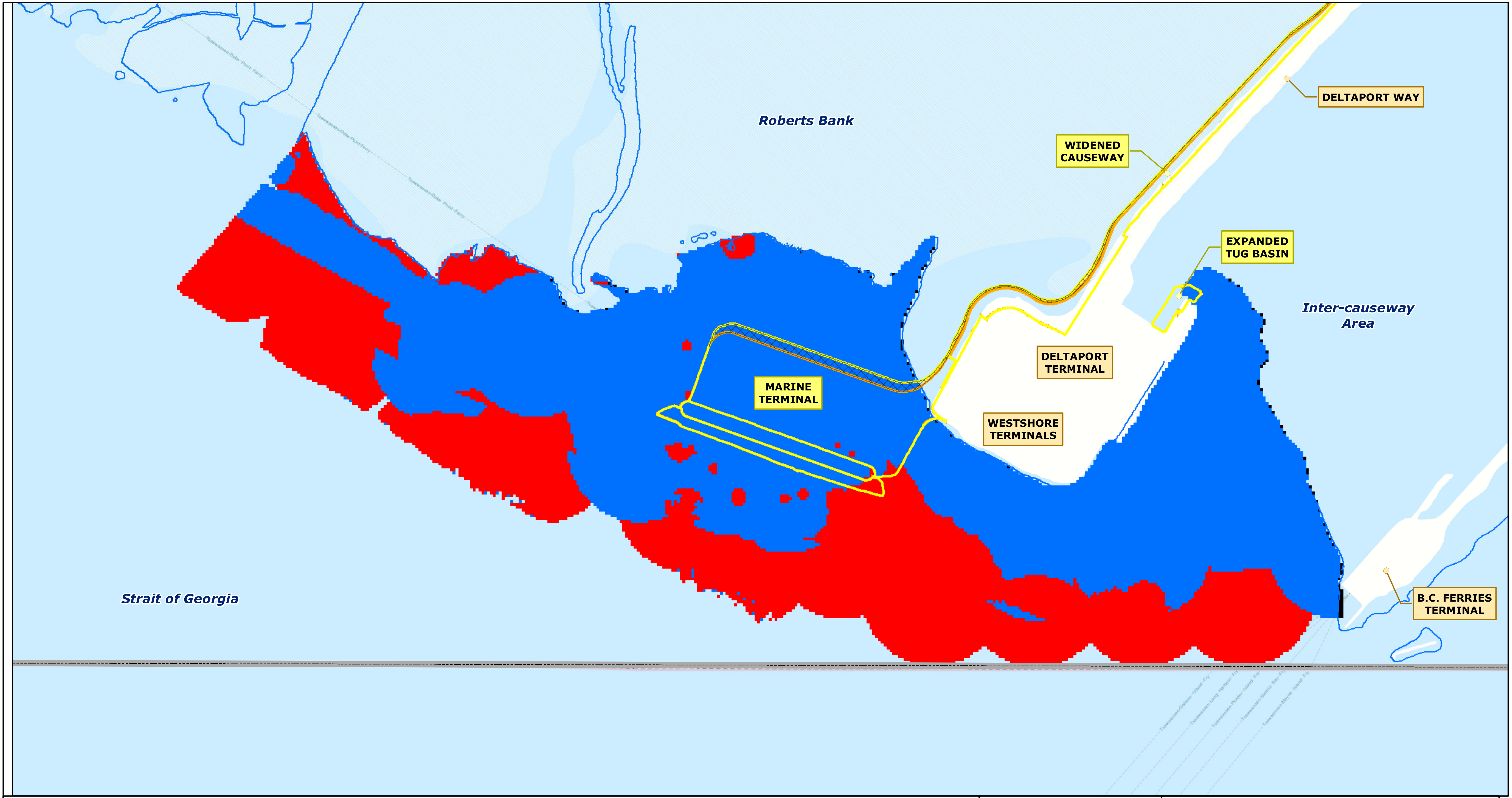
ROBERTS BANK TERMINAL 2

FOOTPRINT REDUCTION AREA OVERLAID ON 2019 HABITAT MAP

DATE:	FIG No.
17/02/2021	3

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Path: S:\Geomatics\Projects\102738\10\Habitat\mxd\working\210205_ProjectFootprint_SandLance_Crabs\mxd\Fig4__102738_10_Sandlance_ReducedFootprint_210217.mxd



Legend

- ☐ BOUNDARY OF PROJECT AREA
- ☐ REDUCED FOOTPRINT
- ▨ RELEASED HABITAT
- U.S.A.-CANADA BORDER
- 0 m (CHART DATUM)

HABITAT SUITABILITY

- ■ UNSUITABLE
- 🟦 MODERATELY SUITABLE
- 🟥 HIGHLY SUITABLE

PROJECT COMPONENT

EXISTING LANDMARK

0 0.5 1
Kilometres
1:25,000
NAD 1983 UTM Zone 10N

N

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PORT of vancouver

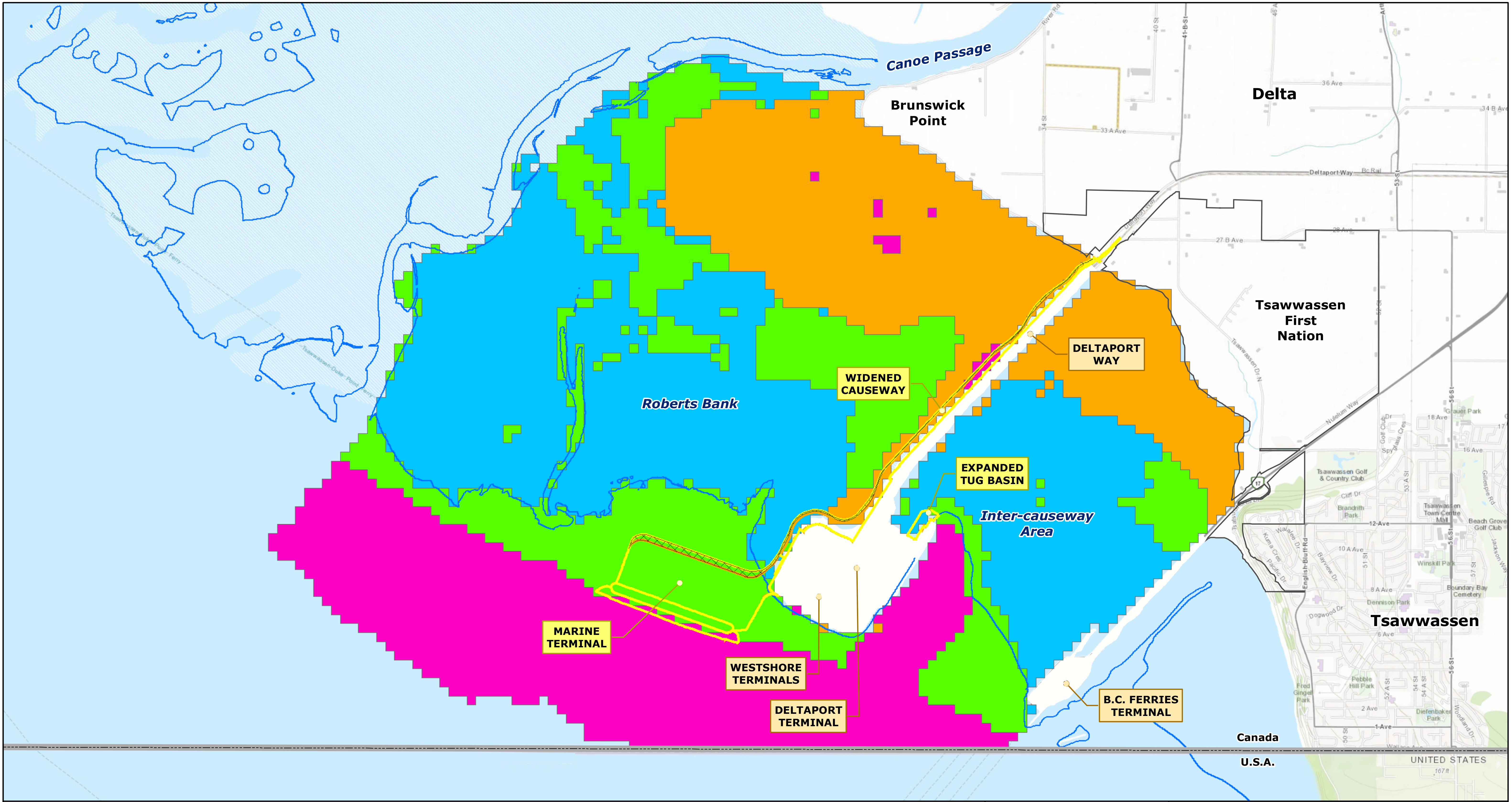
ROBERTS BANK TERMINAL 2

SAND LANCE HABITAT AND NEW REDUCED PROJECT FOOTPRINT

DATE: 17/02/2021

FIG No. 4

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community



Path: S:\Geomatics\Projects\102738\10\Habitat\mxd\working\210205_ProjectFootprint_SandLance_Crabs\mxd\Fig5__102738_10_DungenessCrabJuv_ReducedFootprint_210217.mxd

Legend

- ☐ BOUNDARY OF PROJECT AREA
- ☐ REDUCED FOOTPRINT
- ▨ RELEASED HABITAT
- --- U.S.A.-CANADA BORDER
- — 0 m (CHART DATUM)

HABITAT SUITABILITY

- 🟪 UNSUITABLE
- 🟧 LOW SUITABILITY
- 🟩 MODERATE SUITABILITY
- 🟦 HIGH SUITABILITY

PROJECT COMPONENT

EXISTING LANDMARK

0 0.5 1

Kilometres

1:40,000

NAD 1983 UTM Zone 10N

N

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ROBERTS BANK TERMINAL 2

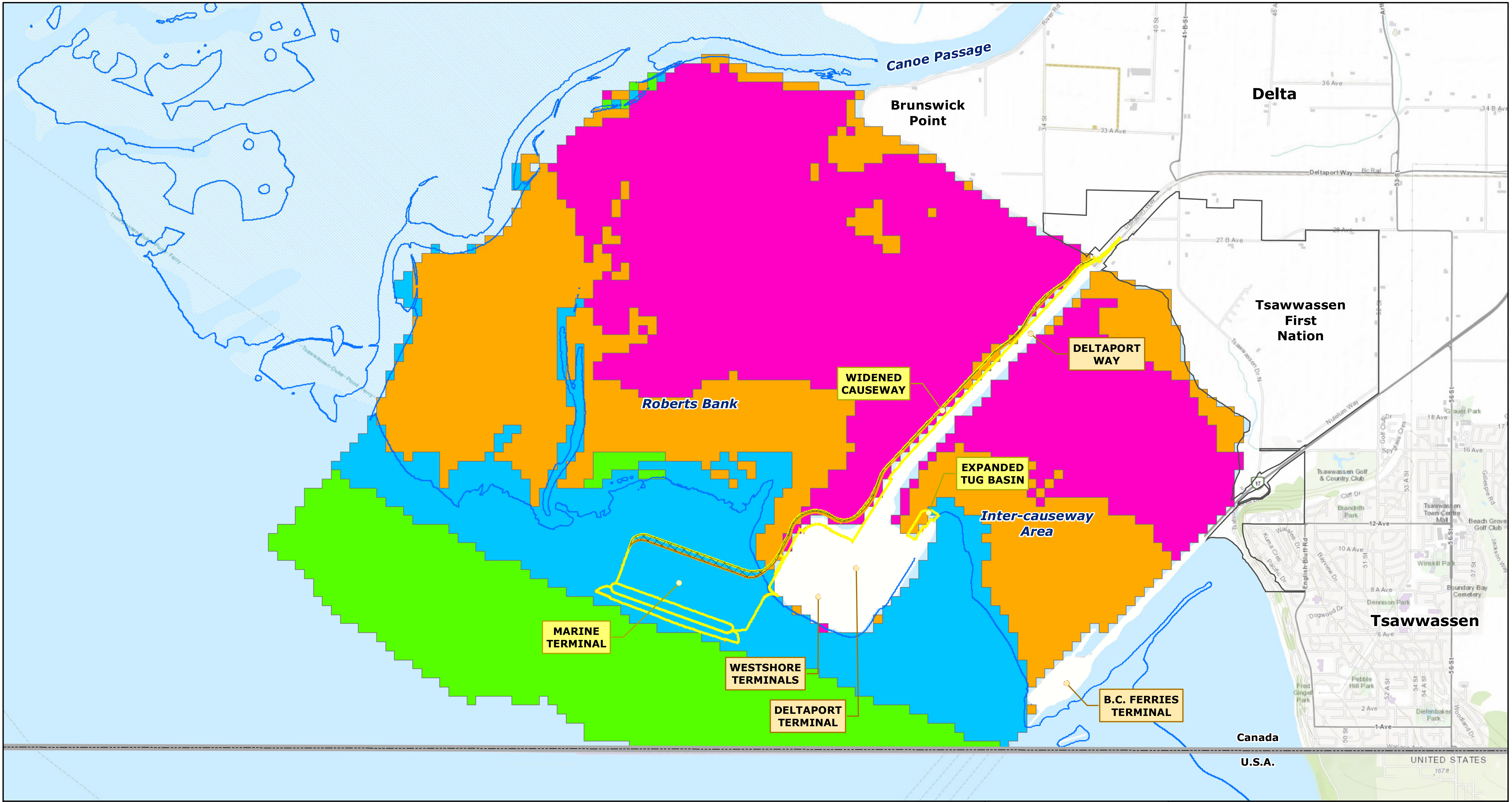
DUNGENESS CRABS - JUVENILE AND NEW REDUCED PROJECT FOOTPRINT

DATE: 17/02/2021

FIG No. 5

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Path: S:\Geomatics\Projects\102738\10\Habitat\mxd\working\210205_ProjectFootprint_SandLance_Crabs\mxd\Fig6__102738_10_DungenessCrabAdult_ReducedFootprint_210217.mxd



Legend

☐ BOUNDARY OF PROJECT AREA

☐ REDUCED FOOTPRINT

▨ RELEASED HABITAT

- - - U.S.A.-CANADA BORDER

— 0 m (CHART DATUM)

HABITAT SUITABILITY

🟪 UNSUITABLE

🟧 LOW SUITABILITY

🟩 MODERATE SUITABILITY

🟦 HIGH SUITABILITY

0 0.5 1
Kilometres
1:40,000
NAD 1983 UTM Zone 10N

N

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ROBERTS BANK TERMINAL 2

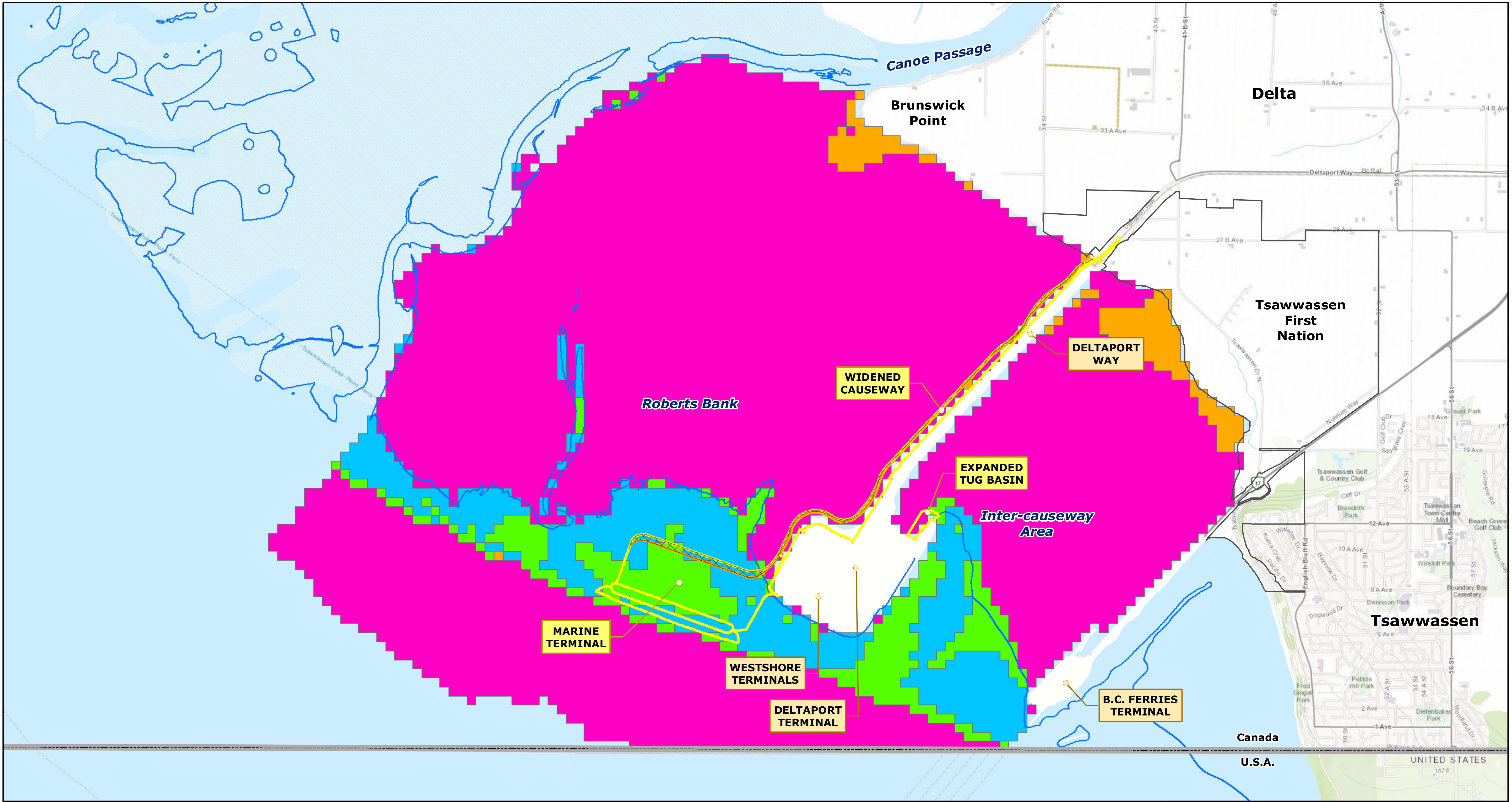
DUNGENESS CRABS - ADULT AND NEW REDUCED PROJECT FOOTPRINT

DATE: 17/02/2021

FIG No. 6

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Path: S:\Geomatics\Projects\102738\10\Habitat\mxd\working\210205_ProjectFootprint_SandLance_Crabs\mxd\Fig7__102738_10_DungenessCrabGrav_ReducedFootprint_210217.mxd



Legend

▭	BOUNDARY OF PROJECT AREA
▭	REDUCED FOOTPRINT
▨	RELEASED HABITAT
- - -	U.S.A.-CANADA BORDER
—	0 m (CHART DATUM)

HABITAT SUITABILITY

🟪	UNSUITABLE
🟧	LOW SUITABILITY
🟩	MODERATE SUITABILITY
🟦	HIGH SUITABILITY

PROJECT COMPONENT

EXISTING LANDMARK

0 0.5 1
Kilometres
1:40,000
NAD 1983 UTM Zone 10N

N

DRAFT

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ROBERTS BANK TERMINAL 2

DUNGENESS CRABS - GRAVID FEMALES AND NEW REDUCED PROJECT FOOTPRINT

DATE: 17/02/2021

FIG No. 7

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community