ISSN 2816-4083

Fisheries Centre Research Reports

2022 Volume 30 Number 1

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Institute for the Oceans and Fisheries,
The University of British Columbia, Canada

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Please cite as:
Taft, S., Oldford, G., Lilley, P.L., Oetterich, S.B., Morin, J., George, M., George, M., and Christensen, V. (2021). Reconstructing the pre-contact shoreline of Burrard Inlet (British Columbia, Canada) to quantify cumulative intertidal and subtidal area change from 1792 to 2020. Fisheries Centre Research Report 30(1) 48 pp.

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Fisheries Centre Research Reports are Open Access publications
ISSN 1198-6727

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This research report is indexed in Google Scholar, ResearchGate, and the UBC library archive (cIRcle).

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Director's Foreword

To understand our present and envision the future, we must also understand our past.

This document, and its companion piece, *Historical Ecology in Burrard Inlet: Summary of Historic, Oral History, Ethnographic, and Traditional Use Information*, seek to help us understand the impact that colonial settlement and development has had on our landscapes and impacted ecosystems through resource extraction, infrastructure development, urbanization, and industrial activity. Today, particularly in southwestern British Columbia, we are seeing these accrued impacts in severe, long-term effects on ecosystems and physical environments, and on the lifeways, cultural practices, and traditional diets of Indigenous communities.

I salute the authors of these Fisheries Centre Research Reports for their determination in helping to understand the shifting baselines in the Burrard Inlet and the Tsleil-Waututh Nation, and how they have challenged the ecosystems and peoples who live in this coastal area.

Prof. William Cheung
Director and Professor, Institute for the Oceans and Fisheries
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Abstract

Colonial development has severely altered landscapes throughout Canada, including in Tsleil-Waututh Nation's (TWN) territory, centred on present-day Burrard Inlet, BC, where urban and industrial expansion has modified the inlet's shoreline for well over a century. These shoreline changes have degraded the ecosystem and affect TWN in innumerable ways, but non-Indigenous communities have not considered the impacts of total shoreline change in detail, and generally accept shoreline changes that have occurred since European contact as the "baseline" condition of Burrard Inlet. In this study, we therefore used multiple lines of evidence to reconstruct the shoreline of Burrard Inlet as it existed prior to European contact in 1792 and quantified the spatial extent of intertidal and subtidal area change in the inlet from 1792 to 2020. The results demonstrate that, across Burrard Inlet, a total of 1,214 ha of intertidal and subtidal areas have been lost to development and change, including 55% (945 ha) of the inlet's intertidal areas. The most severe shoreline alteration occurred in False Creek and the Inner Harbour, including loss and elimination of ecologically productive and culturally important intertidal habitats at False Creek Flats (>99% intertidal area lost), the Capilano River Estuary (80% intertidal area lost), and the Seymour-Lynn Estuary (56% intertidal area lost). This shoreline loss has fundamental consequences to Burrard Inlet's ecosystem and TWN's ability to exercise constitutionally-protected rights. Further, this work demonstrates that any potential future shoreline loss must consider historical shoreline change and cumulative effects in Burrard Inlet.

Introduction

Using multiple lines of evidence to understand cumulative ecosystem change in Canada

Throughout Canada's history, colonial settlement and development has greatly altered landscapes and impacted ecosystems through resource extraction, infrastructure development, urbanization, and industrial activity. In present-day southwestern British Columbia, these impacts have occurred and accumulated over more than a century, with severe, long-term effects on ecosystems and physical environments, and corresponding impacts to the lifeways, cultural practices, and traditional diets of Indigenous communities. Yet, despite the significant impacts on ecosystems and Indigenous peoples, there are often limited Western or Euro-Canadian records or documentation focused on these cumulative effects. Further, establishing direct linkages between specific historical human activities and corresponding environmental effects can be difficult when multiple activities are occurring concurrently, and in complex landscapes or seascapes that are also subject to natural environmental fluctuations and changes. As a result, it remains easy to underappreciate the magnitude of total landscape-scale change that has taken place since colonization began in Canada, and difficult to perceive long-term changes within important terrestrial and aquatic ecosystems, leading to a phenomenon called shifting baseline syndrome (SBS) (Pauly 1995).

Shifting baseline syndrome occurs when current generations are not adequately aware of past changes to a system such that they perceive the current degraded or impaired conditions as "normal". Current conditions then become the *de facto* baseline from which subsequent changes and impacts are assessed (Pauly 1995). Over time, every new generation accepts previous impacts and historical environmental degradation as part of their baseline to be used as a new reference point, thereby accommodating continuous impacts to a system without comprehending the true magnitude of environmental change (Jones et al. 2020). Importantly, SBS is a significant issue in places that undergo rapid development. Therefore, counteracting SBS and characterizing total impacts to a system requires a fixed historical baseline of conditions from before rapid change began, to act as a permanent reference point from which all subsequent changes are measured. However, establishing historical environmental conditions is challenging, partially because people assume there is inadequate information to properly understand the past environment.

To address this perceived lack of information regarding past environmental conditions in Canada, historical baselines must consider information beyond data sources conventional to Western science. For example, the means by which early Euro-Canadian settlers intentionally or unintentionally documented environmental conditions and subsequent changes with Western knowledge, record keeping, and science can be very informative. Documents such as navigational, parcel, or insurance maps, community plans, archival records, photographs, and scientific surveys often contain useful information for understanding early post-contact change. Further, archaeological data, ethnographic information, and historical documents often provide invaluable historical ecological information (Egan & Howell 2001).

In addition to Western record keeping, types of Indigenous Knowledge, such as Indigenous Traditional Knowledge (ITK), oral histories, stories, traditional use studies (TUS), place names, songs, weavings, and other types of information, can inform pre-contact and historical conditions, subsequent colonial development, and cumulative change over many generations (Lyman 2017; Torben & Lockwood 2012; Pauly et al. 1998). This knowledge can provide continuous information and observations about a system at a regional scale from well-before European contact to the present. Also, Indigenous Knowledge often considers connections between socio-ecological systems over many generations rather than compartmentalizing information based on discrete subjects and short timescales. As a result, different types of Indigenous Knowledge are essential to inform a complete record of change in southwestern British Columbia since European contact.

Together, different types of information from early Euro-Canadian settlers and Indigenous Knowledge can establish a robust understanding of historical environmental conditions, and the pace and magnitude of total regional change since European contact. This method of using both Western and Indigenous ways of knowing is referred to as Two-Eyed Seeing (Bartlett et al. 2012) and has wide applications, including for fisheries management and historical research (Abu et al. 2019; Mantyka-Pringle et al. 2017; Giles et al. 2016). Importantly, Two-Eyed Seeing can focus on specific places and impacts to more accurately assess long-term change in a region. In this paper, we use this approach to quantify shoreline change within Burrard Inlet in present-day southwestern British Columbia, the centre of Tsleil-Waututh Nation's (TWN) territory, and the main harbour of metropolitan Vancouver and Canada's largest port.

Cumulative shoreline change in Burrard Inlet from a Tsleil-Waututh Nation perspective

The Tsleil-Waututh people have used, occupied, and governed what is now known as Burrard Inlet, British Columbia, Canada, and its shorelines according to Coast Salish protocol for thousands of years (Morin et al. 2021, 2018). However, since the late 1800s, urban, industrial, and port development, pollution, and resource exploitation have greatly altered the inlet and its shoreline. This has reduced the opportunity for TWN and other local First Nations to access and utilize the waters and beaches for harvesting food, cultural practices, and other constitutionally protected rights. Without constraints, continued development and commercial activity along the Burrard Inlet shoreline will further alter landscapes, stress ecosystems, and negatively affect the local ecosystem and TWN.

The shoreline, as the interface between terrestrial and marine systems, has always been of central importance to TWN lifeways and culture. The nature of this shoreline, in part, determined where canoes could be landed or launched, and where traditional settlements were located. The intertidal area was crucially important for harvesting practices – clams, crabs, fish, and seaweeds – and was carefully managed with clam gardens and wooden fish traps (Lepofsky et al. 2007; Morin 2015). A common saying within TWN is that "when the tide went out, the table was set", reflecting the abundant and readily available food in the intertidal zone of Burrard Inlet. Furthermore, certain parts of the shoreline are known to hold significant spiritual powers and are used by TWN people as part of their spiritual training (Morin 2015). Important TWN ceremonies are held at the shoreline, as it is also at the interface between physical and spiritual realms. All these aspects of the shoreline mark it as one of the most important features of the TWN world. Loss of this shoreline and intertidal ecosystems impedes TWN resource harvesting activities, spiritual practices, and ability to support and transmit their traditional culture.

In addition to the importance to TWN's way of life, the shoreline is integral to a healthy coastal ecosystem. As the transition zone between ocean and land, shorelines link the terrestrial and ocean biomes and facilitate the transfer of energy, nutrients, and organisms between them. In particular, the intertidal zone, the area between the lowest elevation exposed to air and the highest elevation washed by tides throughout the tide cycle (Meadows & Campbell 1988), is of critical importance. This highly productive area provides diverse habitat, nursery, refuge, and foraging grounds for a vast range of culturally, ecologically, and economically important species. This includes marine animals, such as juvenile salmon, forage fish (e.g., herring and smelt), bivalves (e.g., clams and oysters), crabs, and seabirds (e.g., waterfowl and gulls); marine vegetation, such as eelgrass, saltworts (e.g., pickleweed), sedges, and rushes; terrestrial mammals such as bears, wolves, coyotes, and mustelids (e.g., fishers and river otters); and other birds such as eagles and corvids.

Similarly, estuaries are highly productive ecosystems formed where rivers and streams enter the ocean, and freshwater and saltwater mix. They typically develop on shallow deltas of sediment (silt and sand) carried downstream and deposited as flows slow down and spread out over the gently sloping marine shoreline. Estuarine habitat in Burrard Inlet supports six of the seven species of Pacific salmon, as well as a range of forage

and flat fish, shorebirds, and shellfish species. Approximately 112 streams flow directly into Burrard Inlet (Balanced Environmental Services Inc 2010); the three largest are the Seymour, Capilano, and Indian Rivers.

Juvenile salmon use nearshore areas in Burrard Inlet during spring and summer months (Levy 1996), and originate from 17 known spawning streams in the inlet, as well as from the Fraser River (Naito & Hwang 2000). In general, juvenile salmon restrict their movements to habitats between 0.1 m and 2.0 m depth until they reach a size that allows them to exploit deeper channel and open water habitats and associated prey resources (Simenstad et al. 1982). Intertidal marshes, eelgrass beds, and kelp forests all provide food, refuge, and resting areas for juvenile salmon, when they are at a life stage highly susceptible to predation (Fresh 2006; Lamb et al. 2011; Mumford 2007).

In addition to salmon, forage fish rely on intertidal habitats to complete their life-cycle, and are a critical link in the marine food web as a critical food source for larger fish and other fish-eating marine species, including Chinook (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*), and many birds, including regionally-significant populations of Great Blue Heron (*Ardea Herodias*), Western Grebe (*Aechmophorus occidentalis*), and Barrow's Goldeneye (*Bucephala islandica*) (de Graaff 2014; Worcester 2011). Sand lance (*Ammodytes hexapterus*) and surf smelt (*Hypomesus pretiosus*) are beach spawners, and need a mix of gravel and sand beaches to spawn, while Pacific herring (*Clupea pallasii*) typically spawn on intertidal marine vegetation such as eelgrass and seaweeds (de Graaff 2014). Beaches with natural erosion processes and marine riparian vegetation provide optimal habitat.

Burrard Inlet contains a diverse community of shellfish including bivalve species like clams, mussels, and oysters. Shellfish play an important role in Burrard Inlet: they filter out and break down contaminants and are a reliable food source for seabirds, shorebirds, and other predators. In Burrard Inlet, shellfish can be found in rocky intertidal areas, tidal flats, and estuaries. Shellfish are also important as a food source for wildlife (Lilley et al. 2017). For example, beds of blue mussels are found off Stanley Park and are important feeding grounds for Surf Scoters (Worcester 2011).

Of these diverse, numerous species that rely on healthy shorelines, many are of vital importance to TWN as food sources and integral to their culture. Salmon, forage fish, clams, and waterfowl are especially important to TWN's subsistence economy, and harvesting sites were historically distributed throughout Burrard inlet (Lepofsky et al. 2007; Morin 2015; Tsleil-Waututh Nation 2016). TWN's way of life depends on the health of these marine species in Burrard Inlet, which in turn depend on intact habitats and ecologically functional shorelines. When the intertidal zone is filled in or excavated for urban, port, and industrial development, all of these habitats are completely destroyed and the above functions are lost, severely impacting these species and TWN's way of life. Further, short of this outright elimination, activities and developments at or adjacent to the shoreline indirectly impact the value, quantity, and productivity of intertidal habitats, such as dredging (Wenger et al. 2017), shoreline hardening and armouring (Dugan et al. 2018), constructing seawalls (Peterson et al. 2000), installing overwater structures such as piers and marinas (Nightingale & Simenstad 2001), and removing riparian vegetation (O'Toole et al. 2009). All of these impacts to shorelines exist within Burrard Inlet.

Although Burrard Inlet has seen significant shoreline change from development and human modifications, change has been incremental and gradual over time, similar to other coastal areas in North America (Hapke et al. 2013). This has shifted the perception of Burrard Inlet's importance toward its role as an industrial port and urban harbour, rather than as the home of TWN and a provider of healthy wild foods. To counter this shifted baseline, a pre-contact baseline is required to establish conditions of Burrard Inlet before rapid changes began following colonization, in order to properly understand impacts of colonial development on the ecosystem and

TWN. This baseline must account for total environmental changes since European contact in 1792, including to the ecosystem, chemistry, and physical characteristics of the inlet.

To date, there is no comprehensive spatial assessment of changes to the Burrard Inlet shoreline from colonial development. Therefore, in this study, we use multiple lines of evidence including historical and modern maps, archival documents, and Indigenous Knowledge, assisted by geographic information systems (GIS), to reconstruct the historical shoreline of Burrard Inlet and quantify the spatial extent of intertidal and subtidal area change in the inlet since Europeans first arrived in the area. Further, we discuss how these changes directly affect TWN and the Burrard Inlet ecosystem. Finally, we highlight ways that this foundational spatial analysis can quantify and inform future work to determine specific impacts of cumulative shoreline change on TWN's way of life.

Methods

To reconstruct the historical shoreline prior to European contact (1792), we used a combination of spatial data, maps, and a participatory mapping approach (Dunn 2008; Álvarez Larrain & McCall 2018) to draw information from a wide variety of sources, including historians, archaeologists, and local Indigenous Knowledge Holders. The year 2020 was selected to represent current conditions and used in shoreline and intertidal change analysis to understand the cumulative effects of Vancouver's colonial history. We ultimately created geospatial files ('layers') representing an approximation of the pre-contact shoreline, including the high and low tide marks, and intertidal area for Burrard Inlet, British Columbia, Canada, which were used to quantify intertidal and subtidal area change from 1792 to 2020.

Reconstructing the Pre-Contact (1792) Shoreline

The layers representing the pre-contact shoreline were compiled using multiple lines of evidence including cartographic resources (e.g., 1893 navigational chart and 1912 Goad's Fire Insurance Map), Indigenous Knowledge (e.g., participatory mapping process), archival materials (e.g., interviews, letters, books), and imagery and elevation data. The layers contain annotation associated with segments of shoreline documenting the source(s) and other metadata captured during the process.

Navigational Chart of Burrard Inlet (1893)

While both British and Spanish explorers created maps of Burrard Inlet in 1792 (MacDonald 1994; Lamb 1984), and there are other maps and depictions of the inlet from the mid-1800s (Appendix A: Supplemental Methods), these maps were not accurate or detailed enough to reliably assess the historical shoreline. However, a detailed map titled "Burrard Inlet" from the "Government of the Dominion of Canada" and dated 6th March 1893, was selected as the focal resource for further evaluation to confirm its accuracy and extract the coastline representative of the late 1800s (Appendix A: Supplemental Methods, Figure A-1). The map is attributed to hydrographer Captain W.J.L. Wharton, the command of Staff Commander J.G. Boulton, and to surveys by W.J. Steward with the exception of the "North Arm" (now referred to as "Indian Arm") and "Queen Charlotte Channel" (now "Howe Sound") which were drawn from previous surveys conducted in 1859-60 (Dorricott & Cullon 2012). The map is #922 engraved by Davies & Company and contains two insets, one for Vancouver Harbour and one for Second Narrows (Central Harbour). This map was the first marine navigational chart completed as part of the Canadian hydrographic surveys initiated under *British North America Act,* which established a federal responsibility for safe navigation of Canadian waters (Meehan 2004; Dahl et al. 2015). The map was thus produced as a marine navigational aid with attention to hazards, tides, marine depths, and shoreline using the best survey and cartographic methods of the time.

Historical records indicate that most of the shoreline surveying was done by foot while the marine depth profiling was done by ship (Meehan 2004). A landmark observation point in Port Moody is noted with

geographic coordinates and indicated on the map near the town site. The Vancouver Harbour inset map declares Brockton Point as 49˚17'45" N 123˚ 6'53" W in a note under the main title. The inset map depicting First Narrows (Inner Harbour) and Stanley Park area has a note that several landmarks were sighted from 'Brockton point', 'C.P.R. Co's wharf', and 'eastern tea shed' with a notation used to indicate the direction of the landmarks:

a) "Chimney of Sugar Refinery in line with Brockton Pt Eb S ¼ S" (75.9375˚);
b) "Congregational Church Tower in line with N.W. corner of C.P.R. Co's wharf Sb E 5/8 E" (18.0300˚);
c) "Methodist Church Tower in line with centre of eastern tea shed Sb E ¼ E" (4.0625˚);
d) "N.W. Side of Indian sheds in line with Brockton Pt. W 5/8 S" (97.03125˚) (brackets: translation of quadrant notation to degrees clockwise from north).

The information provided indicates the map was produced using straight line bearings from landmarks including survey markers with known latitude and longitude; however, latitudes and longitudes were not known with great accuracy at the time. For example, modern navigational charts place Brockton Point at 49˚18'3.18" N 123˚7'1.2" W, which is 893 m from Brockton Point as declared by the map. Thus, the map is likely to be higher in accuracy with respect to angles and the shape of the coastline than to the locations given as coordinates. Although no projection is given, a Mercator (conic) projection is likely the best match. Mercator was a common projection at the time for marine charts as it preserves direction (angles) such that all constant bearings are represented as straight lines on the map.

"Neap" (i.e., minimum) tide heights are noted to be 11 ft (3.35 m) and "spring" (i.e., maximum) tides are noted to be 13 ft (3.96 m). Numbers on the marine portion of the map represent water depth in fathoms (1 fathom = 1.83 m). It appears marine depths are expressed relative to neap low tide, although this is not explicitly clarified. Depth contours are given at 2, 10, and 20 fathoms in the main chart and 2, 5, and 10 fathoms in the inset charts. Letters were used in some marine areas to denote gravel ('g'), mud ('m'), rock ('r'), sand ('s'), shells ('sh'), and stones ('st'), and kelp is denoted with a symbol. Underlined numbers on the map are stated to be elevation (feet) above higher high tide and numbers without an underline on dry banks are stated to be heights above lower high tide (feet). Other numbers indicate depths (fathoms) below lower high tide.

It is not clear from the information provided on the map how 'shoreline' was defined for survey and cartography purposes. Underlined numbers on the map are stated to be elevation (feet) above spring tides and numbers without an underline on dry banks are stated to be heights above lower high tide (feet). However, neither of these numbers are frequently used by the cartographer. For example, the significant sand bank in the Central Harbour has no elevation markings, although local knowledge later revealed it to have been submerged at high tide. The same situation is observed near Port Moody and other historically important intertidal areas. Thus, we are left uncertain whether there could be a difference between high water mark and a shoreline defined by changes in vegetation or landform. Given the purpose of this map was to ensure safe marine navigation, the cartographers were not primarily concerned about the difference between high-water mark and 'shoreline' and rather focused on navigational hazards. The difference between high tide mark and landforms representing 'shoreline' can become significant in areas with low elevations and salt marshes. The geography of Burrard Inlet does not include many such areas, though, and so we suspect that 'shoreline' and high-water mark are reasonably coincident, with the solid line on the map a reasonable representation of both high-water mark and landform changes familiarly identified as 'shoreline'.

The main map extends east-west from roughly 3,300 m west of Point Grey to Port Moody in the east, and north-south from False Creek in the south to Indian Arm, roughly. Scale bars are given as "Cables" (1/10 of nautical mile, 100 fathoms, 169 – 220 m; Fenna 2002), seconds of Longitude, and "Statute Miles" (land-mile; 1.609 km).

The natural scale of the main map is listed as 1:36,235. The Vancouver Harbour inset map has a natural scale listed of 1:18,100 and extends 1200 m west of Stanley Park to roughly Moodyville in the east. This inset includes lines representing streets and city blocks. The second and smaller inset representing Central Harbour has a natural scale listed as 1:18,246 and represents approximately a 4,400 m stretch east to west.

Georectification of 1893 Navigational Chart

Effort was taken to ensure that the georeferencing process did not magnify inaccuracies of the 1893 map. Known features depicted on the map were used for georeferencing but the listed latitudes and longitudes were not assumed accurate. All reference layers were re-projected to Mercator ('World Mercator' WGS84, EPSG = 3395) using ESRI ArcMap 10.6.1 to match the 1893 Map projection and to reduce the complexity of the georectification. The ArcMap 'georeferencing' toolset was used for georectification.

Several supplemental geospatial layers were acquired for reference and to use as control points during georeferencing (Appendix A: Supplemental Methods, Table A-1). A high-water mark contour ("higher high tide") was acquired from the Canadian Hydrographic Service (CHS, 2020; 2014, ID # 5028437, North American Datum 1983, Projection: Universal Transverse Mercator Zone 9N, Digitized from orthophotos, scale: 1:1250, approximate resolution 1 m). Navigational hydrographic charts were acquired in GeoTIFF format from CHS and re-projected to Global Mercator projection in the WGS84 datum. The layers in 'ENC S-57' format were also projected from geodetic (i.e., latitude and longitude) to Global Mercator in the WGS84 datum. Additional geospatial layers were downloaded from the City of Vancouver and City of North Vancouver Open Data portals including street, building, and block outlines. For the City of North Vancouver, a digitized layer representing road centre lines from 1930 was available. Several older CHS navigational charts were also used for reference.

Control points were selected from reference layers (Appendix A: Supplemental Methods, Table A-2). Prominent city block corners and street intersections from the map that have remained unchanged since 1893 were selected (e.g., the Hotel Vancouver, the Railway Station, Granville Street blocks, etc.). Prominent coastline features depicted on the modern navigational charts were also used in selecting control points, including Point Atkinson in West Vancouver, a coastline feature on western Point Grey, Berry Point near Capitol Hill in Burnaby, a coastline feature near Brockton Point in Stanley Park, a coastline feature near Sunnyside Beach in Port Moody, a feature in Deep Cove, and an inlet in Port Moody. Care was taken to distribute control points widely across the map, although no control points were selected in Howe Sound and North of Racoon Island in Indian Arm due to the lower survey and cartographic accuracy of those areas in the 1893 map (acknowledged by the cartographer in notes on the map). Because of the lower survey accuracy in Indian Arm, and little evidence of significant shoreline change in the area since 1792, Indian Arm was excluded from detailed spatial analysis quantifying shoreline change since European contact. A total of 22 control points were selected, and a spline transformation (aka 'rubber-sheeting') was chosen for georectification which resulted in a total Root Mean Square (RMS) forward error of 1.4e-05 m. The map was then exported as a georeferenced TIFF with 7.12 m resolution (pixels slightly smaller than the estimated map resolution) and resampled using bilinear interpolation for continuous data.

A total of 11 ground control points (GCP) were used for georectification from the Vancouver Harbour map inset into the 1893 Map (Appendix A: Supplemental Methods, Table A-3). Again, prominent city block corners and street intersections from the inset map were chosen that were likely to be unchanged since 1893 (e.g., the Hotel Vancouver, the Railway Station, Granville Street blocks, etc.). The CHS high water mark coastline and the CHS navigational chart were used to select a GCP on the rocky northern coast of Stanley Park. Using the spline transformation resulted in a total Root Mean Square (RMS) forward error of 1.15e-06 m. The map was then exported as a georeferenced TIFF with a 3.55 m resolution resampled using bilinear interpolation for continuous data.

The Central Harbour inset map was not georectified due to a lack of modern features to use as control points.

Digitization of Shoreline from 1893 Maps

ArcMap 10.6.1 (Environmental Systems Research Institute Inc., Redlands, CA, USA) was used to manually digitize the shoreline from the georeferenced maps. To facilitate length and area comparisons to modern-day shoreline, low-tide, and intertidal, a standardized minimum segment length was chosen based on the horizontal resolution of the maps. This method minimizes the effect of the higher resolution of modern layers which when compared to the lower resolution historic layers would appear to be more sinuous, an effect of the 'coastline paradox' (Stoa 2019). Reference scales were used to estimate coastline resolution by multiplying the reference scale by a factor of 1/2000 using "Tobler's Rule" (Tobler 1988, 1987). Thus, the main map's intrinsic horizontal coastline resolution was estimated at 18.1 m (minimum horizontal error +/- 9.05 m) and the Vancouver Harbour inset map maximum horizontal coastline resolution was estimated to be 9 m (minimum horizontal error +/- 4.5 m). During digitization in ArcMap, a standard distance was set between each vertex corresponding to the map resolution.

Goad's Fire Insurance Map (1912)

The 1893 shoreline data were cross-referenced with another map produced for fire insurance purposes in 1912. This map, referred to the 'Goad's Fire Insurance Map', was used to digitize a feature marked as "Original Shoreline" (circa 1880) along the northern shoreline of downtown Vancouver. This map was used for fire insurance liability purposes and appears to have been one in a series. A scanned and georectified version of this map created by the City of Vancouver from the 1912 printed version was used as the basis for this digitization process (City of Vancouver 2014). While this series of fire insurance maps apparently extends back to at least 1897, these were not obtained. However, the "original shoreline" depicted on the scanned map is likely the same throughout the series, representing a fixed reference point, as its date indicated (circa 1880) predates the start of the series. Care was taken to ensure that the digitized line vectors had a minimum distance between vertices of 9 m to standardize shoreline resolution for length and area calculations. The resolution, accuracy, and source for the original shoreline depicted on this map is unclear.

Interpreting Shoreline Modification in Early Historical Maps

The georectified features extracted from the 1893 navigational chart and Goad's Fire Insurance Map were used as a starting point for reconstructing the 1792 shoreline and intertidal zone. The 1893 low tide line was suspected to be less accurate than the 1893 shoreline for several reasons. First, it appeared to be less detailed. Second, it appeared to diverge from the modern shoreline in areas with rocky bottom or steep relief, which are unlikely to have changed much since 1792. Given that the surveyors reportedly did most of the surveying on foot (Meehan 2004), we suspect that they surveyed the shoreline in detail and relied on depth soundings or relatively less accurate surveying methods to depict the low tide line. The west side of Stanley Park was one example where the low tide line looked suspiciously inaccurate. Further, it was unclear from the map descriptions whether the low tide line represented the extreme low tides represented periodically in the semi-diurnal tidal cycle. A decision was made to replace the 1893 low tide line with the modern, high-accuracy low tide line and to modify it in areas that have clearly been dredged.

In several locations, shoreline modifications from urban and industrial development were evident on the 1893 map. This primarily included the south shore of the Inner Harbour near present day downtown Vancouver, between Lost Lagoon and Clark Drive; the north shore of False Creek, from approximately present-day Granville Bridge to Main Street; and intermittent development along the south shore of False Creek approximately between present-day Oak Street and Main Street. Additionally, minor shoreline modification was noted on the

north shore of the Inner Harbour, near present-day Moodyville Park in North Vancouver, and on the south shore of the Inner Harbour near present-day New Brighton Park in Vancouver.

To address these locations that had been modified before 1893, we compared the 1893 navigational chart and the "Original Shoreline" on the Goad's Fire Insurance Map. The shorelines from the two maps aligned closely and within the degree of horizontal error from the digitized 1893 map in areas with no apparent shoreline modification. However, the "Original Shoreline" on the Goad's Fire Insurance Map captured the south shore of the Inner Harbour near present day downtown Vancouver, and significant portions of False Creek before much of the urban development represented in the 1893 map. Therefore, a hybrid of the high tide line indicated in the 1893 navigational chart and the Goad's Fire Insurance Map provided a representative pre-contact shoreline condition for the majority of Burrard Inlet.

Participatory Mapping

Still, through discussions with TWN Knowledge Holders and an initial review of archival information, there were indications that shoreline modification had occurred prior to the production of the 1880 "Original Shoreline" in Goad's Fire Insurance Map. Therefore, we used a participatory mapping approach (Dunn 2008; Álvarez Larrain & McCall 2018) to integrate different types of information to better estimate the extent of the shoreline and intertidal in 1792, approximately 100 years prior to adequately detailed and accurate maps produced for the area.

The participatory mapping approach began with open-ended discussions in the spring and summer of 2020 involving two TWN Knowledge Holders and staff, Micheal and Michelle George, TWN staff Spencer Taft, consulting archaeologist Dr. Jesse Morin, UBC PhD candidate Greig Oldford, UBC professor Dr. Villy Christenson, and consulting biologist Patrick Lilley. These discussions informed a targeted workshop on October 28, 2020, to draw the estimated pre-contact high tide line, as informed by TWN Knowledge and Euro-Canadian documents and archival materials.

During the targeted workshop, participants recounted TWN oral history regarding historical shoreline features at locations of interest, including historical canoe routes through areas demarcated as land in the geospatial layers extracted from the 1893 navigational chart and Goad's Fire Insurance Map. Concurrently, participants reviewed Euro-Canadian documents and archival materials pre-dating these maps, such as Captain George Vancouver's and Peter Puget's account of arriving in Burrard Inlet in 1792 (Lamb 1984; Puget 1792; Vancouver 1798). In the workshop, participants had on-hand printed and digital maps from 1893 and 2020 that included topographical features, and elevation and bathymetric data. Following consideration of TWN Knowledge, archival materials, and maps, participants used felt markers and Esri ArcGIS Desktop mapping software to draw an estimated version of the pre-contact shoreline near downtown Vancouver and Stanley Park as it existed prior to colonial development captured on the 1893 map. Notes were taken and associated with different segments of shoreline using the attribute tables of the geospatial layers. Discussions focused primarily on two locations: an intertidal connection from present-day English Bay to Lost Lagoon, and an intertidal connection from the Inner Harbour to False Creek.

Archival Searches

Following the participatory mapping session, a targeted archival search focused on key resources and the locations of interest provided detailed information on historical shoreline features and locations, described in detail below. This information was considered alongside historical and current topographical features to refine the pre-contact shoreline location near Downtown Vancouver and Stanley Park. Geospatial data was updated to reflect the input of participants based on TWN Knowledge, Euro-Canadian documents and archival materials, and relevant maps. A qualitative score representing relative uncertainty was assigned to each line segment. This

was primarily a way to visualize areas with relatively high uncertainty. An estimate of horizontal error was also assigned based on a visual assessment using GIS data and discussions about each line segment.

Also, keyword searches of several archival databases were undertaken to identify written or oral descriptions of shoreline features or configuration in areas altered prior to the production of colonial maps that came up during the participatory mapping. Two features or areas were of particular interest were: (1) A potential tidal connection between English Bay and the Inner Harbour at the current location between Second Beach and Lost Lagoon; and (2) A potential tidal connection connecting False Creek and the Inner Harbour in the vicinity of Carrall Street. Key references searched included two websites that include early post-contact Vancouver historical information (buildingvancouver.wordpress.com and changingvancouver.com), and *Early Vancouver*, a seven-volume book set written by Vancouver's first City Archivist, Major James Skitt Matthews that documents City's early history, including a number of accounts of interviews with early settlers and Indigenous leaders and Elders (Matthews 1955, 2011). Traditional use information within TWN's records database were also searched for similar shoreline references. This included the TWN Elders Knowledge Study (2013-present) and the TWN Use Study: Foreshore and Marine Areas (Tsleil-Waututh Nation 2011). Search terms included close landmarks, historic and current street names, and other shoreline-related terms.

The information developed through the participatory mapping process and archival search was used to refine the shoreline derived from the 1893 navigational chart and draw the estimated high tide line as it existed prior to European contact in 1792. A second participatory mapping session was held on March 23, 2021, where participants had an opportunity to view and comment on the revised digital shoreline segments. Following feedback from this session, minor revisions and refinements were made to the digital shoreline to create the final version of the spatial file of Burrard Inlet's pre-contact shoreline.

Present-day (2020) Shoreline and Intertidal Zone

Digital files in International Hydrographic Organisation (IHO) S-57 Electronic Navigation Charts (ENC) formats were acquired from the Canadian Hydrographic Service, specifically the vector files for charts V-3493, V-3494, V-3495, and V-3496. Under this standard, the low-tide contour represents the lowest low tide mark and the high-water mark contour represents the highest high tide mark (standard). The coastlines were extracted by selecting features with codes 'COALNE' (coastline) and 'SLCONS' (artificial structures or armored coastline) using the FME software (www.safe.com). To create an intertidal polygon, the modern high-water mark was connected to the low-water mark through operations and manual edits in ArcMap, resulting in intertidal zone polygons.

During compilation of the navigational charts, CHS combines data from multiple surveys (as noted on the charts). Thus, the accuracy of the map varies across the charts making it difficult to assign a single estimated measure of accuracy to the entire area. Given that Burrard Inlet is an important waterway for navigation, it is relatively intensively surveyed and horizontal accuracy is estimated to be sub-metre – more than adequate for comparisons to the pre-contact layers. In the raster navigational charts, the shoreline is distinguished from the high-water line whereas in the vector version of the CHS chart data, we did not find a layer explicitly representing 'shoreline' – only a high-water line feature was present. Examining the navigational charts revealed that in the study area the high-water contour and the shoreline were typically coincident. Thus, the high-water contour from the CHS vector data was considered the shoreline for the purposes of this study.

Shoreline and Intertidal Change Analysis

Using the pre-contact (1792) and the present-day (2020) shoreline (high tide line), low tide line, and intertidal geospatial layers, an analysis was conducted to quantify the change in shoreline area between intertidal area, subtidal area, and land area. The study area was defined to include both the shoreline of 1792 and 2020, thus

some areas that were land in 1792 were included in the analysis. The survey quality from the historic maps only poorly represented the 'Indian Arm' fjord north of Racoon Island. This area is typically characterized by steep, rocky shoreline and the shoreline and intertidal are relatively less modified by urban development. After considering these factors, we excluded 'Indian Arm' from the shoreline and intertidal change analysis.

Creation of Change Area Polygons

To calculate the changes in area that have occurred between the two time periods, polygons representing different habitat types on the shoreline – intertidal area, subtidal area, and land area – in 1792 and 2020 were created and classified. Areas where habitat type changed between 1792 and 2020 were identified by overlapping the two polygon layers in ArcMap and creating a new set of polygons delineating any areas of change and the change that has occurred. This was completed using the 'Intersect' function in ArcMap.

Calculation of Change Metrics

To analyze the changes, the following metrics were calculated using the change area polygons:

- **Gross losses/gains** were assessed by calculating the amount of area that has been lost or gained for that habitat type between 1792 and 2020 (e.g., subtidal to land, intertidal to subtidal, intertidal to land, etc.). In contrast to net change, losses and gains were calculated independently. This is intended to capture any conversion of habitat, regardless of whether it was offset by a corresponding loss or gain. Gross metrics were calculated because many of the dominant mechanisms of change within the inlet (e.g., dredging, infilling) are likely to degrade habitat, and net change on its own does not adequately capture the overall impacts of development that have occurred.
- **Net change** was assessed by calculating the difference between gross losses and gain for each habitat type. This metric was intended to assess the net balance between losses and gains for each habitat type.
- **Net tidal area change** is a rolled-up version of net change and was assessed by calculating the net amount of area that was converted from land to intertidal and subtidal area types combined, and vice versa. The metric captures overall change in the wetted area of the inlet.

Summary statistics were derived for each habitat type (subtidal, intertidal, and land) for both Burrard Inlet as a whole as well as for each major sub-basin/reach. Sub-basin/reach boundaries used for this analysis have been used previously for other monitoring and research work in Burrard Inlet and represent different physiographic areas of the inlet (Figure 1).

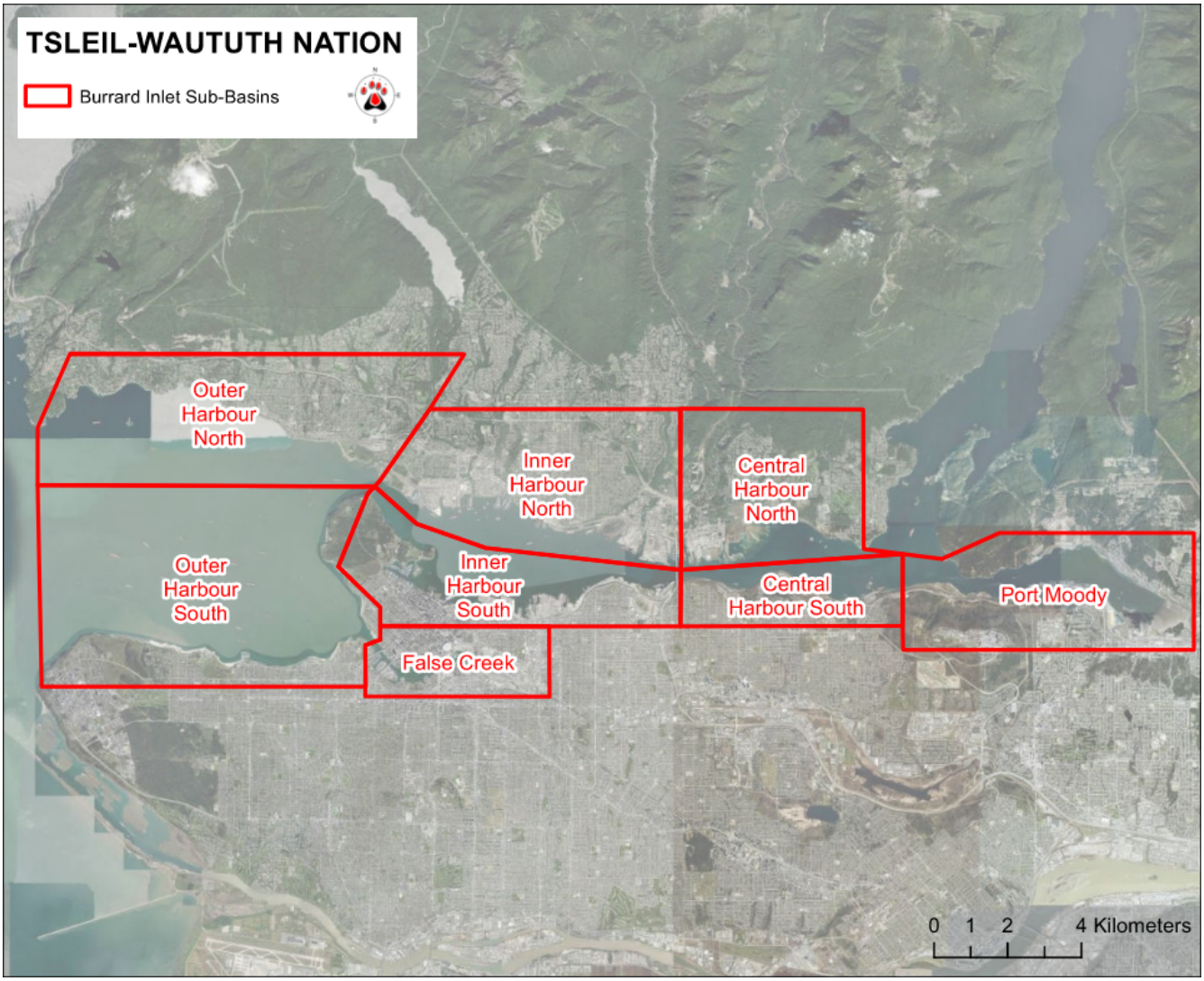

Figure 1. Location of Burrard Inlet and Delineation of Sub-basins/Reaches for Shoreline Change Analysis

Results

Pre-Contact and Present-Day Shoreline and Intertidal Zone

The georectification and digitization of the 1893 navigational chart and Goad's Fire Insurance Map produced shoreline, low tide line, and intertidal areas as digital features that represent Burrard Inlet in the late 1800s. Although the exact accuracy is unknown, these maps appear to have been produced with horizontal accuracies between 10 and 20 metres and likely represent the best balance between age and cartographic survey quality, as older maps reviewed were not accurate enough for our analysis, while more-recent maps depicted an increasingly modified shoreline. The 1893 navigational chart in particular represented a substantial effort of the Canadian Hydrographic Service (Meehan 2004). Still, the participatory mapping process and archival search was crucial to extend information further back to depict the shoreline in 1792, before colonial development in the area began. In combination, these maps, TWN Knowledge, and archival materials successfully informed the shoreline extent for all of Burrard Inlet as it existed in 1792 at the time of European contact (Figure 2).

The participatory mapping process was essential to inform the intertidal connections from present-day English Bay to Lost Lagoon, and from the Inner Harbour to False Creek. TWN Knowledge Holders recounted oral history that indicated these locations were historical canoe routes for TWN ancestors. Additionally, numerous archival resources corroborated this information as being underwater or wetted at high tides, including Captain George Vancouver upon arriving in Burrard Inlet in 1792, and various recollections of residents paddling through these areas in canoes without portaging (Appendix B: Reference Index of Archival Information). From various descriptions, both areas were likely in the high intertidal zone, inundated at very high tides, and likely were salt marsh ecosystems. TWN ancestors may have maintained small canals for canoes in these locations to facilitate paddling through the areas when the tide was not high enough to do so.

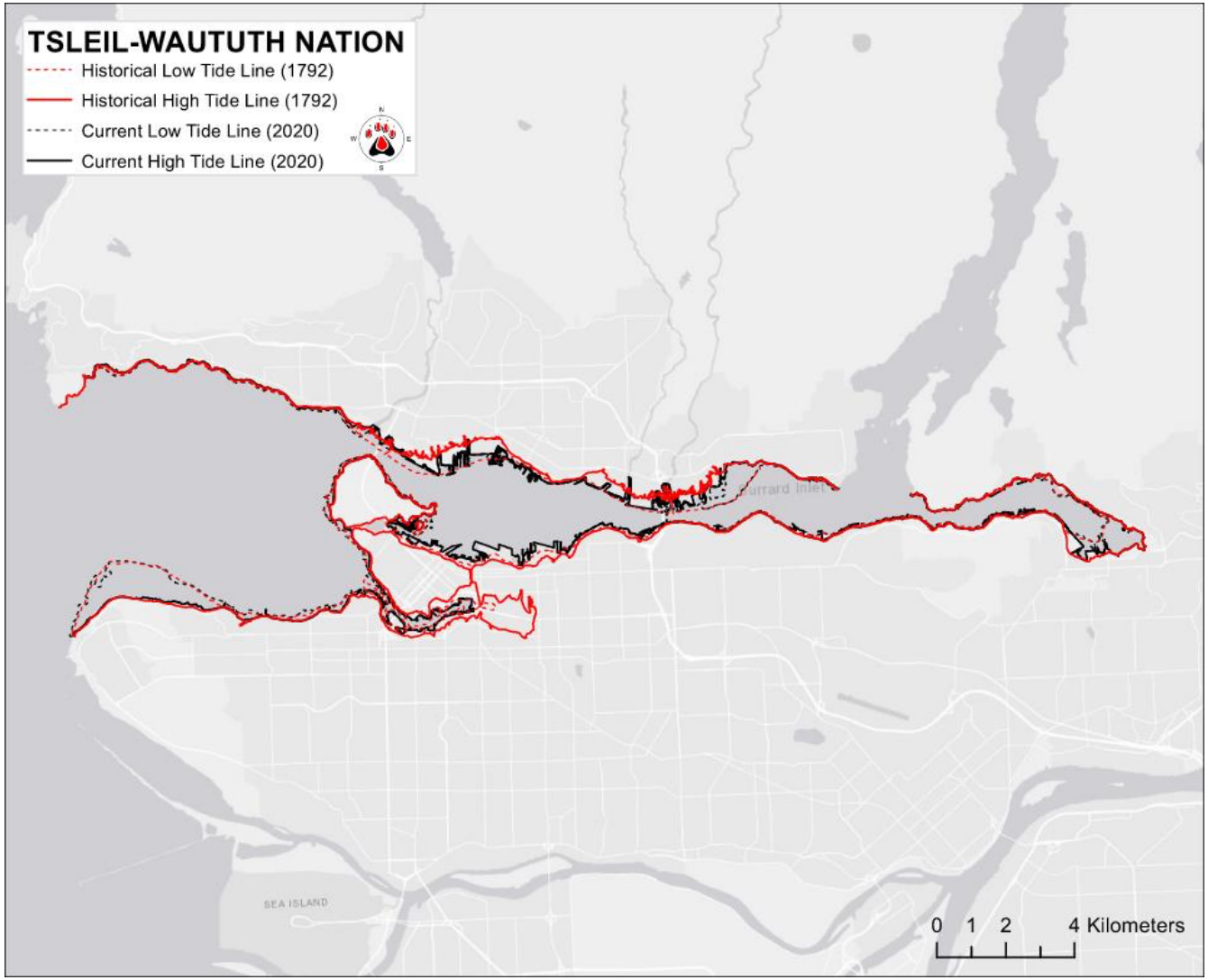

Figure 2. Reconstructed Pre-contact (1792) Shoreline of Burrard Inlet

Shoreline and Intertidal Change

Gross Losses/Gains

Across Burrard Inlet, 945 ha (55%) of intertidal area and 269 ha (3%) of subtidal area has been lost to various forms of shoreline development and change, for a combined total of 1,214 ha (Figure 3; Table 1; Table 2). In contrast, the gain of intertidal and subtidal area due to the excavation and conversion of land to aquatic habitat was modest at 33 ha and 5 ha, respectively.

Intertidal Losses/Gains

Significant loss of intertidal area was seen across multiple sub-basins of Burrard Inlet (Figure 3; Table 1). Gross loss of intertidal area exceeded gross loss of subtidal and land across all sub-basins (Table 2; Figure 3). False Creek had the greatest loss of intertidal area by area and percent area at 286 ha (98%). Inner Harbour North was second greatest at 286 ha (93%), followed by Inner Harbour South at 123 ha (80%); all other sub-basins had less than 80 ha intertidal loss and less than 45% loss by percent area (Figure 3). Intertidal area was disproportionately lost due to infilling to land (704 ha), compared to dredging to subtidal (241 ha). This impact was particularly evident for False Creek and Inner Harbour South where majority of the intertidal area was lost to infilling to land.

Table 1. Intertidal Area (ha) Lost in Burrard Inlet from Pre-contact (1792) to Present-day (2020) by Sub-basin/Reach

Sub-Basin or Reach	Intertidal Retained	Intertidal to Subtidal	Intertidal to Land	Intertidal Lost	% Intertidal Lost
Outer Harbour North	38	18	10	28	42%
Outer Harbour South	379	30	42	72	16%
False Creek	6	40	246	286	98%
Inner Harbour North	23	101	186	288	93%
Inner Harbour South	31	6	117	123	80%
Central Harbour North	119	30	46	76	39%
Central Harbour South	21	2	9	11	35%
Port Moody	147	14	47	61	29%
Total for Burrard Inlet	764	241	704	945	55%

All units are hectares (ha), unless otherwise noted. All units are rounded to the nearest one.

Subtidal Losses/Gains

Although loss of subtidal area was relatively low on a large scale, the relative magnitude of subtidal loss was considerably greater for the False Creek and Inner Harbour South reaches (Table 2). False Creek had the greatest area lost by percent of subtidal at 36%; however, the area lost, 25 ha, was on par with the Inner Harbour North (21 ha; 4%), Outer Harbour North (20 ha; 1%), and Port Moody (19 ha; 4%). Inner Harbour South had the greatest loss by area at 120 ha and second largest by percent area at 12%; all other sub-basins or reaches had less than 5% subtidal lost by percent area. Overall, loss of subtidal area was comparable between conversion to intertidal (113 ha) and conversion to land (156 ha). Subtidal area infilled to land was greatest for Inner Harbour South at 106 ha, making up majority of the subtidal area lost in this sub-basin.

Table 2. Subtidal Area (ha) Lost in Burrard Inlet from Pre-contact (1792) to Present-day (2020) by Sub-basin/Reach

Sub-Basin or Reach	Subtidal Retained	Subtidal to Intertidal	Subtidal to Land	Subtidal Lost	% Subtidal Lost
Outer Harbour North	1755	19	1	20	1%
Outer Harbour South	3268	52	4	55	2%
False Creek	45	4	21	25	36%
Inner Harbour North	499	4	17	21	4%
Inner Harbour South	860	14	106	120	12%
Central Harbour North	227	3	<1	3	1%
Central Harbour South	385	4	3	7	2%
Port Moody	491	15	4	19	4%
Total for Burrard Inlet	7531	113	156	269	3%

All units are hectares (ha), unless otherwise noted. All units are rounded to the nearest one.

Tidal Area Gains

Conversion of land to intertidal or subtidal area was relatively modest (Table 3). Excavation of land to intertidal area was more common, occurring in all 8 sub-basins/reaches, whereas conversion of land to subtidal habitat only occurred in 6 of the 8 sub-basins/reaches. The greatest gain of tidal area was seen in Outer Harbour North with 15 ha of intertidal and 2 ha of subtidal gained. Conversely, >0.1 ha of tidal area was gained in False Creek and four sub-basins have gained 3 ha or less of new wetted tidal area since contact.

Table 3. Tidal Area (ha) Gained in Burrard Inlet from Pre-contact (1792) to Present-day (2020) by Sub-basin/Reach

Sub-Basin or Reach	Land to Intertidal	Land to Subtidal	Tidal Area Gained
Outer Harbour North	15	2	16
Outer Harbour South	3	<0.05	3
False Creek	<1	<0.05	>0.1
Inner Harbour North	9	1	10
Inner Harbour South	1	0	1
Central Harbour North	3	2	4
Central Harbour South	1	0	1
Port Moody	2	<1	2
Total for Burrard Inlet	4	32	36

All units are in hectares (ha). All units are rounded to the nearest one.

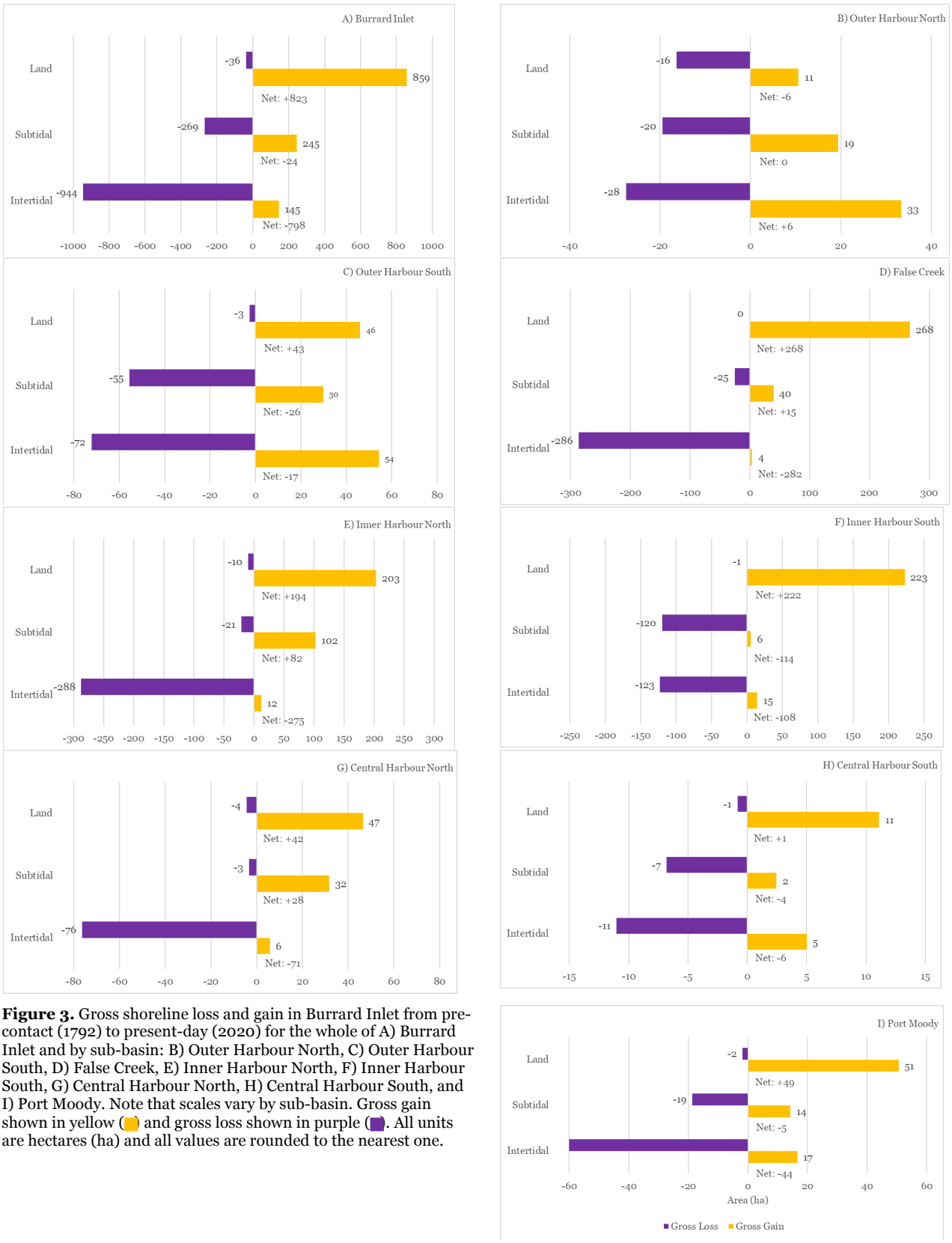

Figure 3. Gross shoreline loss and gain in Burrard Inlet from pre-contact (1792) to present-day (2020) for the whole of A) Burrard Inlet and by sub-basin: B) Outer Harbour North, C) Outer Harbour South, D) False Creek, E) Inner Harbour North, F) Inner Harbour South, G) Central Harbour North, H) Central Harbour South, and I) Port Moody. Note that scales vary by sub-basin. Gross gain shown in yellow (■) and gross loss shown in purple (■). All units are hectares (ha) and all values are rounded to the nearest one.

Net Tidal Area Change

On a net basis, approximately 822 ha of wetted tidal area (i.e., intertidal and subtidal) has been claimed to create new land area in Burrard Inlet since 1792 (Table 4; Figure 4). Net change in tidal area was greatest in False Creek by area (-268 ha) and percent (74%), with most of this being loss of intertidal area (Figure 4). Substantial loss of tidal area was also seen for the Inner Harbour North (-194 ha; 23%) and Inner Harbour South (-222 ha; 20%) reaches, with the former being predominantly loss of intertidal area and the latter being split between subtidal and intertidal.

The Outer Harbour North, the largest of the nine sub-basins, was the only sub-basin to have net gain of tidal area (5 ha; <1%). Central Harbour South had the lowest net loss of tidal area at -10 ha (2%), followed by Outer Harbour South at -42 ha (1%), the second largest sub-basin. Shoreline change in the latter two sub-basins was predominantly conversion of subtidal and intertidal area to land (Figure 4).

Table 4. Net Tidal Area (ha) Change in Burrard Inlet by Sub-basin/Reach from Pre-contact (1792) to Present-day (2020)

Sub-Basin/Reach	Tidal Area in 1792	Tidal Area in 2020	Net Change in Tidal Area	% Tidal Area Change
Outer Harbour North	1840	1846	5	<1%
Outer Harbour South	3780	3737	-42	1%
False Creek	363	95	-268	74%
Inner Harbour North	830	636	-194	23%
Inner Harbour South	1133	911	-222	20%
Central Harbour North	426	384	-42	10%
Central Harbour South	424	413	-10	2%
Port Moody	718	669	-49	7%
Total for Burrard Inlet	9514	8692	-822	9%

All units are hectares (ha), unless otherwise noted.

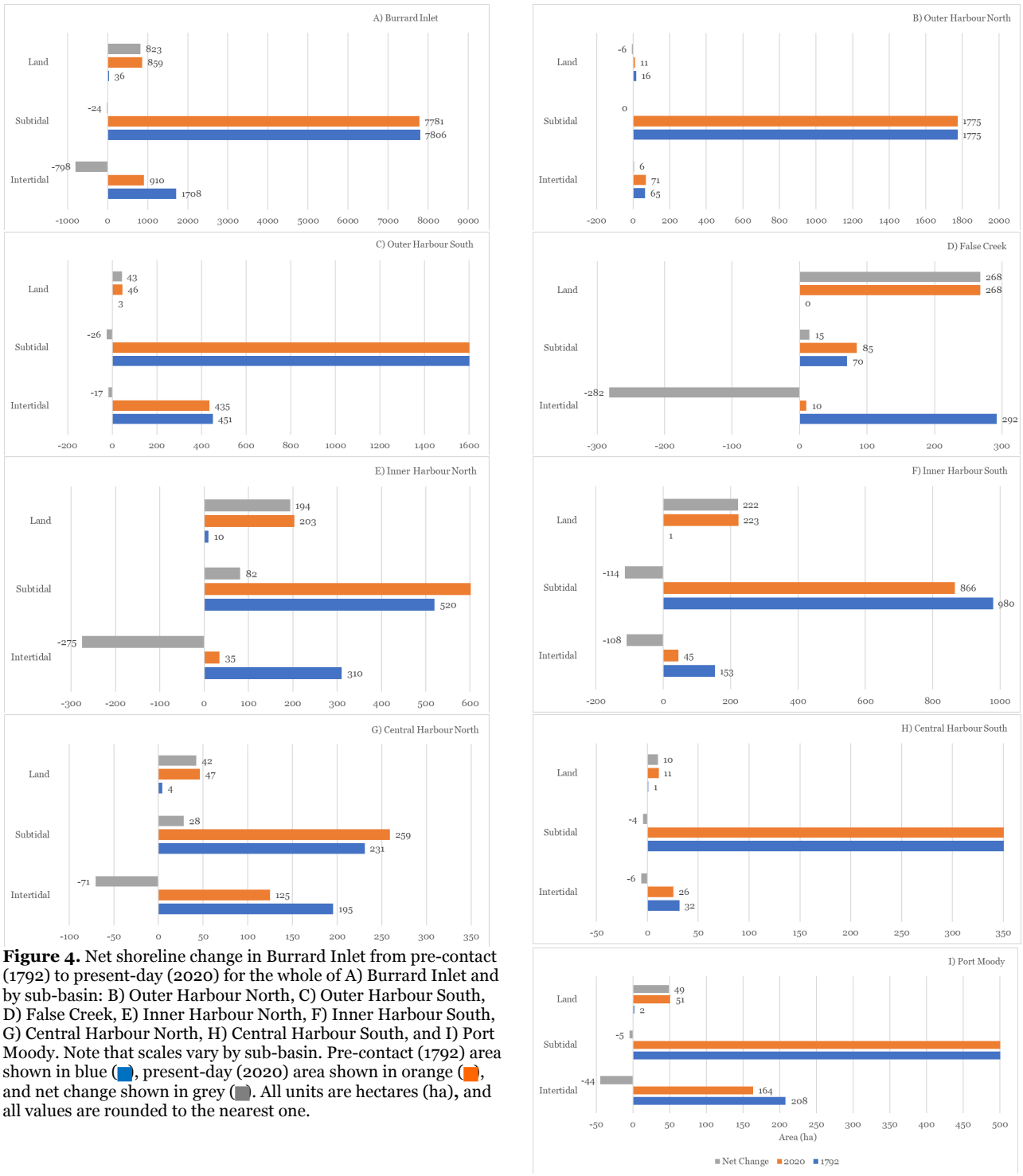

Figure 4. Net shoreline change in Burrard Inlet from pre-contact (1792) to present-day (2020) for the whole of A) Burrard Inlet and by sub-basin: B) Outer Harbour North, C) Outer Harbour South, D) False Creek, E) Inner Harbour North, F) Inner Harbour South, G) Central Harbour North, H) Central Harbour South, and I) Port Moody. Note that scales vary by sub-basin. Pre-contact (1792) area shown in blue (■), present-day (2020) area shown in orange (■), and net change shown in grey (■). All units are hectares (ha), and all values are rounded to the nearest one.

Total Net Shoreline Change Across Burrard Inlet

Total net shoreline change across the entire study area from pre-contact (1792) to present-day (2020) totals 1250 ha. This includes conversion between land, subtidal, and intertidal. Over half (56%) of the total shoreline change resulted from infilling of intertidal areas to create new land area for a total of 704 ha (Figure 5). Of this, False Creek represents the single largest area with 246 ha (2.46 km²) of intertidal habitats that has been lost to infilling associated with urbanization. Conversion of intertidal to subtidal through dredging was the second largest proportion of the total change at 19% representing 241 ha, followed by conversion of subtidal to land at 12% and 156 ha.

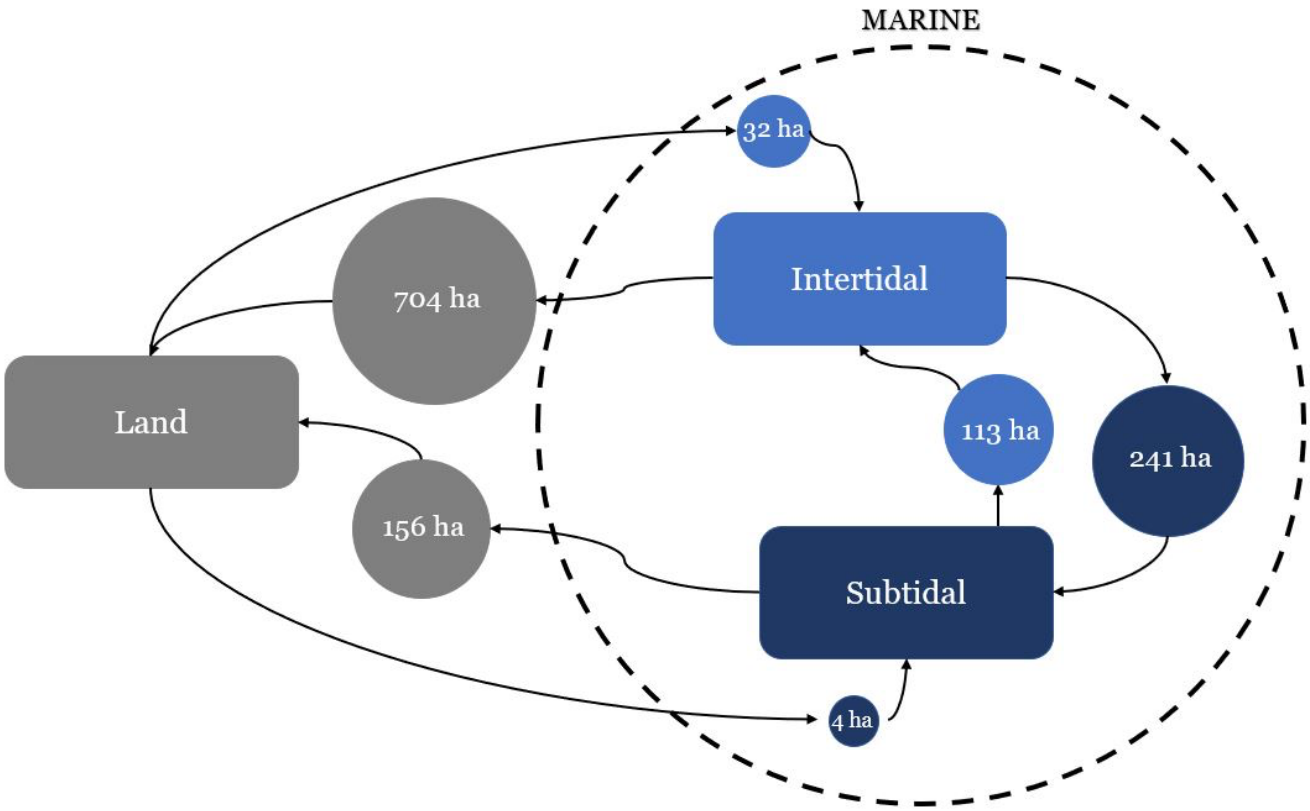

Figure 5. Schematic representation of net shoreline change across Burrard Inlet from 1792 to 2020. All units are hectares (ha) and rounded to the nearest one. The total area of shoreline change in the Inlet over this period was 1250 ha. Circle areas are approximately proportional to the magnitude of shoreline change. The colour of the circle corresponds with the colour of the type present-day (2020).

Areas of Interest

Five areas of interest are presented here either because they are areas of significant shoreline change or because they are representative of broader shoreline changes that have occurred in other areas of the inlet. Selected areas of interest include large estuaries (i.e., Seymour-Lynn Estuary, and Capilano River Estuary), and historically significant intertidal areas that support traditional food species (False Creek Flats, Port Moody Flats, and Spanish Banks). The greatest loss of intertidal area was seen in the Capilano River Estuary where 187 ha (80%) was lost, followed by the Seymour-Lynn Estuary where 160 ha (56%) was lost (Figure 6). The greatest impact relative to area was seen in the False Creek Flats, defined as the historical intertidal area east of the eastern most present-day high tide line in False Creek, where 138 ha of intertidal area was lost, equating to greater than 99.9% of intertidal area lost. In comparison, intertidal area loss was less substantial in Port Moody Flats at 32 ha (22%) and Spanish Banks at 16 ha (5%).

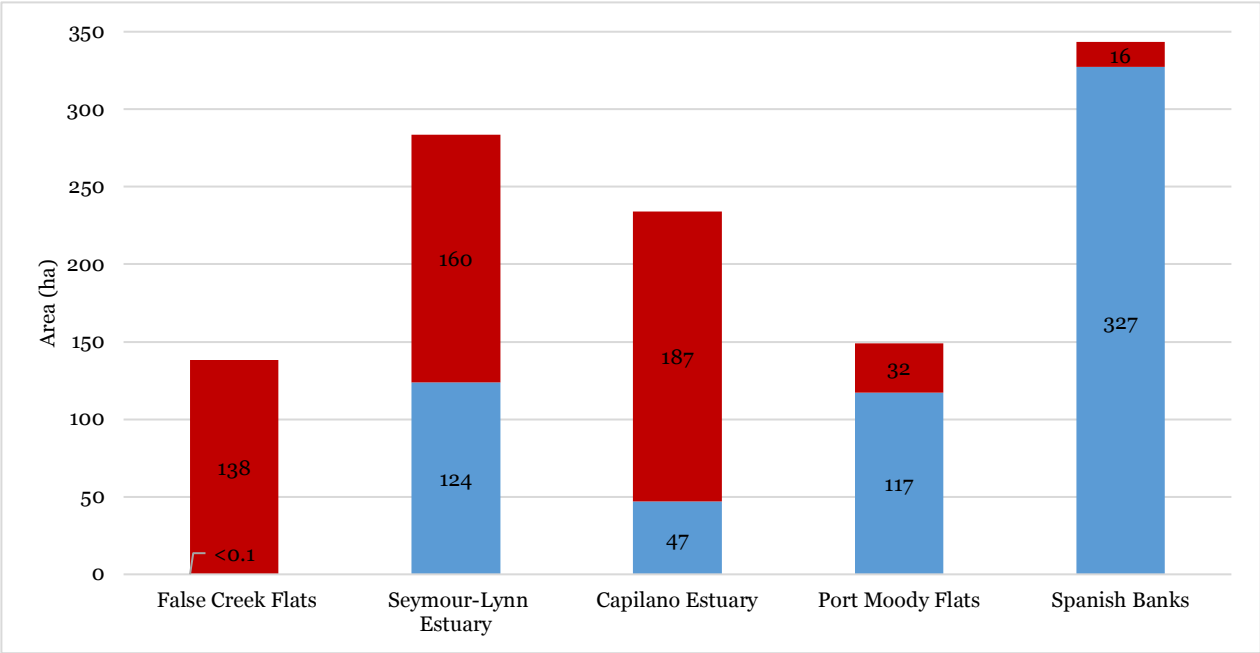

Figure 6. Intertidal area lost in areas of interest in Burrard Inlet from pre-contact (1792) to present-day (2020). The full bar represents the intertidal area in 1792. Intertidal area retained in 2020 is shown in the blue ( ) portion of the bar; Intertidal area lost post-contact is shown in red ( ). All units are in hectares (ha).

Discussion

Multiple lines of evidence successfully quantify cumulative, long-term shoreline change

While it is well known that urban, port, and industrial development has substantially altered the Burrard Inlet shoreline, no previous study has quantified the total shoreline change that has occurred since European contact. By combining Euro-Canadian historical information and recent spatial data with Indigenous Knowledge, this study was able to defensibly reconstruct the pre-contact shoreline and to quantify the spatial extent and cumulative loss of intertidal and subtidal area due to colonial development. Additionally, this process yielded support for TWN's Indigenous Knowledge regarding several previously underappreciated changes and nearly forgotten shoreline features that have been long lost to development.

Specific areas that were initially informed by TWN's oral history included the intertidal connections between present-day Lost Lagoon and English Bay, and from the Inner Harbour to False Creek along Carrall and Columbia Streets. Through the participatory mapping process, TWN Knowledge Holders indicated these areas were historically important canoe routes to provide much shorter and more protected paddling routes from the Inner Harbour to the Outer Harbour and False Creek, allowing TWN ancestors to bypass high currents and additional distance associated with travel through the First Narrows. Based on that information, targeted research in archival materials corroborated that these areas were intertidal and that, at high tides, Stanley Park and the Downtown Peninsula of Vancouver were two islands (Appendix B: Reference Index of Archival Information).

While previous studies have evaluated shoreline change relative to the earliest available aerial photographs of the inlet taken in the 1930s (Stantec 2009), the use of early archival records and Indigenous Knowledge has allowed this record of change to extend to pre-contact conditions for the first time. Without this documentation of pre-contact conditions, many changes to Burrard Inlet's shoreline have been accepted as the pre-development or "natural" baseline condition of urban Vancouver, even though these changes occurred during early colonial

settlement, and industrial and urban development of the area. This is a clear example of shifting baseline syndrome, and how ongoing incremental shoreline change has obfuscated some of the earliest impacts of development on the Burrard Inlet ecosystem and TWN's way of life. As a result, these early impacts are often not acknowledged by Canadian governments, major project proponents, and non-Indigenous communities, when new projects are being proposed or reviewed.

In total, 1,250 ha (12.5 km^2) of the inlet has been converted from one tidal zone to another through colonial development since 1792. This includes 860 ha of marine habitat that is now land, 241 ha of intertidal habitat that is now sub-tidal, 113 ha of subtidal habitat that is now intertidal, and 36 ha of land that are now marine areas. When considered as a whole, these cumulative changes have undoubtedly resulted in significant adverse environmental and cultural effects. Burrard Inlet was historically a highly productive ecosystem that sustained thousands of TWN ancestors for millennia (Morin et al. 2018). The documented habitat loss has inevitably reduced overall ecosystem productivity, particularly for species that utilize the intertidal and subtidal habitat for their life cycle. Many of the species on which TWN traditional food systems depend require intertidal habitats to live and complete their lifecycles, such as clams, herring, salmon, crab, urchin, and diving birds. It is expected that declines in all of these species have been directly tied to the significant loss of shoreline habitats.

It is also important to note that some of the most productive areas are the habitats that have been most impacted by colonial development. This includes large river deltas (Capilano and Lynn-Seymour estuaries), several large, intertidal mudflats, and numerous smaller estuaries, salt marshes, and pocket beaches. Based on Indigenous Knowledge about historic food harvesting areas, the most productive intertidal areas in Burrard Inlet were also the largest. These include False Creek Flats, the Seymour-Lynn Estuary (including Maplewood Mudflats), the Capilano Estuary, Port Moody Flats, the Indian River Estuary, and Spanish Banks. Of these, colonial development has eliminated False Creek Flats (>99% intertidal area lost) and reduced substantially the size of the Capilano Estuary (80% intertidal area lost), the Seymour-Lynn Estuary (56% intertidal area lost), and Port Moody Flats (22% intertidal area lost). In addition to lost intertidal areas, shorelines have been altered in other ways, such as sand additions to expand recreational beaches (Therriault et al. 2002), construction of seawalls, erosion protection, flood protection, or other forms of shoreline armouring. Changes to the Indian River Estuary were not included in this spatial analysis due to a lack of data, however, changes are known to have occurred in this area, including gravel mining (Matthews 1920).

While the impacts of shoreline change are diverse, a small number of development types appear to be responsible for the majority of the intertidal and subtidal habitat conversion. Infilling for shipping terminals and wharfs has resulted in significant losses of both intertidal and subtidal habitat, particularly in the main Port areas within the Inner Harbour. Conversion of intertidal areas to land for industrial and urban development essentially eliminated intertidal habitat in False Creek as early as 1916, when 4.3 million cubic yards of material was dredged from western False Creek and deposited in False Creek Flats to create additional land for Canadian Northern Railway's Pacific Central Station and other industrial land uses (Churchill 1953). In contrast, dredging activities to facilitate navigation and Port operations has driven the conversion of intertidal areas to subtidal habitat. For example, a specialized dredging vessel that could excavate up to 1,200 tons of mud per hour, worked at the First Narrows for 24 hours a day, six days a week, from 1912-1917 (Thirkell 2000), dramatically altering the width and depth of the narrows to allow for access by larger vessels. Ongoing maintenance dredging also occurs in front of several wharf facilities and ship berths. This dredging has converted and maintains a number of previous intertidal areas as subtidal habitat.

Shoreline change, the Burrard Inlet ecosystem, and TWN's way of life

The extensive impacts to the shoreline of Burrard described above have affected innumerable aspects of TWN's way of life and culture, including the ability to harvest traditional foods from their territory. Loss of intertidal

areas have greatly reduced TWN access to some of the most productive resource harvesting areas in Burrard Inlet, where principal food sources, such as clams, crabs, seaweeds, fish roe, and finfish were once harvested in abundance (Lepofsky et al. 2007). This loss has forced TWN people into greater reliance on store-bought processed foods and dislocated people from their traditional harvesting practices. Further, this dislocation of traditional harvesting practices has impaired TWN cultural transmission, from mother to daughter, father to son, and Elder to youth, as such teachings are typically shared on the landscape while undertaking traditional activities. Finally, the limited availability of traditional foods impairs TWN's ability to undertake important cultural activities that require traditional local foods (Morin 2015). Collectively, these impacts to the Burrard Inlet shoreline have corresponding negative effects to TWN's physical, spiritual, cultural and community health.

While lost intertidal habitats have directly eliminated important TWN harvesting locations, reduced opportunities for cultural practices and transmission, and diminished TWN's ability to practice their way of life, there are also many indirect impacts of habitat loss, as intertidal habitats are highly productive ecosystems and essential for many marine species. Reduced intertidal areas within Burrard Inlet will reduce overall productivity of the system and reduce available habitat for ecologically and culturally important plant and animal species, including salmon, clams, waterfowl and forage fish. For example, nearshore marine and estuarine ecosystems are nurseries and refuge for juvenile salmon during a critical period of growth, which affects their subsequent marine survival (Murphy et al. 1998; Tovey 1999). Moreover, forage fish that depend on intertidal habitats to spawn and complete their lifecycles, such as herring, surf smelt, and sand lance, provide a key link in the marine food web, transferring energy from plankton to larger fish (e.g., salmon), marine mammals, and sea birds (Robards et al. 1999; Pikitch et al. 2012). Understanding these indirect impacts to the entire ecosystem's productivity is necessary to fully understand how the heavily altered shorelines have affected Burrard Inlet and TWN's way of life.

Error, Uncertainty, and Limitations

Error and uncertainty are inherent in any process to map or reconstruct landscape changes using limited data and information. With the use of historical maps, error and uncertainty can be introduced in the following ways:

- Inaccuracies in the processes of historical paper map creation based on the typical methods used including sketching of the shoreline between surveyed points (Moore 2000);
- The natural shoreline complexity and the linear distance between surveyed points used to represent the shoreline (Stoa 2019);
- Physical changes and distortions of paper maps, such as uneven shrinkage and stretching due to environmental factors (i.e., humidity), and physical damage from tears, folds, and creases (Moore 2000; Crowell et al. 1991);
- Errors in aerial imagery resulting from the condition of the equipment used, also known as image space distortions, such as lens imperfections or film deformation due to environmental factors (Moore 2000); and
- Errors in aerial imagery resulting from factors outside the camera, also known as object space distortions, such as ground relief, camera tilt, or atmospheric refraction) (Moore 2000).

While some of the limitations of historical maps were determined by the methods used to create them, efforts were made to minimize or remove distortions during georectification. We believe it reasonable to estimate that the mean horizontal error of the final geospatial layers is ~10 m in most areas. However, several areas with higher uncertainty have been highlighted, and merit further investigation.

There are also potential errors associated with identification or interpretation of the location of the high water mark that can be confounded with errors resulting from the specific data source used (Crowell et al. 1991). Generally, the field-interpreted high-water mark (HWM) on historical maps is more accurate than aerial

photographs, where determining the HWM is a desktop exercise. However, the position of the HWM line on the map is more accurately represented when digitizing data from aerial photographs than from historical maps (Crowell et al. 1991).

Even with the application of computerized and manual techniques to correct and minimize distortions in historic maps and aerial photographs, errors will remain (Crowell et al. 1991). However, even with these errors, based on the amount of spatial change detected, we do not expect errors to have an impact on the overall findings or patterns. Furthermore, use of archival documents and ITK in tandem with current and historic cartographic resources and archival information allowed for corroboration of findings through multiple lines of evidence, further minimizing the impact of error and uncertainty.

Natural vs. Anthropogenic Change

Even in the absence of human impacts, shorelines are dynamic and can be altered natural forces such as wind and waves, floods, debris flows, and the natural erosion and deposition of sediments (Río et al. 2013). If these natural forces are also acting in Burrard Inlet, how do we know the impacts observed are due to colonial development and not other factors? While the methods used in this study did not enable us to distinguish between natural and human-related shoreline change, there are several reasons that suggest the majority of the post-contact changes are due to colonial development. First, in areas where natural changes have been observed, these changes have typically been small, often on the scale of 10's of metres. For example, where land has eroded on the north shore of Central Harbour due to ongoing wave and current action near TWN's reserve, this erosion and accretion is still not detectable within the error limits of this investigation, as the horizontal resolution of our methods in this location was estimated at 18.1 m (minimum horizontal error +/- 9.05 m). In many places, the timescale of such natural processes is hundreds to thousands of years longer than our effective study period. Similarly, shoreline change resulting from Indigenous practices, such as clam garden or shell midden construction, were not distinguished from change resulting from colonial development. However, the amount of area likely to have been altered from these practices is small compared to the overall magnitude of change observed. Therefore, despite the lack of distinction between natural, Indigenous, and colonial shoreline changes, we strongly believe virtually all of the post-contact shoreline changes detected in the study are due to colonial activities, primarily urban, port and industrial development, with some of the starkest examples outlined above.

Floating and overwater structure such as docks, marinas, piers, and ports alter the shoreline by shading the intertidal zone, changing the visual character of the shoreline, and altering the flow of water, sediment, and movement along the shoreline (Kerr Wood Leidal Associates Ltd. (KWL) 2021). However, our analysis relied on the high-tide line as delineated by CHS 2020 data, which does not include all of these structures, as they are not hardened, permanent structures that alter the reach of the high-water mark. As such, it is important to recognize that this investigation largely underestimates the true shoreline change in Burrard Inlet when compared to the pre-contact baseline due to the large expansion of overwater structures. This is an important consideration when assessing the cumulative impacts of shoreline change on ecosystems and Indigenous people.

In addition, the metrics used (gross change and net change) do not capture chronology of incremental changes, or areas where multiple iterations of anthropogenic shoreline change have occurred. Although the area of shoreline change may not increase with multiple iterations of changes, the cumulative effects of these developments likely have implications on the environment and Indigenous people, which are not captured within the scope of this study.

Further, this is purely a spatial analysis and does not consider how the functionality of the shoreline has changed for the ecosystem, physical process, and TWN's way of life. Therefore, this analysis does not assess impacts to Aboriginal rights, ecosystem productivity, harvesting opportunities, shoreline access, or how shoreline change

impacts Indigenous Peoples considering culture and cultural heritage, travel routes, settlement patterns, traditional economies, spirituality, or community health. However, it provides fundamental data to inform further analysis focused on all of these topics.

Potential Applications of Findings

The findings in this report have several potential applications, including for general approaches to managing impacts of cumulative effects on ecosystems and Indigenous peoples, and specific applications to better understand impacts of development on the Burrard Inlet ecosystem and TWN.

First, this work demonstrates that comparing a pre-contact baseline to current conditions can assess and quantify cumulative environmental change at a landscape scale, particularly where these changes are spatial in nature. This is important as, while cumulative impacts to Indigenous rights and title have been highlighted as a key concern and incorporated into new Canadian impact assessment processes, to date there have been limited approaches put forth and few examples of how to do this. Such approaches should become a regular part of environmental assessments, including regional cumulative effects assessments.

Second, this study demonstrates that using a Two-Eyed Seeing approach (Reid et al. 2021) based in Indigenous and Western ways of knowing can result in a better understanding of historical conditions and subsequent changes over longer time periods than using Western ways of knowing alone. This approach can help counteract SBS by establishing historical baselines from before rapid change began. This is important, as SBS continues to result in the gradual acceptance of ongoing impacts and loss to ecosystems, and long-term cumulative changes must be measured from a fixed starting point. For example, in Canada, Crown agencies generally consider forecasted impacts of a proposed project compared to a baseline of current, or recent, conditions. After that project is built, associated ecosystem stressors and degradation may be accepted as part of the ecosystem's new baseline, and subsequent environmental assessments could use this degraded state as an acceptable baseline to alter further. From a development perspective, this can result in ever-easier justification of impacts to already degraded systems and can lead to a risk that specific ecosystems are sacrificed for economic development without adequate consideration of constitutionally-protected Aboriginal rights in Canada. This contrasts recent findings from the Canadian judicial system, which acknowledged that as more impacts accrue in a First Nations' territory, development becomes ever-harder to justify, as the Crown must still fulfill its constitutional obligations to uphold Indigenous ways of life (*Yahey v. British Columbia, 2021*). Therefore, new projects and their cumulative impacts can only be properly considered when the extent of past change is clearly documented and understood.

Third, this paper also shows the importance of Indigenous communities leading or being included in cumulative effects work. The synergistic interaction between historical/archival information and Indigenous Knowledge can only occur when Indigenous communities are involved or leading these assessments. Our hope is that the general approach outlined in this paper further facilitates Indigenous involvement and a Two-eyed Seeing approach in Canadian impact assessment decision-making and cumulative effects work.

Finally, this work can directly inform additional analyses to better understand how cumulative shoreline loss specifically affects Burrard Inlet and TWN's way of life, including: reduced overall ecosystem productivity; loss of specific habitat types (e.g., mudflat, salt marsh, eelgrass meadow, etc.) and consequent impacts to individual species; altered tidal circulation, sediment transport, and erosional processes; impacts to culturally and spiritually important places for TWN; reduced shoreline and water access for TWN people; elimination of important harvesting locations for TWN; and any other impacts of shoreline loss to the ecosystem and TWN people.

Acknowledgements

Adrienne Morrison, Records Manager, Tsleil-Waututh Nation, conducted the archival keyword searches of TWN and other written and oral history sources. Aaron Blake Evans, Archaeologist & Cultural Heritage Specialist, Wolf & Crow Research Ltd., also provided archival search support. Allison Hunt, GIS & Information Management Analyst, Inlailawatash Limited Partnership, conducted the shoreline change analyses in ArcMap and oversaw production the maps for this report. Meaghan Efford, PhD student, Institute for the Oceans and Fisheries, University of British Columbia, provided advice and input which helped improve the manuscript.

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Appendix A: Supplemental Methods

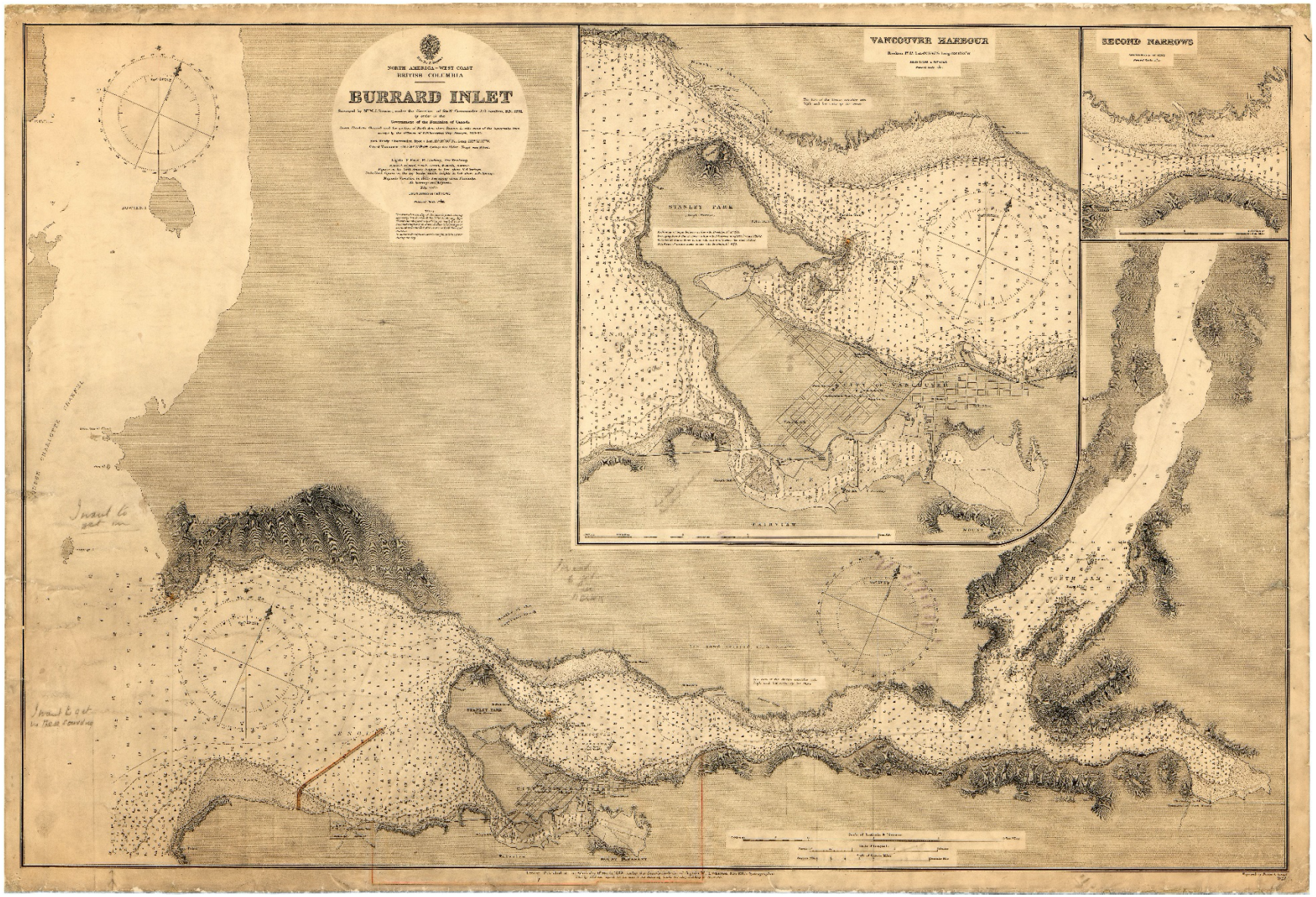


Figure A-1. Navigational Chart of Burrard Inlet (1893). Source: Government of the Dominion of Canada (1893)

Table A-1. Geospatial layers used to assist with determining the approximate location of the pre-contact shoreline.

Layer Name	Original File Type	Description	Time Period Represented	Source	Scale	Approximate Horizontal Resolution	Original Map Projection and Datum
1792 Map Vancouver	Raster (PNG)	British map appears to depict Stanley Park as an island	1792	Vancouver (1798)	Unknown	Unknown	Unknown
1792 Map Valdez	Raster (PNG)	Spanish map depicts Stanley Park as an island	1792	Jane (1930)	Unknown	Unknown	Unknown
1863 Crease Sketch Map	Raster (JPG)	Has a numbered key describing features	1863	BC Archives # CM A1071	Unknown	Unknown	Unknown
1893 Map	Scanned Map (JPG)	The Government of Canada's first marine navigational chart	1893; Collected from surveys in late 1800's	City of Vancouver Archives, 2021	Main map: 1:36,235; inset: 1:18,100	Main map: ~18 m; inset: ~9 m	Unknown, possibly Mercator
Goad's Fire Insurance Map 1912	Georectified Raster (GeoTIFF)	Produced for fire insurance purposes, depicts "original shoreline" in downtown Vancouver	1912 (shoreline pre-1800's)	City of Vancouver Open Data Portal, 2021	~1:10,000	< 5 m	UTM Zone 10N; NAD82
City Blocks, Streets, Buildings	Shapefile (SHP)	Used for georeferencing	Present-day	City of Vancouver Open Data Portal, 2021	1:10,000	5 m	Unprojected; WGS84
Centre lines of streets in North Vancouver	Shapefile (SHP)	Used for georeferencing	1930	District of North Vancouver Geoweb, 2021	1:10,000	5 m	UTM Zone 20; NAD83
Vancouver Old Streams	Shapefile (SHP)	Used for general reference	1880	Lesack & Proctor, 2011	1:20,000	10 m	UTM Zone 10N; NAD83
CHS Navigational Charts #3481, #3493, #3494, #3495	GeoTIFF	Used for georeferencing and general reference	Present-day	CHS, 2016	#3481: 1:25,000, #3493, #3494, #3495: 1:10,000	Larger scale: 5 m; Smaller scale: 12.5 m;	Mercator; NAD83 / WGS84
CHS ENC High and Low Tide	S-57 (ENC)	Electronic navigational chart contours and sub-tidal areas used for present-day intertidal and shoreline; Contour zero represents "highest high" tide. Low tide contour is "lowest low" tide (source).	Present-day	CHS, 2020	#V-3493; #V-3494; #V-3495; #V-3496	< 5 m	Mercator; NAD83/WGS84
Survey for Stanley Park Seawall Repairs project	Esri Geodatabase (GDB)	Present-day high resolution survey data Stanley Park Seawall; shoreline was believed to be paved over by seawall in some areas	Present-day	KWL, 2021	Digital data Drawings at 1:600 scale	< 0.1 m	UTM Zone 10N; NAD83
Burrard Inlet Sub-	Shapefile (SHP)	Sub-basins used for several	Present-day	ENV & TWN, 2021	1:10,000	5 m	UTM Zone 10N; NAD83

basin Boundaries		decades in Burrard inlet for water quality surveying and reporting					
ALOS Global Digital Elevation	GeoTIFF (TIF)	Digital elevation data used for reference, especially when selecting a modern contour to use in Carroll St. area	Present-day	JAXA, 2021	~1:60:000	30 m	Unprojected; WGS84
Satellite Imagery in ArcGIS Dekstop 10.6.1	Raster (various, pre-tiled)	Satellite imagery used for reference	Present-day	Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community	~1:2000	~1 m	World Mercator (Web)
LiDAR Data	Point Cloud (XYZ)	Downloaded and compiled for reference, especially when selecting a modern contour to use in Carroll St. area	Present-day	City of Vancouver Open Data Portal, 2018	1:720	0.36 m	Horizontal: UTM Zone 10N, NAD83 (CSRS) Vertical: CGVD28GVRD

Table A-2. Control points used to georectify the 1893 map (Main)

maprow	mapcol	x (EPSG: 3395)	y (EPSG: 3395)	Lat (EPSG: 4326)	Lon (EPSG: 4326)
7758.041	4836.25	-13674274.46	6290526	49.28249	-122.838
3219.07	4349.44	-13706357.5	6293950	49.3026	-123.126
3198.189	4655.73	-13706510.76	6291725	49.28953	-123.128
3304.597	4706.37	-13705734.35	6291378	49.28749	-123.121
3276.1	4968.01	-13705949.86	6289560	49.27681	-123.123
3342.868	4931.47	-13705487.31	6289812	49.27829	-123.118
3410.633	4792.63	-13704993.58	6290787	49.28402	-123.114
3423.978	4759.45	-13704946.64	6291007	49.28531	-123.114
3396.894	4870.12	-13705115.57	6290231	49.28075	-123.115
3493.604	4785.16	-13704425.36	6290828	49.28426	-123.109
3639.791	4808.87	-13703403.63	6290662	49.28329	-123.1
1048.374	5201.11	-13721727.77	6287812	49.26653	-123.264
3801.87	4797.91	-13702232.31	6290752	49.28381	-123.089
1047.996	3689.12	-13721815.49	6298593	49.32987	-123.265
1028.642	3659.32	-13721890.18	6298801	49.33109	-123.266
5405.597	4534.91	-13690974.4	6292661	49.29503	-122.988
6083.183	3806.91	-13686182.71	6297842	49.32546	-122.945
6342.278	4153.4	-13684283.52	6295385	49.31103	-122.928
6987.453	3553.39	-13679733.15	6299683	49.33627	-122.887
7185.39	4388.25	-13678342.15	6293717	49.30123	-122.875

Table A-3. Control points used to georectify the 1893 map (Inset)

maprow	mapcol	x (EPSG: 3395)	y (EPSG: 3395)	Lat (EPSG: 4326)	Lon (EPSG: 4326)
5454.058	2276.42	-13704425.57	6290827	49.28425	-123.109
5371.838	2287.75	-13704730.46	6290793	49.28405	-123.112
5399.851	2381.57	-13704625.74	6290466	49.28213	-123.111
5289.31	2474.51	-13705007.52	6290124	49.28012	-123.114
5062.615	2265.24	-13705812.01	6290855	49.28442	-123.121
4772.4	2576.65	-13706828.08	6289762	49.278	-123.131
6146.028	2337.89	-13701975.28	6290622	49.28305	-123.087
5672.045	2426.96	-13703665.52	6290315	49.28125	-123.102
4694.561	1936.51	-13707102.31	6292003	49.29116	-123.133
4907.468	1397.75	-13706378.25	6293973	49.30274	-123.126
4969.889	2687.07	-13706128.08	6289380	49.27575	-123.124

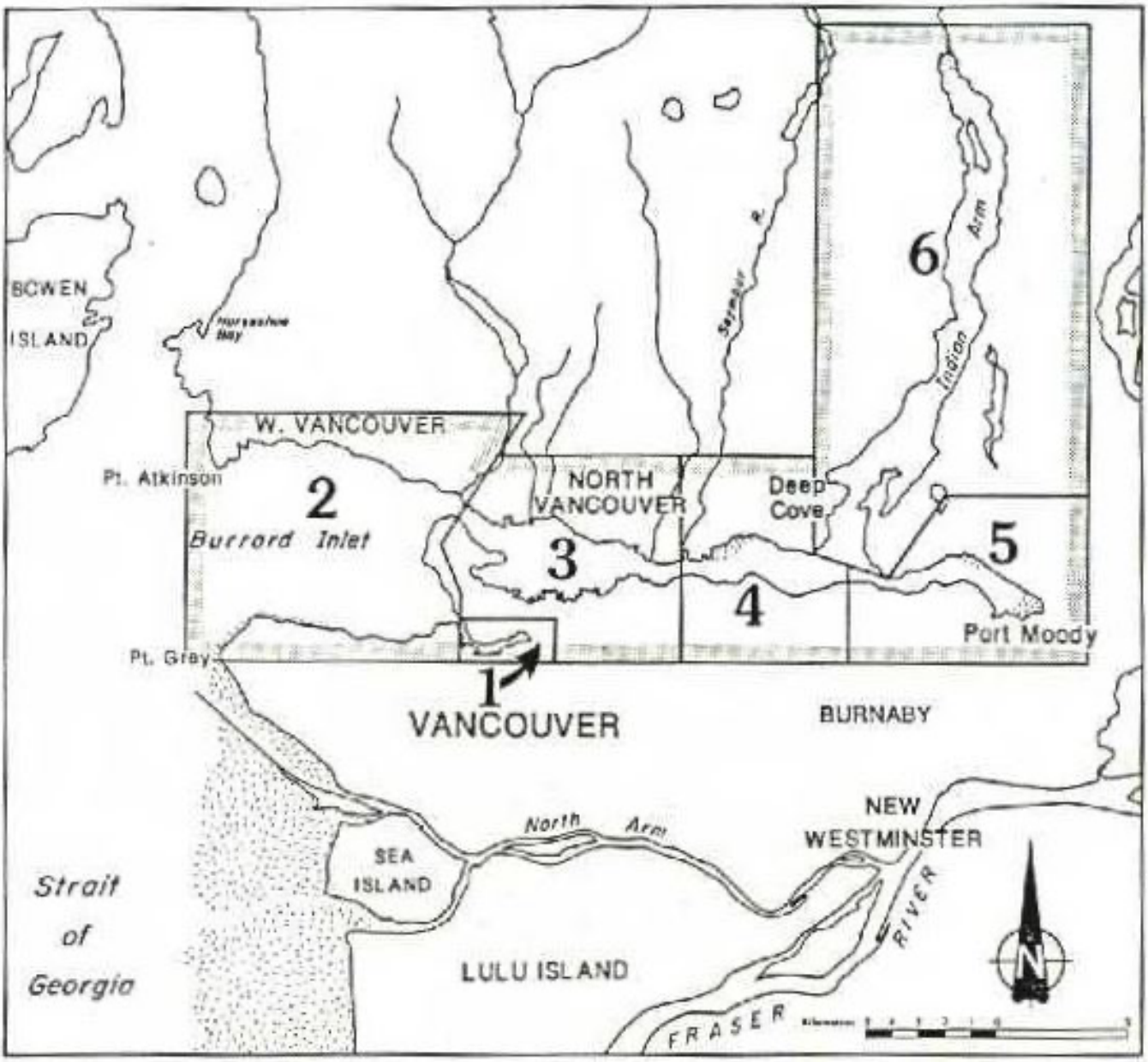


Figure A-2. Sub-basins in Burrard Inlet as defined for Ambient Water Quality Objectives: 1) False Creek, 2) Outer Burrard Inlet (Outer Harbour), 3) First Narrow to Second Narrows (Inner Harbour), 4) Second Narrows to Roche Point (Central Harbour), 5) Port Moody Arm, 6) Indian Arm. Source: Ministry of Environment (1990)

Appendix B: Reference Index of Archival Information

Intertidal connection between Lost Lagoon and English Bay			
Reference Number	**Reference**	**Full Text/Excerpt**	**Notes / Interpretation**
1.	Vancouver, George. 1798 A Voyage of Discovery to the North Pacific Ocean, and Round the World: In Which the Coast of North-west American has been carefully examined and accurately surveyed: undertaken by His Majesty's command, principally with a view to ascertain the existence of any navigable communication between the North Pacific and North Atlantic Oceans, and performed in the years 1790, 1791, 1792, 1793, 1794 and 1795, in the Discovery sloop of war, and armed tender Chatham, under the command of Captain George Vancouver. Printed for John Stockdale, Picadilly, London. Pp.300	"From Point Grey we proceeded first up the eastern branch of the sound, where, about a league within its entrance, we passed to the northward of an island which nearly terminated its extent, forming a passage from 10 to 7 fathoms deep, not more than a cable's length in width. This island lying exactly across the canal, appeared to form a similar passage to the south of it, with a smaller island lying before it."	Vancouver describes Stanley Park as an island at the narrow entrance to Burrard Inlet.
2.	Jane, Cecil, ed. 1930. A Spanish Voyage to Vancouver and the Northwest Coast of America; Being the Narrative of the Voyage Made in the Year 1792 by the Schooners Suitl and Mexicana to Explore the Strait of Fuca. London: Argonaut Press.	Map of the voyage of the Sutil and Mexicana illustrates an island at the entrance to Burrard Inlet.	The island is approximately in the eastern portion of the Outer Harbour, or the location of Stanley Park.
3.	Mathews 1932 (2011) Early Vancouver, Volume 2. Narrative of the Pioneers of Vancouver, BC, Collected During 1932. City of Vancouver Archives. Pg 19.	"I can recall the waters of English Bay almost flowed—at extreme high tide probably did do so—across from Second Beach to Coal Harbour."	Described by Andrew Paull (Qoitchetahl), secretary of the Squamish Indian Council of Chiefs.
4.	Mathews 1945 (2011) Early Vancouver, Volume 5. Narrative of the Pioneers of Vancouver, BC, Collected During 1936 - 1945. City of Vancouver Archives. Pg 119.	Note by JSM: Capt. Vancouver stated, in his Journal, 1792, that the entrance to Burrard's Canal is almost blocked by an island (Stanley Park), and a smaller island (Deadman's Island) is beside it. It may be, at the hour the navigator was entering the First Narrows, that the tide was high, or very high, and that he saw Indians, in canoes, crossing at what is now Second Beach from English Bay to Lost Lagoon, or at Campbell Avenue from the harbour to the old head of False Creek, and, as he would not be able to judge the depth of water at these shallow, narrow passages from the surface of the water, he was justified in assuming that they were as navigable, almost as the First Narrows, and so assumed Stanley Park to be an island.Next year Captain Vancouver passed through the Narrows, and saw the other side, and this is what he wrote: "this island" (Stanley Park) "lying exactly across the channel, appears to form a similar passage" (Lost Lagoon) "to the south of it, with a smaller island" (Deadman's) "lying before it."	Interpretation of George Vancouver's description of sailing through the First Narrows of Burrard Inlet.

5.	Mathews 1944 (2011) Early Vancouver, Volume 4. Narrative of the Pioneers of Vancouver, BC, Collected During 1935 - 1939. City of Vancouver Archives. Pg 258.	Mr. Kenvyn: "Dr. Bell-Irving wrote once, in a book I think, that he had crossed from Coal Harbour into English Bay, passed up False Creek and back again into Burrard Inlet—somewhere up the creek—without getting out of the boat." J.S.M.: Old Haxten, the Indian woman, now over 100, at North Vancouver, says she used to go through from Coal Harbour to Second Beach in a canoe, and Herbert Neil, Squamish Indian, in his conversation, 26 June 1935, says he used to go shooting ducks in False Creek, and crossed from inlet to creek in his canoe at Campbell Avenue, whenever the tide was not too low.	
6.	Mathews 1945 (2011) Early Vancouver, Volume 5. Narrative of the Pioneers of Vancouver, BC, Collected During 1936 - 1945. City of Vancouver Archives. Pg 119.	Andrew Paull: "Haxten" (who is over 100 years old and still living at North Vancouver with Mr. Paull) "Haxten told me that she used to cross from Coal Harbour to English Bay in a canoe." Query: But did she say that they dragged the canoes? Mr. Paull: "No. A canoe does not draw much; only two or three inches." (Note by J.S.M.: He means at very high tide; not otherwise.)	
7.	Steele, Richard (1985). The Stanley Park Explorer. Whitecap Books. Pg 104.	Vancouver resident Donald Burton, born just after the turn of the century, remembers completely circumnavigating Stanley Park in a canoe without once having to portage. This was done by paddling from Deadman Island towards Lost Lagoon under a wooden bridge that stood where the solid causeway is now, then across Lost Lagoon into a creek on its western end that, at high tide, became a navigable stream that drained into the light surf of Burrard Inlet at Second Beach. From there it was a matter of continuing around Stanley Park until returning to Coal Harbour and Deadman Island. The Park Superintendent of 1914 noted that the immediate surroundings of the creek were "swampy and practically useless for public use". To improve this section of the park, 4120 cubic meters of fill were added, alongside a wooden boom to protect city infrastructure at Second Beach from winter storm surge. According to a 1916 report, the land between Second Beach and Lost Lagoon was so shallow that waves completely covered the area at high tide, explaining the lack of trees.	
8.	Keraj, Sean (2013). Inventing Stanley Park: An Environmental History. UBC Press. Pg 107.	"As the superintendent reported in 1914, 'The lower section of the Picnic ground here [Second Beach] has been swampy and practically useless for public use in the	Indicating the area between Second Beach and Lost

		past, and it was decided to fill this in with sand the total quantity required being some 17,000 cubic yards.' The board hired the Pacific Dredge Company to pump sand onto the low-lying area near Second Beach in 1914, a measure that dumped fill on the picnic grounds and the beach, raising the isthmus that joined the park to downtown Vancouver."	Lagoon was an intertidal marsh
9.	Keraj, Sean (2013). Inventing Stanley Park: An Environmental History. UBC Press. Pg 107.	"the tidal range was wide, which meant low tides drained most of its western basin (Lost Lagoon), and high tides pushed seawater as far as Second Beach, salinating the soils and creating marshy conditions."	Indicating the area between Second Beach and Lost Lagoon was an intertidal marsh

Intertidal connection between False Creek and Inner Harbour near present-day Downtown Eastside Vancouver

Reference Number	Reference	Full Text/Excerpt	Notes / Interpretation
10.	Mathews 1932 (2011) Early Vancouver, Volume 2. Narrative of the Pioneers of Vancouver, BC, Collected During 1932. City of Vancouver Archives. Pg 16.	"August Kitsilano....When we went to Gastown we went by canoe to Royal City Planing Mills at south end of Carrall Street, and cross to Burrard Inlet on rough sort of trail. I don't remember a trail from Smam-chuze" (foot of Howe Street), "what would be the use of struggling through the bush when it was so easy to paddle."	
11.	Mathews 1932 (2011) Early Vancouver, Volume 2. Narrative of the Pioneers of Vancouver, BC, Collected During 1932. City of Vancouver Archives. Pg 131.	"the shoreline ran back about as far as Trounce Alley between Cordova Street and Water Street." Note: in 1898 and for some years after, the waters of Burrard Inlet seeped through the fill—on which the C.P.R. railway ran—onto the low land below Water Street. This low land ran from about the foot of Carrall Street to at least beyond Abbott Street—the old Methodist Hall stood on stilts, and so was the sidewalk in front of it. The land of the beach would be from eight to ten feet below the present level of Water Street, and was a stinking hole.	Described by Hugh E. Campbell, member of Volunteer fire brigade.
12.	Mathews 1932 (2011) Early Vancouver, Volume 2. Narrative of the Pioneers of Vancouver, BC, Collected During 1932. City of Vancouver Archives. Pg 131.	For the Indians before the white man came, it must have been a convenient spot to cut across from Burrard Inlet to False Creek—when they did not use the Campbell Avenue route—for the waters of the creek and the inlet could not have been more than 300 yards apart, and at high tides perhaps much less; at extreme high tide the whole ground was a sopping bog. The whole area from Abbott Street to Columbia Street was very swampy, as several narratives recount. J.A. Mateer (20 July 1931) says, "I helped to pile, cap, bridge and plank Dupont Street" (Pender Street East) "between Carrall and Columbia; the tide came right up to the corner of Columbia and Dupont." Another authority says, "Hastings Street was an awful hole, almost	Indicating that the area along present day Hastings Street, between Abbott and Columbia, was salt marsh at high tide. Dupont Street is present-day Pender Street; Dupont roughly translates from French as "from the bridge". Today, the intersection of Columbia St and Pender St is approximately equidistance

		impassable even in summer for a team." W.F. Findlay speaks of portaging canoes, large canoes, across Carrall Street.	from False Creek and the Inner Harbour.
13.	Mathews 1935 (2011) Early Vancouver, Volume 3. Narrative of the Pioneers of Vancouver, BC, Collected During 1933 - 1934. City of Vancouver Archives. Pg 137.	"Hastings street—between Carrall and Columbia streets, where the temporary City Hall is now—was much lower than the present street surface level; the first wooden sidewalk was on stilts; it was high in the air, perhaps seven or eight feet above the wet land; at high tide it was possible to get wet feet on that low land." (Note: explanation of low land between False Creek and the Inlet. In Mayor MacLean's annual report for 1886 he says two bridges have been built; one of these was on Dupont Street; perhaps the other was Seventh Avenue. J.A. Matter, *Early Vancouver*, Vol. 1, says, "I helped bridge Dupont" (Pender) "Street between Columbia and Carrall streets. Water Street between Abbott and Carrall was planked at one time, but the edge of the water was the north side of Water Street.")	Indicating that the area along present day Hastings Street, between Carrall and Columbia, was intertidal and wetted during high tide.
14.	Mathews 1935 (2011) Early Vancouver, Volume 3. Narrative of the Pioneers of Vancouver, BC, Collected During 1933 - 1934. City of Vancouver Archives. Pg 268.	"In the winter, a great big pool of water on Hastings Street between Columbia and Carrall streets, great big pool spreading out all over the land about there; it was low land, almost level with high tide"	
15.	Mathews 1945 (2011) Early Vancouver, Volume 5. Narrative of the Pioneers of Vancouver, BC, Collected During 1936 - 1945. City of Vancouver Archives. Pg 119.	Major Matthews: Did you say that the Indians used to paddle their canoes through from False Creek to Burrard Inlet at Campbell Avenue? (Hastings Viaduct.) Mr. Neill: "Yes. I know because I have done it myself." Query: Didn't you have to drag the canoe? (Over the land.) Mr. Neill: "Well, sometimes. When the tide was not high enough." Query: Where were you going? Mr. Neill: "Just shooting ducks around False Creek and in the inlet." Query: When was that? Mr. Neill: "I was old enough; born 1890." Interjection by Andrew Paull: "Haxten" (who is over 100 years old and still living at North Vancouver with Mr. Paull) "Haxten told me that she used to cross from Coal Harbour to English Bay in a canoe."	

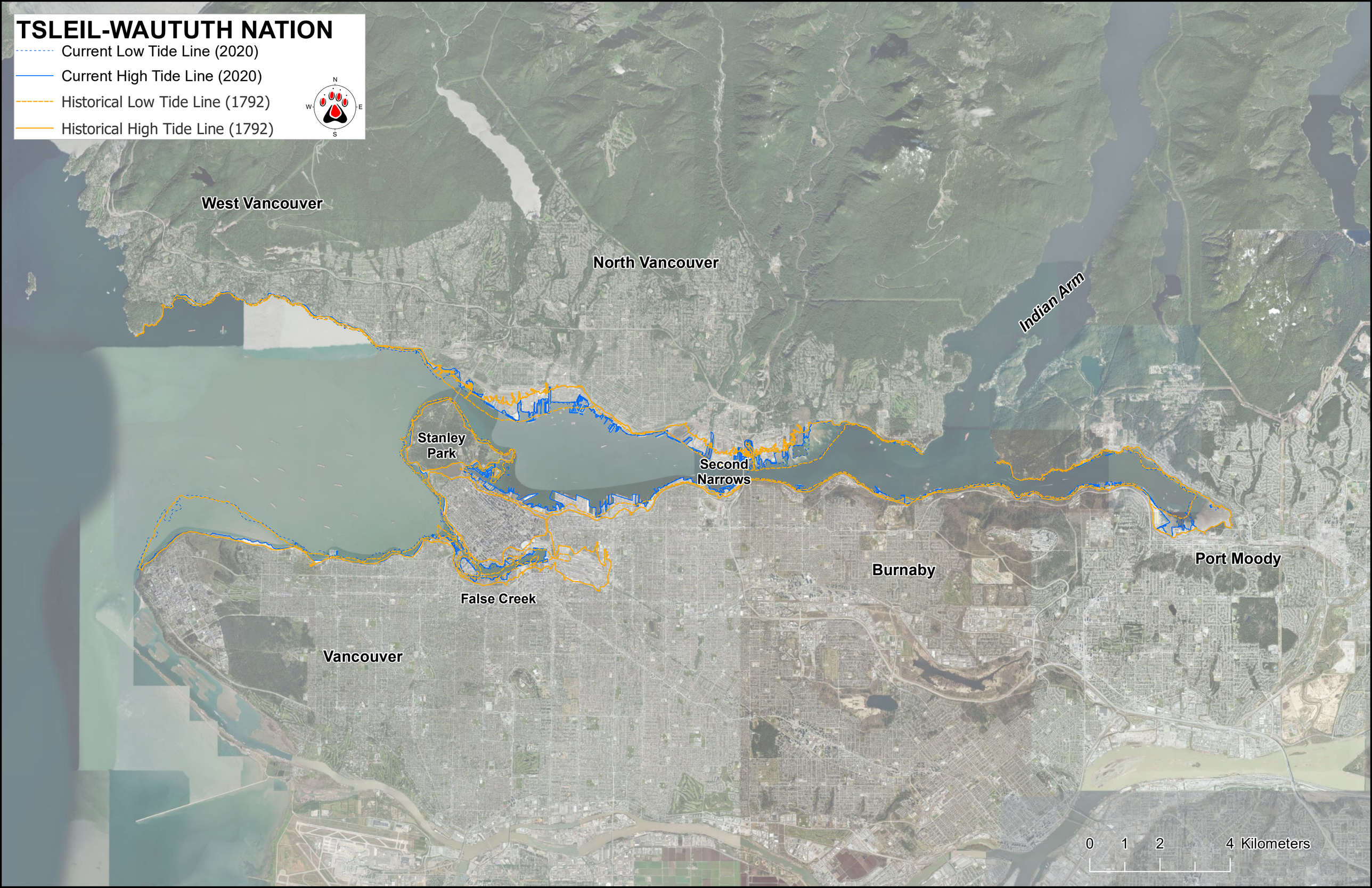
Query: But did she say that they dragged the canoes?

Mr. Paull: “No. A canoe does not draw much; only two or three inches.” (Note by J.S.M.: He means at very high tide; not otherwise.)

Query: How about Hastings Street.

Mr. Neill: “Well, when I was a little boy, it used to be pretty swampy around the corner of Dupont” (Pender) “Street and Columbia.”

Appendix C: Historical Shoreline Maps


TSLEIL-WAUTUTH NATION
Current Low Tide Line (2020)
Current High Tide Line (2020)
Historical Low Tide Line (1792)
Historical High Tide Line (1792)
N
W
E
S
West Vancouver
North Vancouver
Indian Arm
Stanley Park
Second Narrows
False Creek
Burnaby
Port Moody
Vancouver
0 1 2 4 Kilometers

1792 High Tide Line
1792 Low Tide Line
1792 Intertidal Area

2020 High Tide Line
2020 Low Tide Line
2020 Intertidal Area

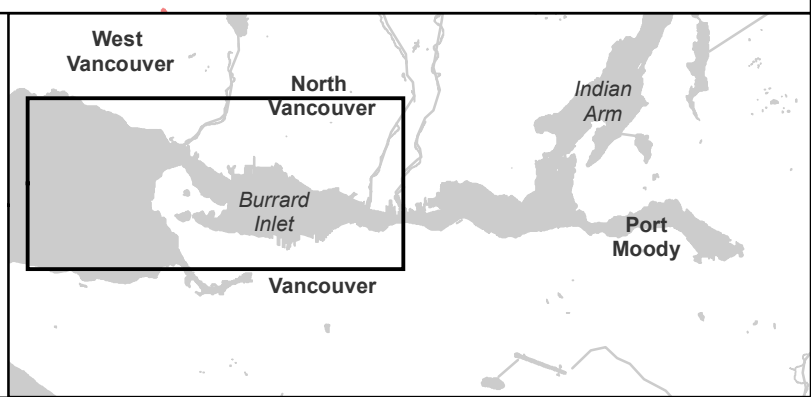
Intertidal Area Loss
Intertidal Area Gain

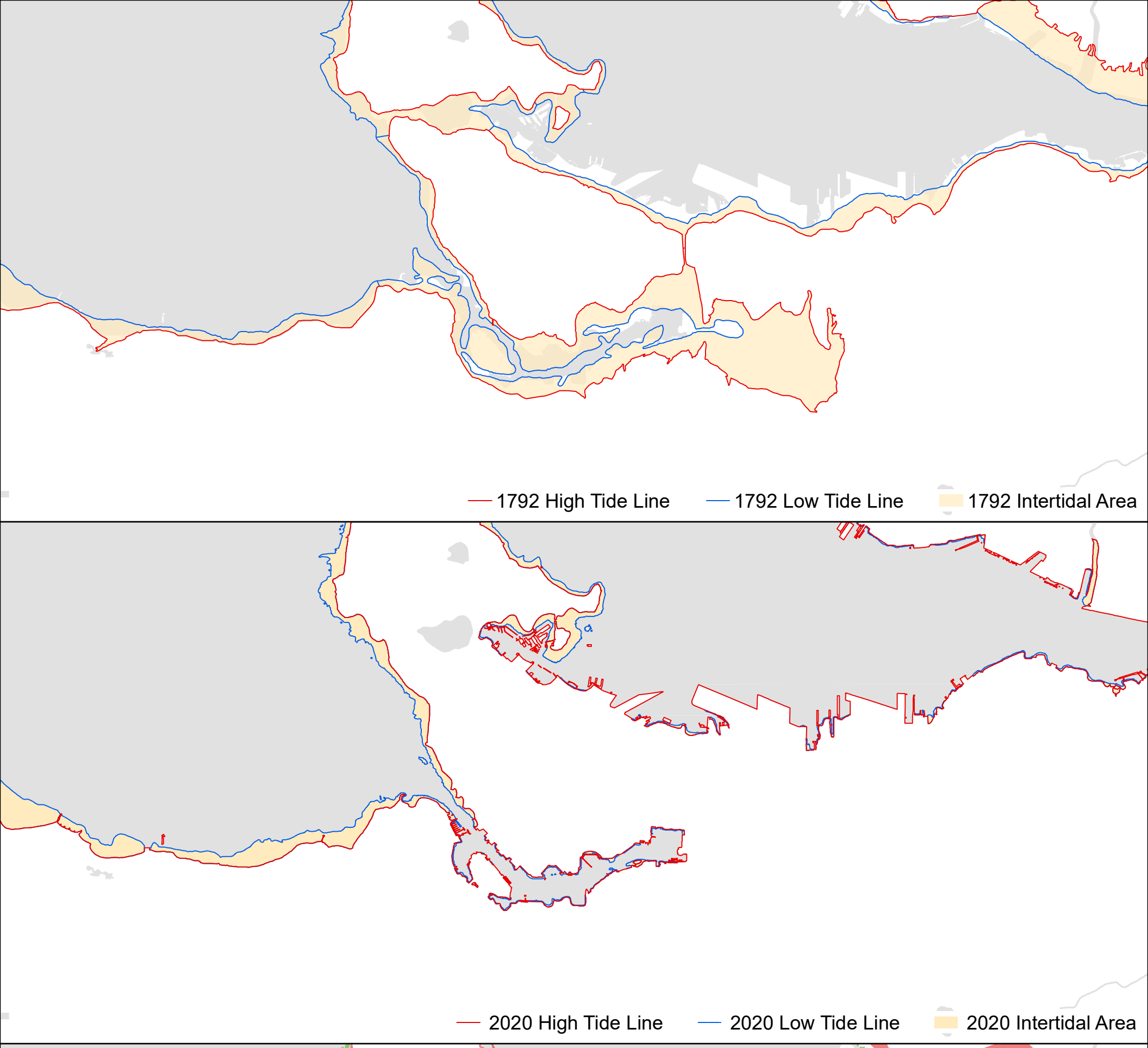
TSLEIL-WAUTUTH NATION

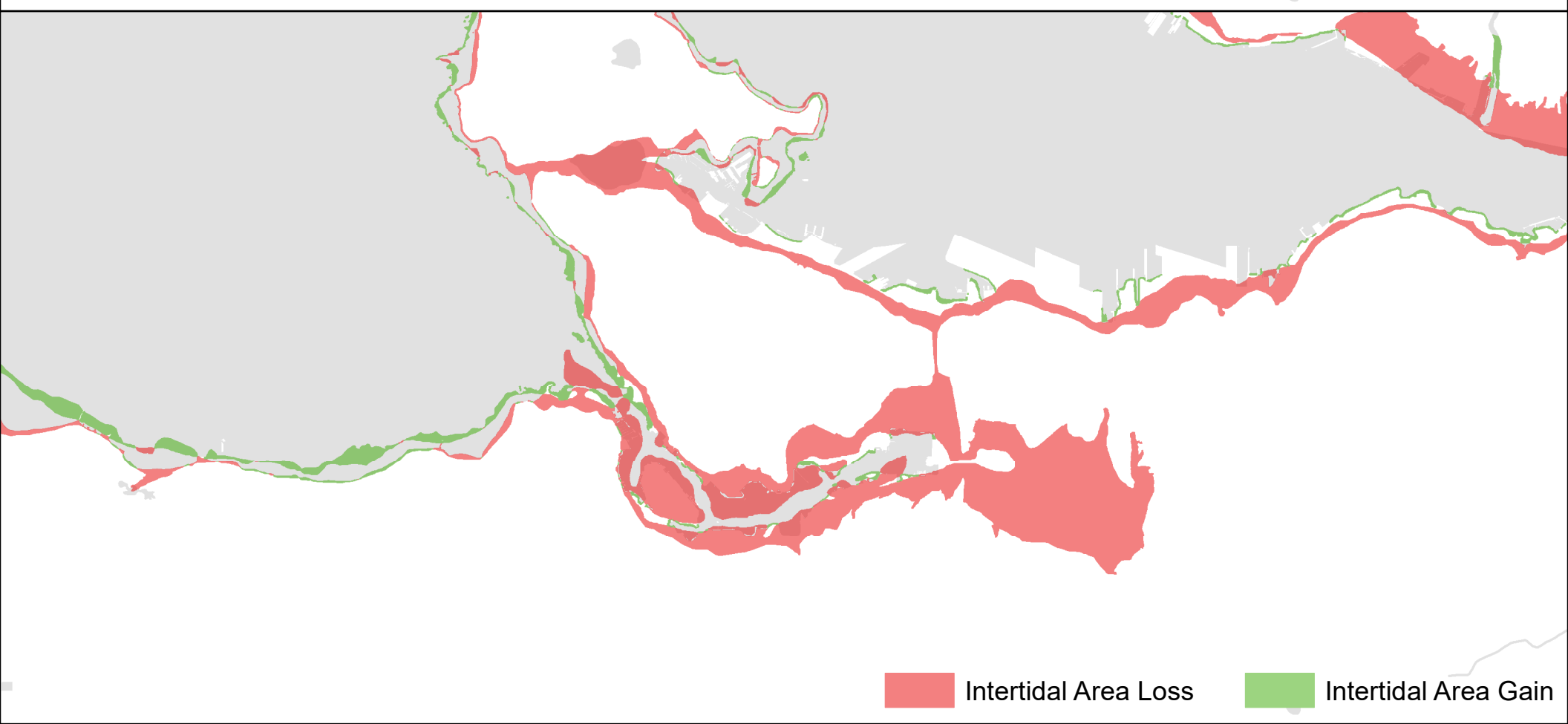
Capilano River and Stanley Park Intertidal Change

N
W
E
S

0 0.5 1 Kilometers

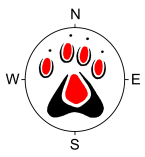




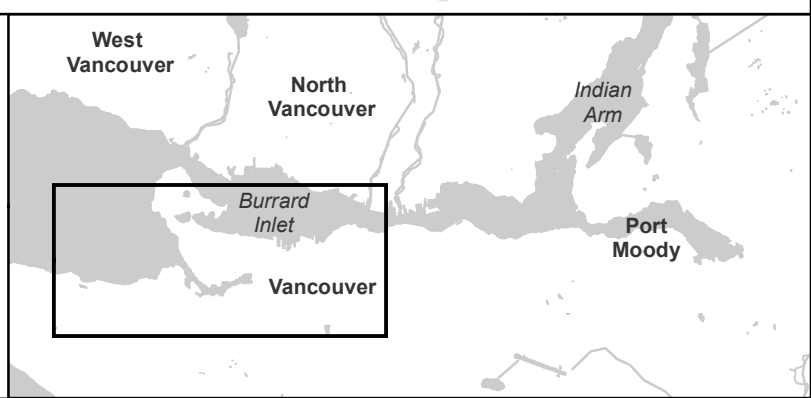


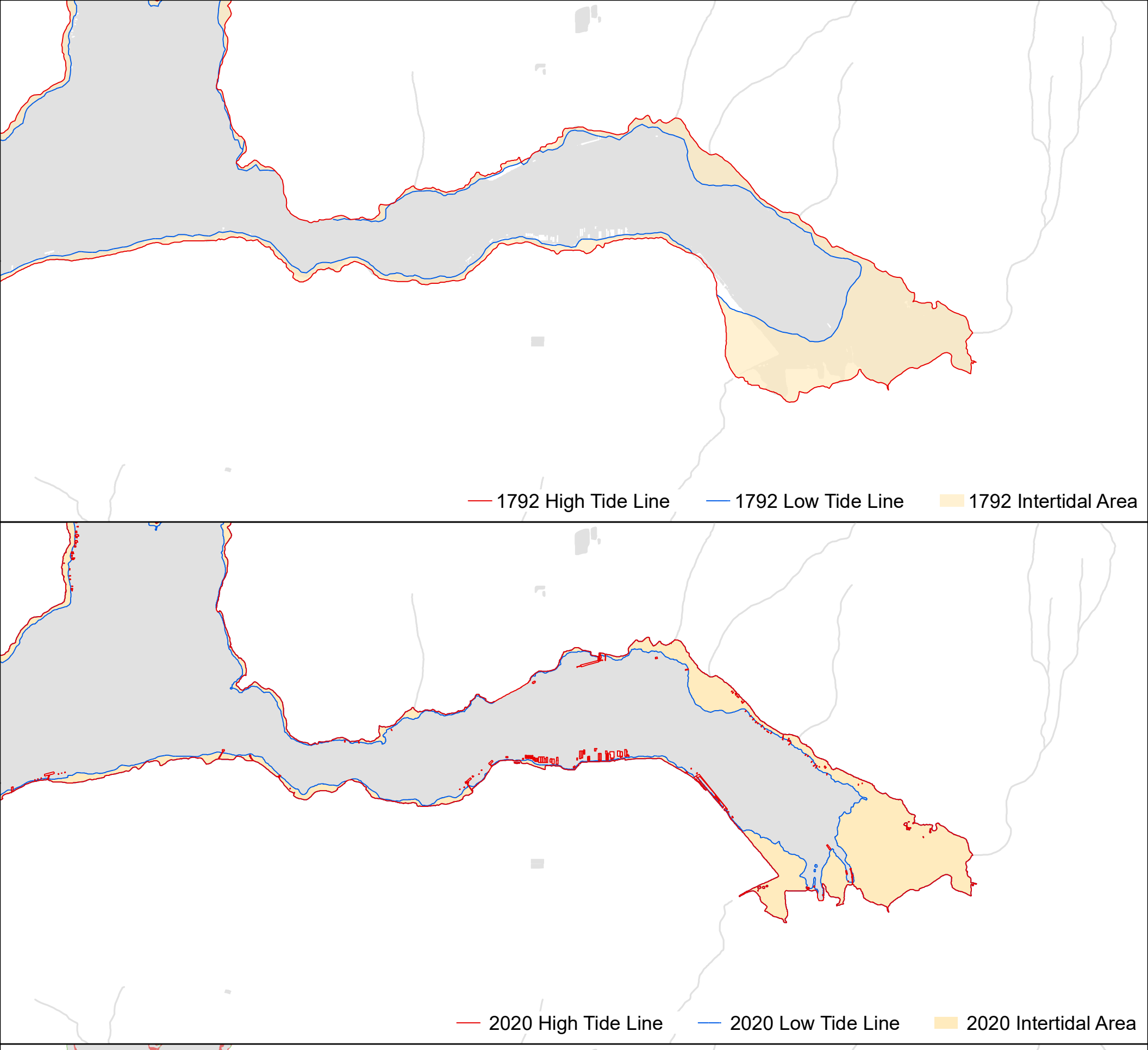
TSLEIL-WAUTUTH NATION

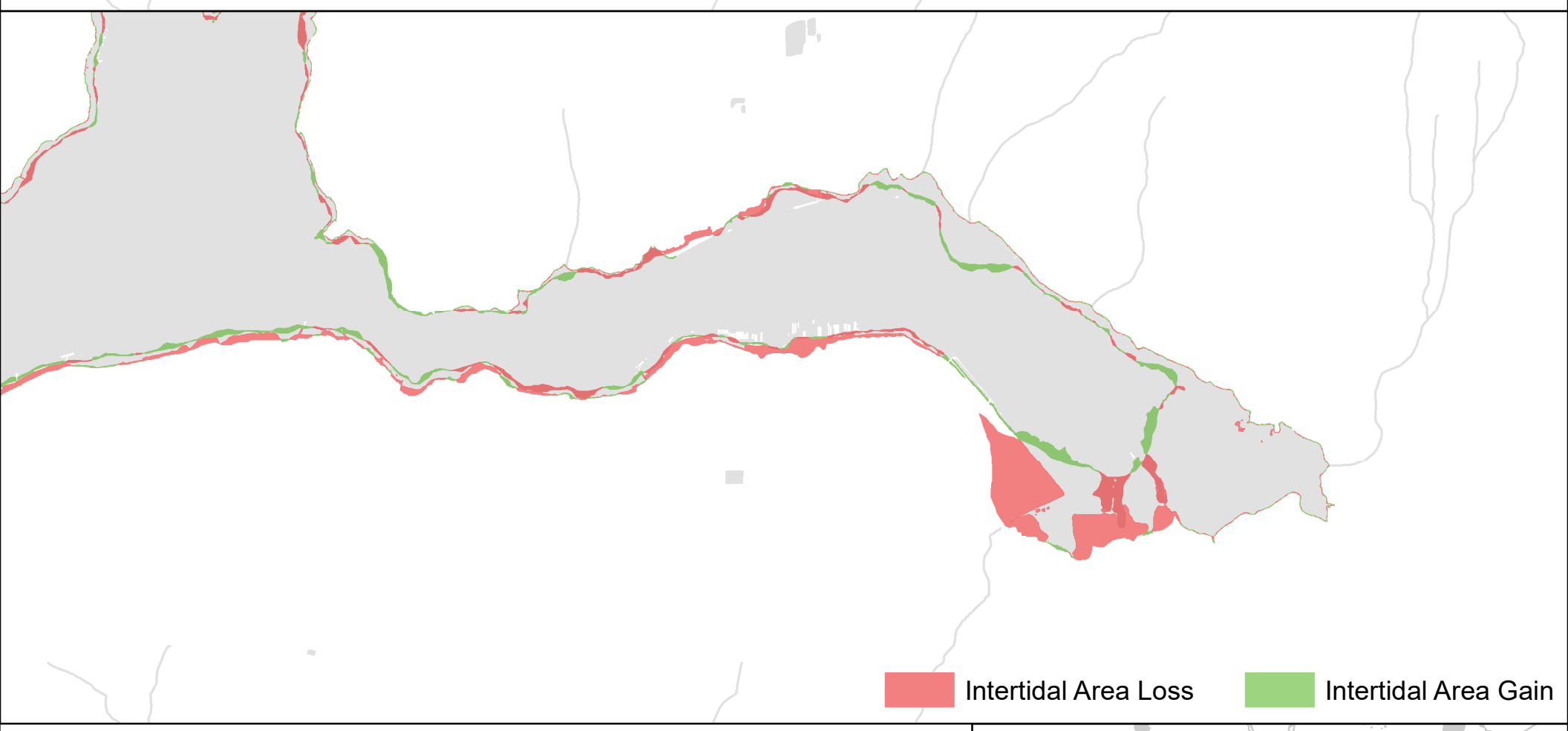
False Creek Flats Intertidal Change



0 0.5 1 Kilometers

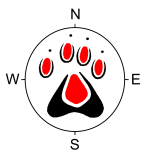






TSLEIL-WAUTUTH NATION

Port Moody Intertidal Change



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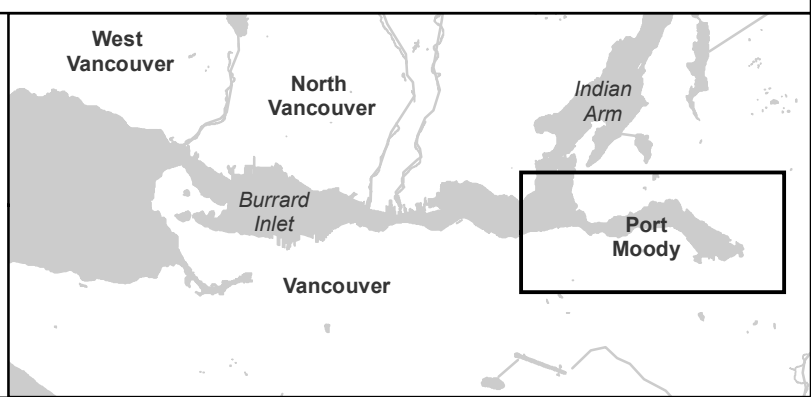
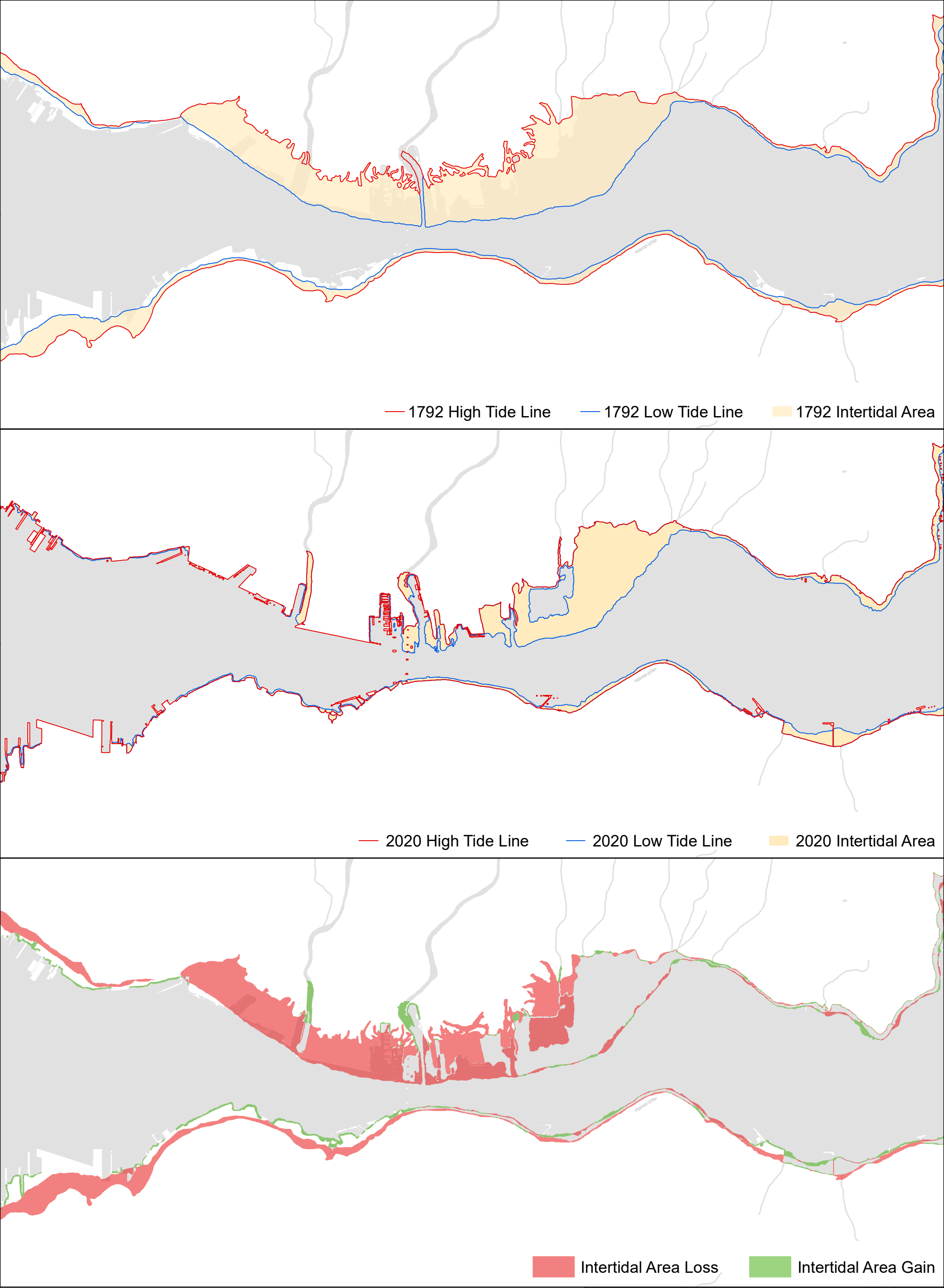
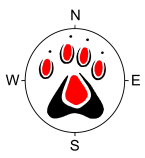




TSLEIL-WAUTUTH NATION

Second Narrows Intertidal Change



0 0.5 1 Kilometers