



Wave Study & Coastal Flood Inundation Mapping for the District of North Vancouver

Final Report

DNV PO#99307-OS-125
DHI Project No.: 42804121



May 2025

Prepared for District of North Vancouver



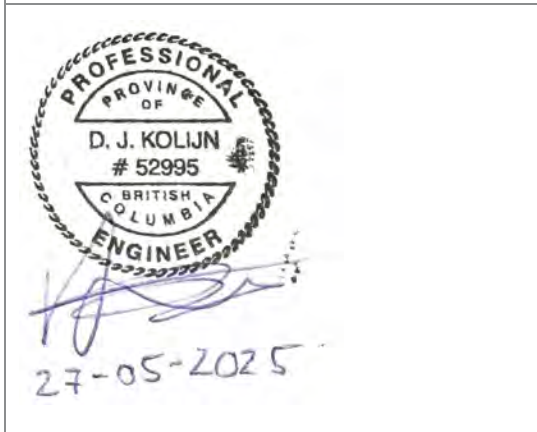
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Plain Language Summary

A detailed wave study and coastal mapping assessment was completed for the District of North Vancouver (DNV) to establish more robust standards and guidelines that will help the District to better manage coastal flood hazards and risks due to sea level rise and atmospheric events. The data and mapping information generated as part of this study can be used going forward to support asset management (water, wastewater, drainage and natural assets), climate change adaptation strategies and emergency management and response plans.

The study provides updated coastal flood maps for the DNV shoreline, incorporating future sea level rise, storm surge, tides, waves, and land subsidence. These maps serve as a reference for the DNV and professionals to establish flood construction levels (FCLs) and setbacks, helping to reduce risks associated with coastal flooding and erosion for future development. In establishing the FCLs, the study divides the DNV shoreline into 98 sections, assessing each based on shoreline type, wave exposure, and flood risks. To model future conditions, two sea level rise scenarios were considered: 0.5 m by 2100 and 1.0 m by 2150. Given the uncertainty in sea level rise projections, the 1.0 meter scenario is recommended for planning, ensuring a more cautious approach.

The study also includes a qualitative assessment of shoreline erosion risk, identifying areas more vulnerable to erosion such as Cates Landing and Cates Park. However, most of the DNV shoreline was found to have a relatively low erosion risk.

Key recommendations and findings from the study include, but are not limited to:

- **The DNV should adopt the 1.0 m sea level rise target** (life up to 2100) for coastal flood hazard mapping (or flood construction level mapping) and general information provided to the public/property owners.
- **The DNV should use a Flood Construction Level metric** to determine building setback, as it is a more consistent methodology and technical basis for defining setbacks.
- **Land use planning strategies should be developed** to effectively respond and adapt to sea level rise to minimize costs and hazards. Development should be outside of SLR planning area.
- **Sea Level Rise projects and corresponding Flood Construction Level requirements should be reviewed every 10 years**, with a focus on updating FCL elevation requirements and updates to related floodplain regulations (bylaws or development permit areas).

The findings from this report have several applications:

- **Land Use Planning** – Helping the DNV establish flood-safe zoning and building guidelines.
- **Development Regulations** – Ensuring new buildings meet FCL requirements for long-term safety.
- **Emergency Preparedness** – Informing flood response and climate adaptation strategies.
- **Community Awareness** – Providing valuable information to coastal property owners and residents.

Technical Executive Summary

This report outlines the development of coastal flood inundation maps along most of the DNV shoreline which incorporate future sea level rise, storm surge, tides, wave effects, and local land subsidence. The maps are intended to be a reference document for the DNV and qualified professionals to establish, or assist in establishing, site-specific Flood Construction Levels (FCLs)¹ and setbacks to help ensure the risks associated with coastal flooding and erosion are mitigated in the design and construction of new development.

Coastal flood inundation mapping in British Columbia is generally governed by a set of guidelines (Ausenco Sandwell, 2011b) and documentation (APEGBC, 2017) which prescribe how a qualified professional should calculate and define a FCL along a specific reach of shoreline. In this study, the FCL is interpreted as a combination of a 200-year return period total water level, sea level rise, local land subsidence, wave effects for a 200-year return period storm event, and a standard 0.60 m freeboard allowance. The 200-year total water level component of the FCL combines both tidal and atmospheric (i.e., storm surge) effects. The FCL without the freeboard is known as a Flood Construction Reference Plane (FCRP), and without wave effects, the FCRP is a Designated Flood Level (DFL)².



A set of 25 map sheets have been developed for the DNV shoreline as part of this study. The extents of the study are defined by coastal lands from the road allowance west of the 2800 block Dollarton Highway to the northeastern point of the DNV jurisdiction within Indian Arm. The Burrard Inlet-3 Indian Reserve lands are excluded from this study. Across this area of interest, the FCL and DFL have been defined at 98 individual shoreline reaches. The delineation of shoreline reaches requires a detailed interpretation of the DNV shoreline and its exposure to wave and water level hazards. The DNV shoreline ranges from shallow inter-tidal flats, to beaches, embankments, built shoreline infrastructure, alluvial materials, and rock embankments or cliffs. The shoreline was therefore discretized into distinct reaches using a combination of visual evidence collected from a site visit, interpretation of a 3D digital terrain model, shoreline classifications, prevailing wave conditions along the shoreline, and DNV geographic information system (GIS) data such as infrastructure footprints, and property boundaries. The number of reaches used in this study provide sufficient discretization and resolution to facilitate reliable flood hazard mapping to support planning and shoreline management decisions along the entire shoreline.

The selection of a sea level rise scenario is integral to the mapping process to establish the FCL at each reach. As of 2024, the latest scientific models and projections indicate a relative sea level rise at Vancouver of no more than 0.50 m between 2023 and 2100, and a relative sea level rise less than 1.0 m by 2150. Given the uncertainty associated with sea level rise projections, and the need for flexibility in determining sea level rise impacts as climate science evolves in the future, this report provides guidance for both the 0.5 m and 1.0 m sea level rise scenarios. For planning purposes, it is proposed to adopt a

¹ Uses the Designated Flood Level plus an allowance for Freeboard to establish the elevation of the underside of a wooden floor system or top of concrete slab for habitable buildings. In the case of a manufactured home, the ground level or top of concrete or asphalt pad, on which it is located, shall be equal to or higher than the above-described elevation. It also establishes the minimum crest level of a Standard Dike.

² The observed or calculated elevation for the Designated Flood and is used in the calculation of the Flood Construction Level. In coastal areas, the Designated Flood Level (DFL) includes the appropriate allowance for future sea level rise, tide and the total storm surge expected during the designated storm.

future sea level rise scenarios of 1.0 m, as this projection sufficiently accounts for uncertainties in the coming century.

Two (2) future sea level rise scenarios are presented in the study:

- **Half a meter (0.50 m) of sea level rise** to demonstrate near-term flood impacts in the coming century associated with climate change.
- **One meter (1.0 m) of sea level rise** to be adopted by DNV for FCL mapping purposes. This scenario can be used to update coastal flood hazard maps and used to provide general information about coastal processes and flood hazards to coastal property owners and occupants in the project area.

The 1.0 meter sea level rise target should be formally adopted by DNV, stakeholders and all parties referring to this document.

Several tools and methods were used in this study to characterize wave effects along the DNV shoreline. In the absence of long-term site-specific wave observations, the use of numerical models is necessary to develop a long-term understanding of wave characteristics which can be used to derive statistical interpretations of waves along the DNV shoreline. In this study a storm surge and wave model were developed for Burrard Inlet and Indian Arm, using the MIKE by DHI industry-standard numerical modelling package. Storm surge was simulated for a continuous 40-year period using the MIKE21 hydrodynamic (HD) module, and waves were modelled for a matrix of wind conditions using the MIKE21 spectral wave (SW) module. A detailed assessment of regional and local wind observations was completed to generate reliable and accurate inputs to the wave model.

Wave impacts are assessed using a process known as wave runup, which in this study is defined by a metric known as $R_{2\%}$ ³. Wave induced runup corresponds to the maximum onshore elevation, with respect to the total “still” water level (tide, surge, wind setup, sea level rise, etc.), generated by the waves. It includes both the wave set-up⁴ and the swash uprush⁵. Runup is a complex phenomenon that depends on the incident wave characteristics and its transformation to the nearshore, the local water depths, the bathymetric profile, and the characteristics of coastal structures, if present. The results from the MIKE21 SW model were used to calculate the wave runup at 98 profiles selected within each reach using a 1D profile model (FUNWAVE-TVD). The modelled water levels and wave runup values were subsequently used as input to derive and map the DFL and FCL.

A qualitative interpretation of shoreline erosion risk was also completed as part of this study. A combination of resources, together with anecdotal evidence from DNV staff, were used as lines of evidence to inform the identification of shoreline reaches vulnerable to erosion and shoreline instability. Resources referenced as part of this exercise include literature, historical air photos, imagery collected from site visits, past shoreline classification, the Digital Terrain Model (DTM) developed as part of this project, and the wave runup assessment. Shoreline erosion risk was generally found to be relatively low along the majority of the DNV shoreline, with some exceptions at Cates Landing and Cates Park. It should be noted that the shoreline erosion assessment presented in this report is qualitative in nature and that no sediment transport modelling, detailed sediment budgets, and or geomorphology analysis were undertaken as part of this scope of work.

The one meter (1.0 m) sea level rise (SLR) scenario and corresponding FCLs can be used to update official DNV coastal flood hazard resources. These resources can be used to inform planning of building

³ The runup exceeded by 2 percent of the runup values attained by a group of irregular waves.

⁴ Elevation of the mean water level at the shoreline due to wave breaking in the surf zone.

⁵ Up and down propagation of a wave after collapse on the beach. Swash is the decelerating uprush phase and backwash is the accelerating downrush phase.

setbacks, land use strategies, and zoning. For the year 2100 it is recommended to establish requirements for new buildings to meet FCL and Setbacks in accordance with Provincial Guidelines (Ausenco Sandwell, 2011b), or to meet flood protection requirements as established by Qualified Professionals.

Building setback should be established as the greater of 15 m from the future Estimated Natural Boundary or a distance to where the native land elevation equals the Flood Construction Level. It is recommended to avoid use of the Natural Boundary to inform setbacks, and to instead adopt the FCL to establish building setbacks. The FCL provides a more consistent methodology and technical basis to define building setbacks. Although the FCL values developed as part of this study can be used as a basis for establishing building setbacks, it is strongly recommended to verify the FCL contour using an updated site-specific survey and interpretation of the FCL by a Qualified Professional on a case-by-case basis. Applicant supported studies by Qualified Professionals should be used to customize building “setback” based on coastal risk assessments that consider how SLR combined with wave action and coastal geomorphology may alter shoreline locations, shape and backshore erosion. Guidelines for location of buildings should be based on these planning studies and the expected life of the at-risk asset.

Beyond concerns about individual buildings, the long-term nature of SLR provides an opportunity to minimize risks and impacts by land use planning strategies. During planning for land use and development, mapping and planning strategies for SLR Planning Areas can minimize costs and hazards for both the public and private landowners / insurers. To facilitate land use planning for SLR it is important to establish the future FCL allowances for Year 2100 using the FCL lines on detailed contour maps developed as part of this study. Development should occur outside the SLR Planning Area, to avoid risks associated with SLR.

The mapping effort presented herein also informs and supports the recommendations presented in the 2020 North Shore Sea Level Rise Risk Assessment and Adaptive Management Strategy (KWL, 2020). The work builds on the 2020 study, by developing a more detailed and thorough assessment of site-specific coastal hazards, including detailed wave modelling, wave run-up assessments, and compounding hazards of sea level rise and storm surge. The information provided reinforces concepts and builds knowledge about the impacts of sea level rise initially established at a conceptual level in the 2020 North Shore Sea Level Rise Risk Assessment and Adaptive Management Strategy. The information can be used to inform adaptation plans and community-wide flood management initiatives and can serve to build public awareness about coastal flooding and sea level rise.

It is recommended that sea level rise projections and related FCL requirements be reviewed at least every 10 years. During these intervals, guidelines and requirements in SLR Planning Areas should also be reassessed, with a focus on updating FCL elevation requirements, which may fluctuate as SLR projections become more precise. Findings from this study can be used to update coastal FCLs and setbacks for future development, integrating these into floodplain regulations such as bylaws or development permit areas. Additionally, long-term strategies for avoidance and retreat should be considered within land-use planning updates, including official community and local area plans. FCL values from the study can also be incorporated into asset management plans, including water, wastewater, drainage, and natural assets. Furthermore, climate change adaptation strategies should be revised to align with this study's findings, and the coastal flood mapping should inform emergency management and response plans. Finally, it is encouraged for DNV to use the information from this report to guide stakeholder engagement and dialogue with the community, partners, and government to advocate for climate resilience and readiness.

1 Introduction

The District of North Vancouver shoreline is unique and diverse. The shoreline varies from dense residential properties to large stretches of remote and inaccessible natural shoreline. Aside from hosting a large urban population, the DNV shoreline is situated within Canada's largest port, adjacent to a highly utilized waterway which facilitates global trade and commerce. The shoreline is also situated within Tsleil-Waututh Nation (səlilwəṭ) reserve lands and is home to several Provincial and Municipal Parks. Consequently, this highly utilized and diverse shoreline is integral to the social, economic, environmental, and cultural fabric of DNV. Given its importance, the quantification of flood impacts and associated hazards along the DNV shoreline is essential for long-term shoreline management by DNV. This report outlines the methods used to quantify and describe the flood hazard along the DNV shoreline. This includes the application of mapping products to facilitate recommendations for the appropriate use and application of Flood Construction Levels along the shoreline.

Although sheltered from the Strait of Georgia, the DNV shoreline remains prone to coastal hazards. The relatively deep waters of the Burrard Inlet, Second Narrows, and Indian Arm, combined with a relatively large tidal range (approximately 5 m), make the region a dynamic area, prone to storm surge amplification within the fjord system. The mountainous North Shore, especially through Indian Arm, result in highly localized wind effects and the potential for local gustiness and funneling of wind, which differs from typical wind exposure along open coasts. As such, the wind-wave effects along the DNV shorelines are often highly variable, prone to rapid change along short fetch distances, and unpredictable and volatile in nature.

The significant variation in water levels from tide, combined with surge effects during storms, can result in local variability of wind driven wave impacts along the shoreline. Local wind driven waves have the potential to adversely affect the DNV shoreline with property flooding, wave-induced damages, and erosion. Climate change is projected to enhance nearshore wave energy, as sea levels rise, increasing the need for the identification of, and planning for, coastal flood impacts along the DNV shoreline associated with all coastal processes. Given these challenges and to address these hazards, DHI Water & Environment, Inc. (DHI) was retained by DNV to conduct a nearshore wave study and to map Flood Construction Levels⁶ along the entirety of the DNV shoreline. Impressions of the DNV shoreline, and the variability of built and natural shoreline environments is depicted in Figure 1.1 from a site visit conducted by DHI and DNV in January 2024.

The following chapter outlines the overall study objectives and approach, delineates the project boundaries for the analysis and mapping, and provides a brief overview of study limitations and assumptions.

⁶ A detailed definition of the Flood Construction Level is provided in Section 5.1 of this report.

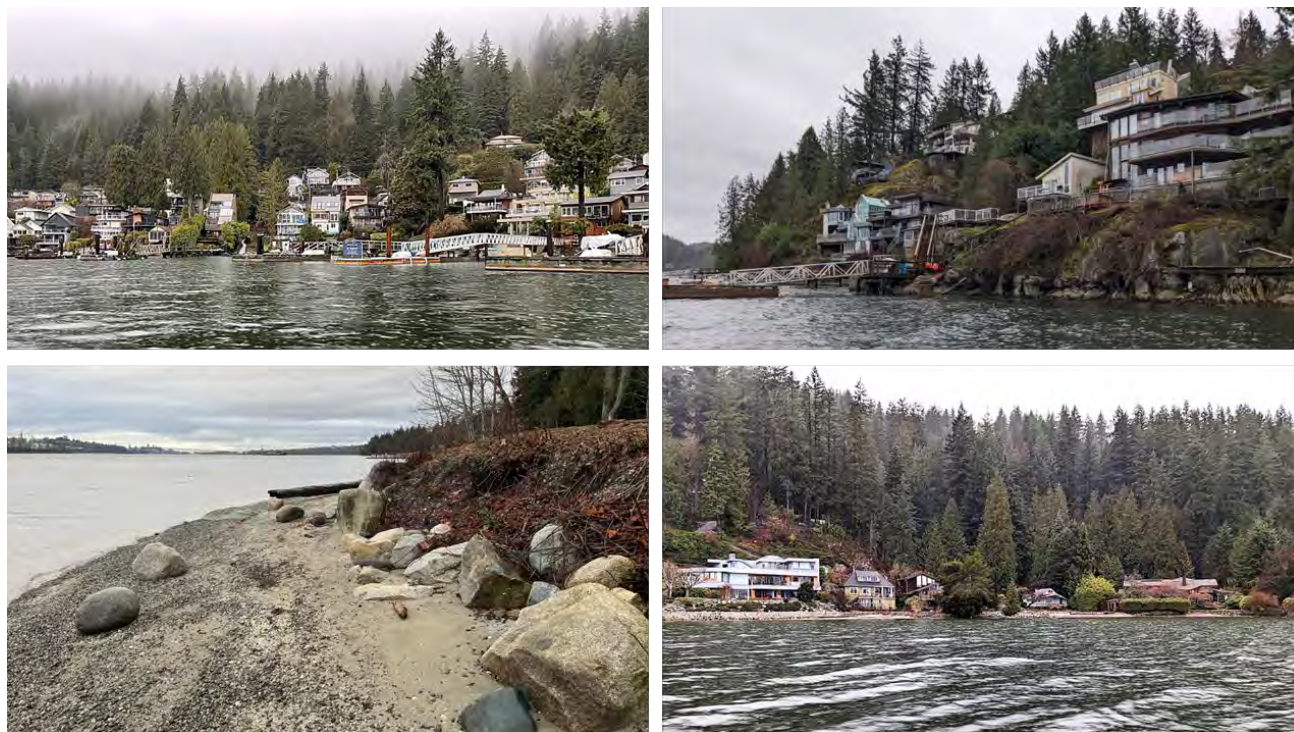


Figure 1.1 Impressions of the DNV shoreline captured by DHI on January 24th, 2024, Site-Visit

1.1 Study Objectives

This project aims to develop coastal flood inundation maps incorporating wave effects for the DNV. These maps will serve as a reference for qualified professionals in establishing site-specific Flood Construction Levels and setbacks, ensuring that coastal flooding and erosion risks are mitigated in the design and construction of new developments. The findings also contribute to a broader DNV initiative to deepen understanding of coastal risks and inform future planning.

In summary, this report provides the following outputs:

1. **A wave modelling study** to assess the impact of wind-generated waves on coastal flooding (Section 4).
2. **Coastal flood inundation maps** that incorporate wave effects (Section 5).
3. The calculation and mapping of **Flood Construction Levels (FCLs)** (Section 5.1).
4. Shoreline Characterization & Erosion Vulnerability within the Context of Flood Mapping (Section 6).

The work presented in this report feeds into a broader program and initiative by DNV to obtain foundational knowledge about coastal flooding and erosion risks along the DNV shoreline, advance multiple recommendations in the 2020 North Shore Sea Level Rise Risk Assessment and Adaptive Management Strategy⁷, to inform target audiences (coastal property owners/occupants in the project area) about the purpose of the wave modelling study, and to update existing coastal flood hazard maps to illustrate hazards associated with coastal processes. Further, the information presented in this report can serve as a

⁷ <https://www.dnv.org/community-environment/sea-level-rise-strategy>

basis for DNV to facilitate long-term land use management and planning decisions, including risk assessments and climate change mitigation strategies, to maintain sustainable shoreline development.

The information presented herein is intended to support broader program objectives and initiatives that will be led by DNV, including:

1. **The identification of any potential social, cultural, and/or environmental impacts** in future adaptation planning efforts along the DNV shoreline.
2. **The need to advance multiple recommendations in the North Shore Sea Level Rise Risk Assessment and Adaptive Management Strategy**, such as continuing to build knowledge about the impacts of sea level rise.
3. **Informing target audiences (coastal property owners/occupants in the project area) about the purpose** of the wave modelling study.
4. **Updating coastal flood hazard maps and providing general information about coastal processes and flood hazards** along the DNV shoreline.

1.2 Study Approach

To map flood inundation, and the Flood Construction Levels associated with both waves and water levels along the specified area of interest (as shown in Figure 1.2) of the DNV shoreline, DHI followed an eight (8) step processes, outlined below in Table 1.1. The table illustrates the data and information required in each step, the analytical process, and resulting output, where the final step (step 8.0) is the mapping of the FCL along the entire DNV shoreline.

Table 1.1 Study Tasks, Inputs, Processes, and Outputs for DNV Flood Inundation Mapping.

Step	Task Description	Input Requirements	Analysis & Processes	Outputs
1.0	Develop DNV Digital Terrain Model (DTM)	- Surface LiDAR - Bathymetric survey - Validation surveys - Validation site visits	Convert and combine datasets to a common vertical datum (CGVD2013) and horizontal projection (UTM Zone 10). Validate DTM to local surveys.	Validated Digital Terrain Model (DTM) for numerical modelling & mapping purposes. See Section 2.2 – Mapping Layers
2.0	Characterize local atmospheric conditions (prevailing winds) that generate waves.	- Local meteorological observations. - Regional and local meteorological hindcast products. - Local observations and anecdotal evidence.	Use network of regional meteorological stations to develop a long-term synthetic wind record, using scaling factors and directional analysis, for a period of at least ~70 years.	Design winds (and consequently waves) for extreme storm events that are representative of meteorological conditions in the Indian Arm and Burrard Inlet. See Section 2.2.4 – Digital Terrain Model (DTM)

Step	Task Description	Input Requirements	Analysis & Processes	Outputs
3.0	Assess Total Water Levels (TWL) which includes tides, storm surge, and sea level rise along the entire DNV shoreline.	- Storm surge residual from the Pacific & Strait of Georgia. - Long-term tidal record at Burrard Inlet. - TWL validation data at Indian Arm and Port Moody. - DNV DTM (step 1.0) - Atmospheric forcing (step 2.0)	Develop a 53-year continuous hourly high-resolution hindcast of Burrard Inlet and Indian Arm using DHI's MIKE21 flexible mesh (FM) hydrodynamic (HD) model to generate sufficient data for TWL analysis and interpretation along the entire DNV shoreline.	Hourly HD model timeseries for extreme-value-analysis (EVA) along the DNV shoreline, to establish TWL annual-exceedance probabilities (including 200-year return periods). See Section 3.1 – Hydrodynamic Hindcast Model
4.0	Assess 200-year wave conditions along the DNV shoreline with and without sea level rise.	- DNV DTM (step 1.0) - Atmospheric forcing (step 2.0) 200-year TWL (step 3.0) - Historical evidence and anecdotal accounts of extreme wave events.	Develop discrete event-based wave simulations throughout Indian Arm and Burrard Inlet using the DHI MIKE21 FM spectral wave (SW) model for omnidirectional extreme wind conditions at 15° intervals, at 200-year water levels.	200-year wave conditions along the DNV shoreline for a variety of wind directions, with and without sea level rise. See Section 3.2 – Spectral Wave Modelling
5.0	Wave runup assessment ($R_{2\%}$)	- DNV DTM (step 1.0) - Atmospheric forcing (step 2.0) - Transect characteristics (i.e. roughness). 200-year TWL (step 3.0) 200-year wave conditions along the DNV shoreline (step 4.0)	Assess wave runup at 98-transects selected at locations of interest using numerical (FUNWAVE-TVD) and analytical (EurOtop, 2018) methods to determine wave runup ($R_{2\%}$) at each transect between defined reach lines.	Wave runup ($R_{2\%}$) values for the purposes of informing the mapping of the Flood Construction Level (FCL). See Section 4 – Wave Runup Assessment
6.0	Flood Construction Level (FCL) assessment	- DNV DTM (step 1.0) 200-year TWL (step 3.0) - Wave runup assessment (step 5.0) - Sea level rise scenarios.	Calculate the FCL which is a combination of the 200-yr TWL, wave runup ($R_{2\%}$), sea level rise (including local land subsidence), and freeboard which is a standard value defined as 0.60 m as described in Section 5.1.	98 FCL values at each transect for mapping purposes. See Section 5.1 – Flood Construction Levels
7.0	Mapping of the Designated Flood Level (DFL)	- DNV DTM (step 1.0) 200-year TWL (step 3.0) - Sea level rise scenarios.	Mapping the DFL on the DTM, which is a combination of the 200-yr TWL, and sea level rise (including local land subsidence)	DFL maps (25 maps sheets), and digital GIS compatible shapefiles for online mapping applications. See Section 5.1 – Flood Construction Levels
8.0	Mapping of the Flood Construction Level (FCL)	- DNV DTM (step 1.0) 200-year TWL (step 3.0) - FCL (step 6.0) - Sea level rise scenarios.	Mapping the FCL on the DTM for various sea level rise scenarios.	FCL maps (25 maps sheets), and digital GIS compatible shapefiles for online mapping applications. See Section 5.2 – Mapping Procedure

1.3 Study Location & Boundaries

The project area is delineated in Figure 1.2, and includes coastal lands from the road allowance west of the 2800 block Dollarton Highway to the northeastern point of the District of North Vancouver in Indian Arm. It should be noted that the Burrard Inlet-3 Indian Reserve lands are excluded from this study. There are approximately 500 properties in the project area. The study area covers approximately 23 kilometers of coastline and includes around 500 properties, encompassing single-family residential lots, parklands, and commercial areas. Particular areas and features of note identified by DNV include, but are not necessarily limited to:

- Residential waterfront lots between Maplewood Flats Conservation area and the Burrard Inlet-3 Indian Reserve;
- Cates Park/Whey-ah-Wichen, a site of ancestral Indigenous significance and a present-day public park, is managed by the District of North Vancouver in collaboration with the Tsleil-Waututh Nation under a cooperation agreement;
- Deep Cove Village Centre, which includes water-oriented commercial uses and popular coastal parks with beach and boat access such as Deep Cove Kayak, Deep Cove Marina, Deep Cove Park, and Panorama Park; and
- Indian Arm, which is a remote, scenic fjord extending north from Burrard Inlet. It is home to secluded coastal properties, some of which are accessible only by boat, and features extensive undeveloped natural parkland.

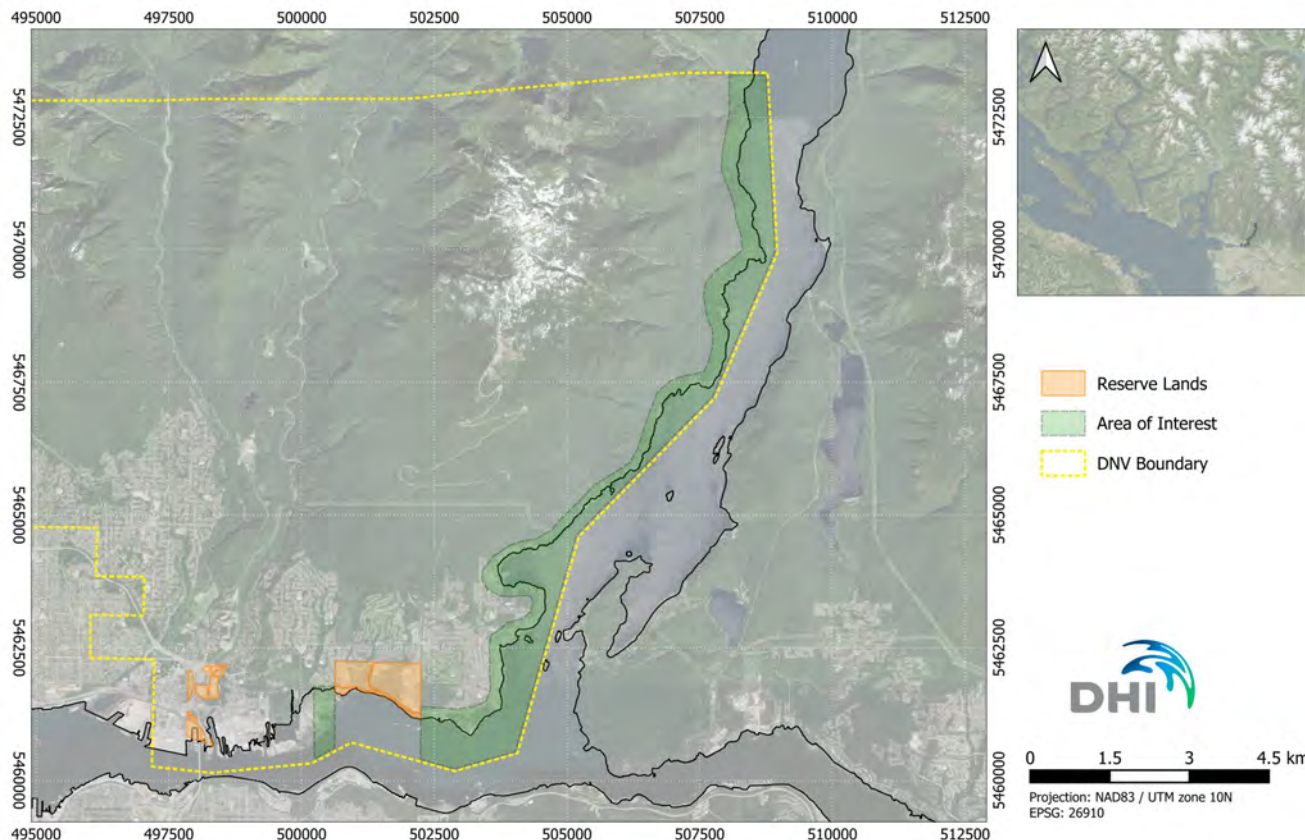


Figure 1.2 Study Area of Interest - District of North Vancouver Shoreline

Coastal lands from the road allowance, immediately west of the 2800 block of Dollarton Highway, to the north-eastern point of the District in Indian Arm, were prioritized for this work because coastal hazards can be managed primarily through development controls, such as a development permit, without the need for community level structural flood protection works (e.g., dikes). The remaining coastal lands in the District may require a higher degree of adaptation planning effort because of complex (e.g. heavy industrial) land uses.

1.4 Study Limitations & Assumptions

Although comprehensive and inclusive of all relevant physical processes and drivers relevant to FCL mapping, there are some inherent limitations and assumptions to this study which should be noted. Further study limitations and technical considerations are detailed throughout this report. In summary:

- Inundation limits consider only coastal processes and do not account for pluvial or fluvial flooding.
- Users should verify the dates of base mapping, aerial photography, surveys, and mapping in relation to development dates in the area. Subsequent developments or changes within the floodplain or channel may alter flood levels and render site-specific map information outdated.
- Under the Flood Hazard Statutes Amendment Act, 2003 (Bill 56), local governments are responsible for decisions about local floodplain development, including floodplain bylaws. For more information, refer to the BC Flood Hazard Area Land Use Management Guidelines.
- The accuracy of the location of a floodplain boundary as shown on this map is limited by the base topography.
- The floodplain limits are not established on the ground by legal survey. A site survey is required to reconcile property location, ground elevations and designated flood level information.
- Erosion, riverine hazards, overland flood effects, and compound flooding are not considered as part of this study.
- Results and mapping are appropriate and applicable on a reach-scale, for planning purposes only. Detailed site specific (i.e. lot level) FCL studies are highly recommended on a case-by-case basis to refine FCL limits for infrastructure specific purposes.

1.5 Disclaimer

This document has been prepared by DHI Water & Environment, Inc. (DHI) in accordance with generally accepted engineering and geoscience practices and is intended for the exclusive use and benefit of the District of North Vancouver and their authorized representatives for specific application to Coastal Flood Hazard Mapping. Variations in actual flood depths and extents may occur, and DHI does not assume liability for such variations. The contents of this document are not to be relied upon or used, in whole or in part, by or for the benefit of others without specific written authorization from DHI. No other warranty, expressed or implied, is made. DHI and its officers, directors, employees, and agents assume no responsibility for the reliance upon this document or any of its contents by any parties other than the District of North Vancouver.

2 Background & Data for Analysis

The following chapter provides a comprehensive summary of the various inputs and data sources required to complete the flood inundation mapping and to generate recommendations for Flood Construction Levels. Various data inputs were used to develop a seamless Digital Elevation Model (DEM) of the DNV shoreline, incorporating both topographic and bathymetric features necessary for numerical modeling of total water levels, waves, and wave runup. These models are forced with metocean and atmospheric datasets from both local and regional sources. Extensive data quality control and review was required to develop a fit-for-purposes modelling dataset. This chapter concludes with a review of the latest sea level rise projections and a recommendation to support modelling and flood hazard mapping.

2.1 Projection Reference System and Datum

Prior to commencement of work, a universal vertical project datum and horizontal reference must be established which will be uniformly applied to all aspects of the project. Spatial data in alternative formats will be converted and validated using industry best practices to ensure consistency with the common projection and datum.

In summary, for the following project, the spatial projection and vertical datum used are:

The horizontal reference system used for this project is the NAD83 UTM Zone 10.

The vertical datum adopted for the project is the Canadian Geodetic Vertical Datum of 2013⁸. All elevations referred to in this report (including water levels) are referenced to CGVD2013, unless stated otherwise.

The details of the data conversion from the Canadian Geodetic Vertical Datum of 1928 (CGVD28) and/or Chart Datum (CD)⁹ for the area, is described in section 2.2.3 (Bathymetric Data).

2.2 Mapping Layers

The flood inundation mapping is projected on top of a seamless Digital Terrain Model (DTM) consisting of both topographic and bathymetric data. This foundational element of the mapping must be properly validated to ensure that mapping is representative and reliable of the proposed flood inundation scenarios. Additionally, the inundation mapping should contain other data layers such as property extents, infrastructure footprints, DNV regional boundaries, reserve lands, and municipal and federal parkland, to name but a few. The following section describes the preparation of these data for use in the mapping process.

2.2.1 Municipal Mapping Layers

Several datasets were acquired from the District of North Vancouver's Open Data portal to support coastal flood inundation and FCL mapping (DNV, 2024). These datasets¹⁰, summarized in Table 2.1, were processed and formatted in ArcGIS Pro 3.2.0.

⁸ [https://natural-resources.canada.ca/sites/nrcan/files/files/pdf/Height_reference_system_modernization_\(EN\).pdf](https://natural-resources.canada.ca/sites/nrcan/files/files/pdf/Height_reference_system_modernization_(EN).pdf)

⁹ Chart datum refers to the lowest normal tide, such that water levels rarely fall below it. Tidal predictions and hydrographic charts from the Canadian Hydrographic Service (CHS) reference this datum.

¹⁰ The municipal dataset used in the study have been provided to DNV via digital delivery dated May 22, 2024, and referenced in memo DHI GIS Data Transfer - 42804121 - District of North Vancouver - Coastal Flood Hazard Maps.

Table 2.1 Municipal mapping layers acquired from DNV open data portal used in the flood mapping

Data Product Name	Data Description	Data Projection	File Name & Type
Buildings	Detailed footprints of all buildings within the study area	NAD 1983 UTM Zone 10N	Buildings (Polygon Shapefile)
Park Lands	Park lands in the study area	NAD 1983 UTM Zone 10N	Park Lands (Polygon Shapefile)
Property Lines	Delineations of property boundaries in the study area	NAD 1983 UTM Zone 10N	Property Lines (Line Shapefile)
Reserve Lands	Boundaries and extents of reserve lands	NAD 1983 UTM Zone 10N	Reserve Lands (Polygon Shapefile)

2.2.2 Topographic Data

DHI acquired processed LiDAR datasets from DNV for the study area for three years - 2013, 2018, and 2022. The extent of the LiDAR data for each year is depicted in Figure 2.1. The LiDAR datasets were provided in different vertical datums: CGVD1928 for 2013 and 2018, and CGVD28GVRD2018 for 2022. The extent of LiDAR 2022 dataset covers the study area and was determined to be sufficient to represent the topographic surface for mapping requirements. A summary of the LiDAR 2022 metadata is provided in Table 2.2. The average point density for the dataset exceeds 2 points/m² for bare earth, qualifying it for the medium flood risk category according to federal flood mapping guidelines, as detailed in Table 2.3.

Table 2.2 LiDAR 2022 Metadata

Attribute	Description
Flight Date	April 2022 - June 2022
Coordinate System	NAD83(CSRS)v6 Epoch 2002 - derived from ITRF2008 (International Terrestrial Reference Frame)
Projection	UTM Zone 10 (Central Meridian 123 West)
Vertical Datum	CGVD28GVRD2018
Average Point Density	>2.0 points/m ² Bare Earth

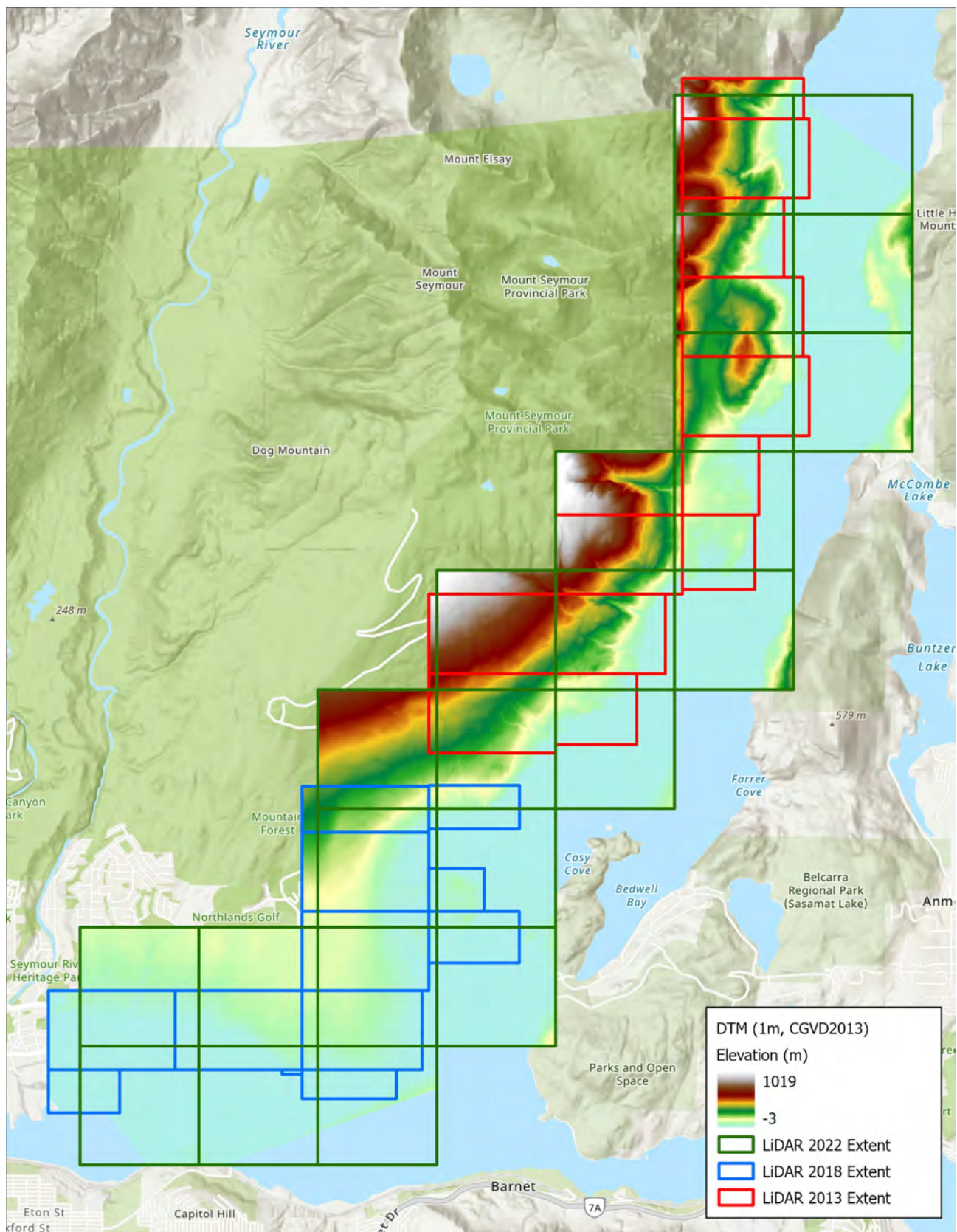


Figure 2.1 Extents of LiDAR datasets for multiples years in the study area

Table 2.3 Federally Recommended Approximate LiDAR Data Accuracy and Density for Flood Mapping Applications

	Flood Risk Category		
	High	Medium	Low
Vertical Accuracy (Open, Level, Hard Surfaces)			
Non-vegetated Vertical Accuracy (NVA) - Vertical Root Mean Square Error (RMSEz)	5.0-7.5 cm	7.5-10.0 cm	10.0 cm
Non-vegetated Vertical Accuracy (NVA) - 95% confidence level ($\approx 1.96 * RMSEz$)	10-15 cm	15-19.6 cm	19.6 cm
Horizontal Accuracy (Open, Level, Hard Surfaces)			
Horizontal Root Mean Square Error (RMSEr)	11-15 cm	30-35.1 cm	35.1 cm
Horizontal Accuracy - 95% confidence level	20-25 cm	50-60 cm	60 cm
Data Density			
Aggregate Nominal Pulse Density (ANPD)	4-10 pls/m ²	2-4 pls/ m ²	2 pls/ m ²

The LiDAR data was converted from CGVD28GVRD2018 to CGVD2013 through two transformations: from the local datum GVRD2018 to CGVD1928 using the HTMVBC00 hybrid geoid model (B.C. Government, 2024), and from CGVD1928 to CGVD2013 using the HTv2.0 to CGG2013a conversion grid (NRCan, 2024). The conversion was facilitated by GPS-H v3.5, a product of Natural Resources Canada (NRCan, 2024).

The topographic and bathymetry datasets were integrated to create a seamless terrain in UTM Zone 10N, CGVD2013. The datasets were combined using the inverse distance weighted (IDW) technique to interpolate and create a raster surface from points. Topographic data was used where both datasets were present, with 12 nearest input sample points used for interpolation. The IDW approach provided a better representation of elevation variations along the cross-shore elevation profile compared to mosaicking the datasets.

2.2.3 Bathymetric Data

A comprehensive bathymetric dataset of Burrard Inlet and Indian Arm was developed using publicly available, high-resolution bathymetric data from the Canadian Hydrographic Service (CHS) non-navigational (NONNA) bathymetry portal, combined with LiDAR data along the shoreline obtained from LiDAR BC. Each of these datasets is further described in Appendix B.1.

The NONNA data is referenced to the CD, and thus needs to be converted to CGVD2013, to integrate it with existing LiDAR topographic data contained in the intertidal regions of the study area. The Canadian Geodetic Survey GPS-H tool was used to correct the bathymetry data from CD to CGVD2013. For this purpose, the NONNA data had to be transformed from CD to CGVD28, as this is the datum required by this tool to generate the conversion.

Tides Canada, part of Fisheries and Oceans Canada (DFO), maintains a comprehensive inventory of tide stations across Canada, including Indian Arm and Burrard Inlet. Using the benchmarks from six (6) stations within Burrard Inlet (Table 2.4), conversion points were generated and then interpolated along the area of interest to convert the data from CD to CGVD28. These benchmarks were also used to validate the conversion from CGVD28 to CGVD2013 by GPS-H, calculating the difference at the six (6) points between both datums, resulting in a maximum difference of 1 cm. Finally, using the correction map obtained from

GPS-H, the final adjustment to the bathymetric data were made to CGVD2013. More details pertaining to the tide stations and spatially varying corrections are presented in Appendix B.2.

Table 2.4 DFO Tidal station and Benchmark
Coordinates in UTM 10N NAD83

Station	Coordinates	Benchmark
Point Atkinson	481620E 5464950N	128-1950
Kitsilano	489871E 5458225N	M17C9001
Vancouver	492750E 5459288N	M08C9006
Port Moody	509744E 5459481N	87C9765
Deep Cove	503778E 5463809N	M18C9030
Indian Arm	508254E 5478800N	M17C9042

2.2.4 Digital Terrain Model (DTM)

The topographic data, and bathymetric data were merged into one (1) seamless Digital Terrain Model, depicted in Figure 2.2, with a vertical datum of CGVD2013 and a horizontal projection of NAD83 UTM Zone 10. The DTM was validated by surveys provided by DNV. The validation of the DTM indicated a strong correlation with the site surveys along the southeast shoreline. Increased uncertainty exists in the northeast extent of the shoreline due to limited validation data and dense vegetation. The DTM closely matched the surveys in the open and populated areas of the shoreline. Consequently, the DTM was deemed to meet the project's requirements and was utilized for determining elevations for flood inundation mapping, including Total Water Levels for 200-year return periods, Flood Construction Levels, and Designated Flood Levels.

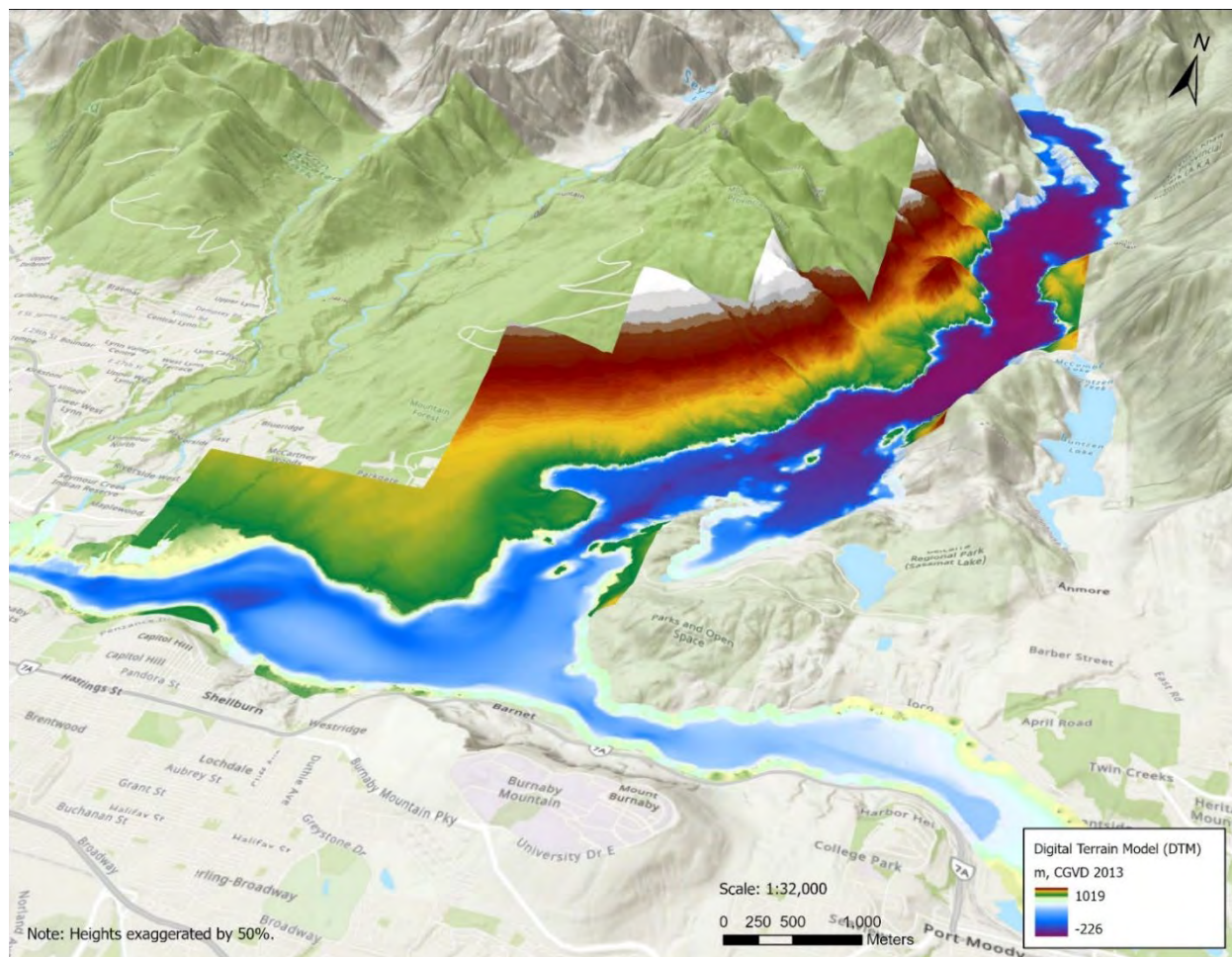


Figure 2.2 The Digital Terrain Model (DTM) developed for the District of North Vancouver shoreline study area, by merging LIDAR and bathymetry datasets

2.3 Characterization of Local Atmospheric Conditions

Local wave conditions along the DNV shoreline, particularly within Burrard Inlet and Indian Arm, are heavily influenced by local atmospheric conditions. Prevailing and shifting wind in Burrard Inlet and Indian Arm are influenced by a variety of factors, including local orographic wind forcings, and broader regional climatic phenomena found in mountainous coastal regions. Orographic wind forcing refers to the influence that mountains or elevated terrain have on the movement and behavior of winds. When wind encounters a mountain range or hilly terrain, it is forced to rise, change direction, or speed up, depending on the characteristics of the terrain. This can create various atmospheric effects, such as wind acceleration, where wind can speed up when funneled through valleys or gaps in mountain ranges, often creating stronger local winds (e.g., valley winds).

Burrard Inlet frequently experiences funneling effects on prevailing air masses, which move according to the orientation of the inlet. In the initial stretch of the inlet, predominant air masses flow east-west, while in the Indian Arm area, they tend to flow north-south. These channeling effects are influenced by the topography of the surrounding mountains, which funnel and redirect the movement of air masses along the inlet's course. Seasonal variations further influence these patterns. During the winter, cold continental

‘outflow’ winds tend to blow from the east toward the sea, while in the summer, westerly winds become more prevalent due to landmass heating (Thomson, 1981).

Long-term observations are required to derive annual exceedance probabilities (AEP) of 0.5% (i.e., 200-year return period) to establish governing wind speeds and directions that generate waves across the relatively short fetches found along Indian Arm and Burrard Inlet. In the absence of local meteorological stations with multi-decadal hourly observations, it is relatively standard practice to use long-term numerical atmospheric hindcast products to characterize extreme wind direction(s) and magnitude(s). These types of hindcast products (i.e., NCAR CFSR¹¹, ECMWF ERA5¹²) are particularly effective on open coasts, where winds are relatively uniform, subject to seasonal variation, and only moderately or mildly influenced by topographic features.

Along the DNV shoreline, the highest resolution, publicly available meteorological hindcast product is the Environment Canada High Resolution Deterministic Prediction System (HRDPS), depicted in Figure 2.3. This system is both a hindcast and a forecast and produces four (4) separate 48-hour forecasts per day for a wide array of atmospheric parameters, at 2.5 km resolution, and is made available to the public for download. Data is available for each of the tiles depicted in Figure 2.3, which illustrates that within Burrard Inlet, the model resolution captures both large portions of land, mountains, and open water, all within one (1) grid tile. The model is therefore not able to discern the local differences driving the wind across the waters of the inlet, and the steep mountain ranges parallel to the inlet. Topographic features which funnel and direct winds around the study area are also not captured at the available resolution. Therefore, long-term numerical meteorological hindcast forcings are unsuitable without further downscaling and site-specific modeling.



Figure 2.3 Overview of Environment Canada’s HRDPS West grid (left), model domain with inset zoom to DNV (right)

Given that long-term numerical atmospheric hindcast products are not appropriate for use in this study, in addition to a lack of local meteorological stations with multi-decadal hourly observations within Indian Arm, a more generalized interpretative approach has been applied to develop governing wind conditions which are appropriate for application in a flood hazard mapping exercise.

The closest and most reliable long-term observation station to the DNV is located at Point Atkinson (844), which provides hourly climatic measurements (including wind speed and direction) from 1996 to 2024.

¹¹ <https://climatedataguide.ucar.edu/climate-data/climate-forecast-system-reanalysis-cfsr>

¹² <https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels?tab=overview>

Another long-term record, though farther away, is located at the Vancouver International Airport (YVR - 51442), which provides hourly data from 1953 to 2024. Both of these stations contain data gaps in different years and for differing variables, which requires some consideration when configuring the data. It is generally understood and acknowledged that wind conditions at Point Atkinson and YVR are not representative of winds conditions locally at Indian Arm and Burrard Inlet along the DNV shoreline. However, it is acknowledged that these observations are generally descriptive of regional prevailing wind and atmospheric conditions, as they are often used and cited in coastal studies throughout Metro Vancouver.

For the purposes of this study, an approach has been adopted which utilizes the atmospheric conditions at these stations as an analogue to scale conditions for application along the DNV shoreline, using shorter duration and local meteorological observations found within Burrard Inlet and Indian Arm. The data from meteorological stations in the Inlet are insufficient and of too short a duration to derive a 0.5% AEP (i.e., 200-year return period), however it can be used to scale the longer-term observations at Point Atkinson and YVR. Specially, this analysis will focus on the magnitude of winds, and not the direction of winds. Due to the complex topography of Indian Arm and Burrard Inlet, wind directions at Point Atkinson and YVR cannot be reliably correlated to local conditions. Therefore, an omni-directional approach is used to assess wind magnitudes for wave analysis. Therefore, the assessment will consider an omni-directional EVA approach with regards to sustained wind magnitude only. This assumption is valid, given the short fetches along which waves are generated within Indian Arm and Burrard Inlet. Waves generated from all directions will thus be considered, and only the relevant and/or most conservative condition(s) selected for analysis.

The correlation of sustained wind magnitudes at Point Atkinson and YVR, scaled to wind magnitudes observed within Indian Arm and Burrard Inlet, and subsequently applied as an omni-directional fetch generated wave analysis in 15° intervals strikes a balance between assessing a more realistic magnitude of wind-generated waves found within the fjords of the DNV, while still ensuring that the analysis is representative of sufficiently conservative scenarios to assess wave hazards along the shoreline. The unofficial stations (installed by private owners) used to scale the winds within Indian Arm and Burrard Inlet have varying record lengths, but provide useful information related to the spatial variability and magnitude of winds (Figure 2.4). Additional details on wind stations, and processing procedures can be found in Appendix C.1.

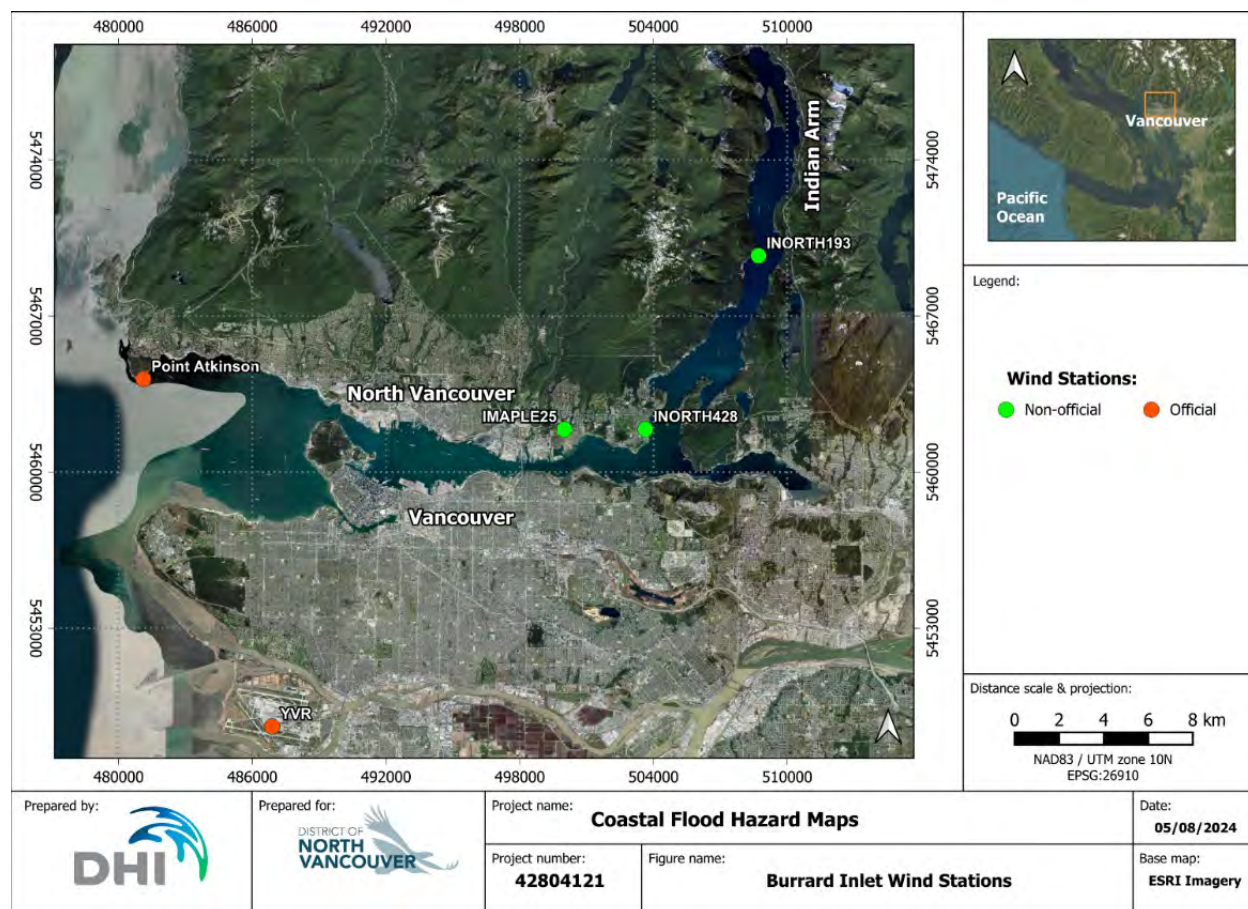


Figure 2.4 Wind Measurement Locations Available for the Area

2.3.1 Wind Variability within Burrard Inlet & Indian Arm

To characterize local variation in wind direction and magnitude, a 1-year period from 2022 to 2023 was assessed where hourly local meteorological records could be compared for the stations identified in Figure 2.4. The comparisons are made using descriptive wind rose diagrams depicting wind intensity (see Figure 2.5). The wind roses clearly indicate a reduction in wind energy within Burrard Inlet when compared to Point Atkinson. This is expected due to the complex coastline morphology, mountain ranges, and surface-level obstacles in the study area. The wind directions indicated by the local stations indicate the anticipated northerly, and southerly direction of winds in the Indian Arm, driven by the mountain ranges along the fjord. Wind intensity decreases at both IMAPLE25 and INORTH428, but slightly stronger winds reappear at INORTH193, as it is more exposed to the main axis of the inlet, as depicted in the previous figure (Figure 2.4). It is concluded that winds at Point Atkinson are also significantly stronger than those observed within Burrard Inlet and Indian Arm, and as such, some reduction is warranted, as summarized by the statistics presented in Table 2.5.

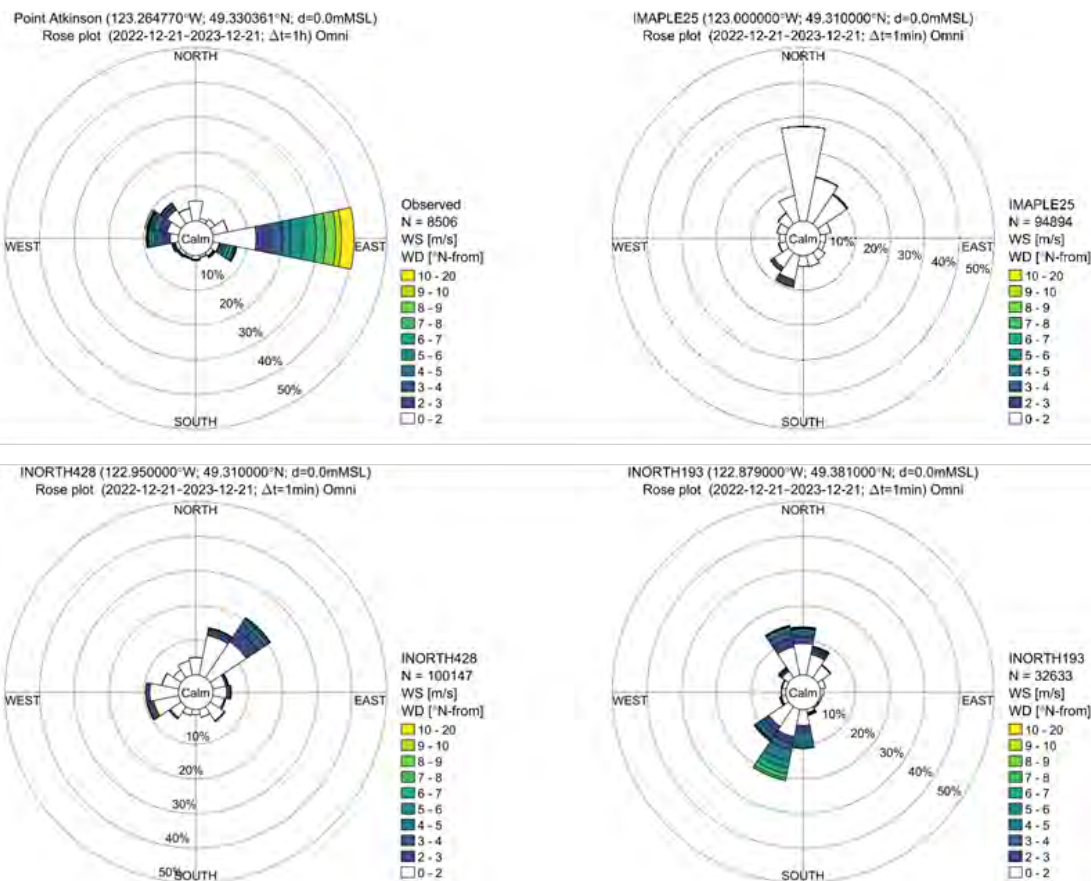


Figure 2.5 Wind rose diagram for Point Atkinson (top left), IMAPLE25 (top right), INORTH428 (bottom left) and INORTH193 (bottom right) stations.

Table 2.5 Statistical Comparison of Wind Speeds among the stations for 2022

WS (m/s)	2022			
	Point Atkinson	IMAPLE25	INORTH428	INORTH193
Max	18.6	8.4	9.3	14.3
P97.5	11.1	2.3	4.0	7.2
P90.0	8.1	1.6	2.5	4.9
Mean	3.3	0.8	1.2	2.1
P50.0	2.2	0.7	0.9	1.3
P10.0	0.6	0.0	0.1	0.0
P2.5	0.0	0.0	0.0	0.0
Std	3.1	0.7	1.1	2.0

2.3.2 Long-Term Winds within Burrard Inlet

To generate a sufficiently long wind time series to derive extreme conditions for use in the wave model, the YVR measurements were merged with those from Point Atkinson and adjusted to standardize them to 10 m, making them comparable. This dataset provides an adequate long-term regional description and record

of atmospheric conditions, under the assumption that all the strong winds captured by the Point Atkinson station are also captured by the YVR station due to their relatively proximity. Considering the variability of the winds within the Inlet and after analyzing the local observations, it was decided to use the INORTH193 station as representative of the Inlet, due to its higher wind intensities and a less sheltered location compared to the other two stations analyzed (IMAPLE25 and INORTH428), resulting in a more conservative and thus a more appropriate scenario for flood hazard mapping.

A scaling factor was applied to the long-term regional record of atmospheric conditions described previously, to derive conditions representative of Indian Arm. This was achieved by reducing the energy from the long-term station by approximately 30%. The result of the adjustment is depicted and described in Figure 2.5. For the purposes of this study, the final dataset is referred to as the long-term Indian Arm wind timeseries. This timeseries was used to generate discrete statistical scenarios of extreme events. Additional details regarding the procedures and criteria for modifying the Point Atkinson station can be found in the Appendix C.1.2.

Basic statistics of the scaled wind record and extreme value analysis are summarized in Table 2.6 and. Extreme value analysis plots are included in Appendix B.1.3. In conclusion, the wind omnidirectional wind speeds presented in Table 2.6 will be applied in the wave study.

Table 2.6 Long-Term Indian Arm Statistics and Omni-Directional Extreme Value Analysis

Wind Dataset	Mean (m/s)	Max (m/s)
Long-Term Indian Arm	2.50	19.20
Annual Exceedance Probability (AEP)	Omnidirectional (m/s)	
100% Annual	13.41	
50% (1-in-2 years)	14.24	
20% (1-in-5 years)	15.34	
10% (1-in-10 years)	16.18	
5% (1-in-20 years)	17.01	
2% (1-in-50 years)	18.12	
1% (1-in-100 years)	18.96	
0.5% (1-in-200 years)	19.80	

2.4 Characterization of Water Levels

Burrard Inlet and Indian Arm are well known for their complex hydrodynamics given the various constrictions, narrows and deep fjord system (i.e., over 200 m deep). Some of the primary drivers which make the hydrodynamics within the area of interest relatively complex include, but are not necessarily limited to:

- Large tidal range (i.e., > 5 m)
- Geographic features with narrow and shallow passages
- Complex bathymetry
- Confluence of rivers and freshwater inputs
- Localized wind and weather effects

The large fluctuations in water levels and the intricate coastal morphology of the area facilitate the rapid movement of a substantial volume of water (within hours) through the nearby First and Second Narrows. This phenomenon generates strong currents that govern the primary hydrodynamics in the region.

An assessment of total water levels for use in the flood inundation mapping is addressed in Section 3.1 (Hydrodynamic Hindcast Model). A long-term hydrodynamic hindcast model, calibrated to local total water level observations, is used to characterize the extreme (200-year return period) total water level gradient along the DNV shoreline.

2.4.1 Astronomical Tides

The Burrard Inlet region experiences semi-diurnal tidal cycles, meaning there are two high tides and two low tides each day. Tidal levels are summarized in Table 2.7. Within Burrard Inlet, astronomical tides display some tidal amplification, a phenomenon commonly observed in enclosed or narrowing waterways. At Point Atkinson, the outermost station in the Inlet, the Highest Astronomical Tide (HAT) measures approximately 2.15 m (CGVD2013). Further within the fjord at Port Moody, the HAT reaches up to 2.22 m CGVD2013). The Indian Arm fjord, located to the north, experiences a slightly higher HAT of about 2.57 m CGVD2013) (Figure 2.6).

Tidal elevations for the four (4) main stations at Burrard Inlet are presented in Table 2.4 in both local CD and CGVD2013. The table was compiled using the following sources:

- Fisheries and Oceans Canada (DFO) tides and water levels data archive.
- Benchmarks presented in Figure 2.7.

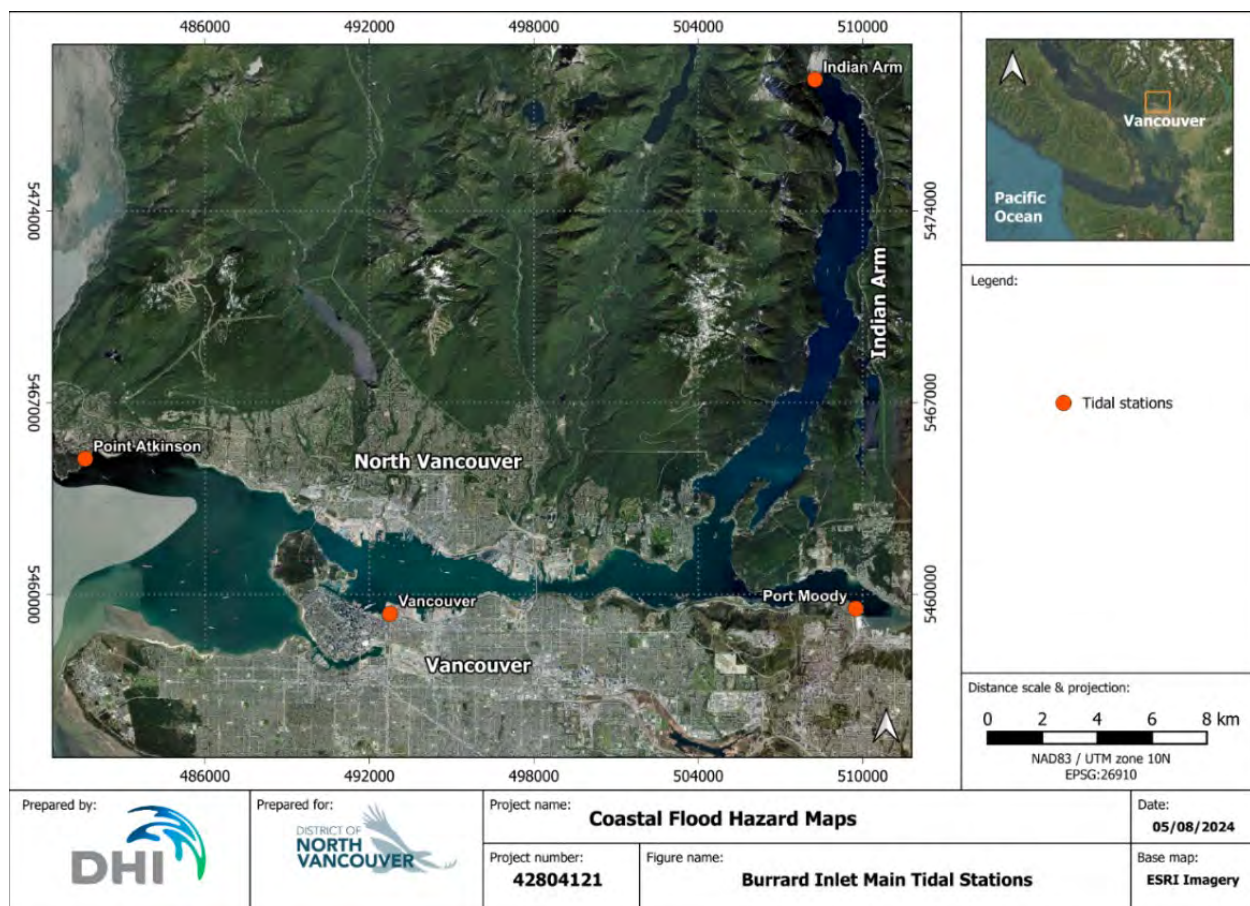


Figure 2.6 CHS Tidal Stations along Burrard Inlet

Table 2.7 Tides at Burrard Inlet

Left is Chart Datum; right in bold is CGVD2013

Tidal Heights	Tide in Meters							
	Point Atkinson		Vancouver		Port Moody		Indian Arm	
Highest Recorded Water Level	5.70	2.80	5.75	2.87	5.96	2.98	5.87	3.02
Highest Astronomical Tide (HAT)	5.05	2.15	5.08	2.20	5.20	2.22	5.42	2.57
Higher High Water Large Tide (HHWLT)	5.00	2.10	5.01	2.13	5.15	2.17	5.30	2.45
Higher High Water Mean Tide (HHWMT)	4.46	1.56	4.47	1.59	4.58	1.60	4.69	1.84
Mean Water Level (MWL)	3.09	0.19	3.06	0.18	3.08	0.09	3.17	0.32
Lower Low Water Mean Tide (LLWMT)	1.24	-1.66	1.17	-1.71	1.12	-1.87	1.18	-1.67
Lower Low Water Large Tide (LLWLT)	0.09	-2.81	0.06	-2.82	0.02	-2.97	0.08	-2.77
Lowest Astronomical Tide (LAT)	-0.08	-2.98	-0.10	-2.98	-0.05	-3.04	-0.02	-2.87

2.5 Sea Level Rise Projections

In British Columbia, it is standard practice to apply guidance regarding sea level rise projections from the 2011 Policy Discussion Paper - Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use, as prepared by Ausenco Sandwell for the British Columbia Ministry of Environment (Ausenco Sandwell, 2011a). Since the release of this document, there have been no updates on guidance related to sea level rise, and therefore it is still considered one of the primary guiding documents for practitioners for the purposes of flood hazard mapping. The document provides the following guidance regarding the establishment of policy for climate change adaptation in the coastal waters of British Columbia (Ausenco Sandwell, 2011a):

1. Sea level rise (SLR) in the future is expected to be both faster and higher than previously anticipated (as of 2011). A large degree of the related uncertainty can be eliminated by recognizing that it seems likely that sea level will rise but the rate at which it rises, and therefore the particular sea level rise on a given date, carries the most uncertainty.
2. For planning purposes, it is recommended that the rates and trends reflected in Figure 2.7 should be used (reference to 2011).
3. The choice of appropriate response options or adaptation measures is so site specific that their identification and adoption must be the responsibility of local governments, with guidelines and other support provided by the province.
4. As of 2011, scientific information on the expected changes in storms approaching British Columbia coastal waters and their characteristics, specifically on the intensity of the storms, their related wave conditions and the associated storm surges in the future, is only starting to emerge. Based on the available information it appears reasonable to conclude that no significant change is expected in coastal BC waters; however, further investigations are warranted to fully assess the regional implications and to further assess future trends.

5. The present recommended rates and trends for SLR have significant implications for British Columbia coastal communities.

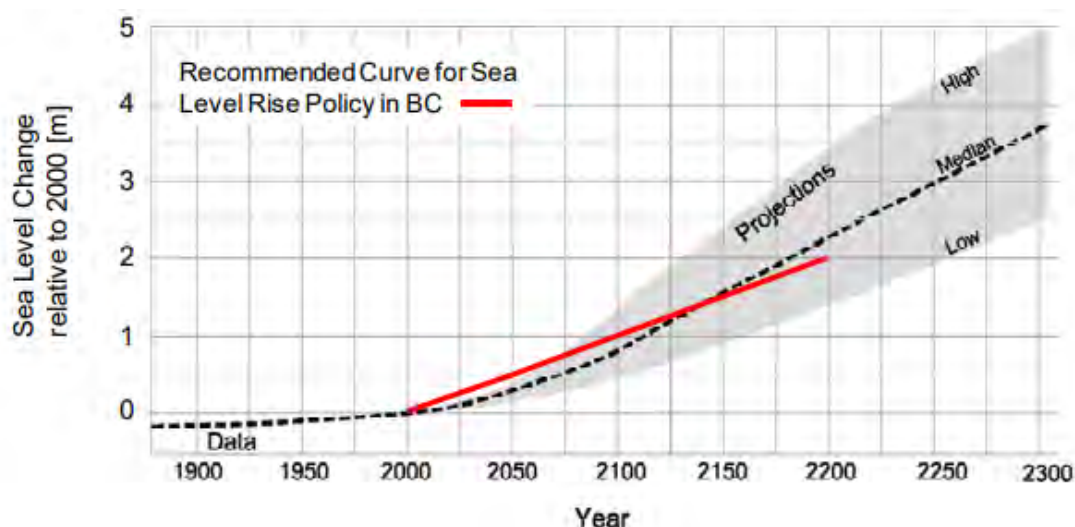


Figure 2.7 Recommended Global Sea Level Rise Curve for Planning and Design in BC

Additional guidance for the application of global sea level rise scenarios for various development and land-use timeframes is provided in Table 2.8 (Ausenco Sandwell, 2011a).

Table 2.8 Sea Level Rise Recommendations and Their Application for BC Sea Dike and Coastal Flooded Land Management Guidelines

Development/ Land Use Timeframe	Global SLR	Regional SLR	Application	Comment
For short to medium term - life of 25 to 50 years	0.5 m	To be developed on a site-specific basis. See Appendix B for existing crustal movement rates along coastal BC shorelines.	Evaluation of existing structures (sea dikes)	This estimate is slightly higher than suggested by the present range of SLR estimates and planning curves and anticipates revision soon (circa 2014).
For longer term - life of up to 2100	1.0 m		Definition of requirements for permanent structures (sea dikes) that can be expected to be upgraded again in the future as science and knowledge increases	This is consistent with the present "extreme high" estimates in BC Sea Level Report 2008.
For issues with long life (> 100 years), and as a sensitivity example	2.0 m		Consideration of long-term land use and planning issues having very long-term implications – especially where decisions may be made that allow or encourage concentration of high value or high population density uses.	This value is a balance between the current often stated upper limit of ~ 2 m for updated accounting of ice sheet mass loss by 2100 and potential increases identified by others.

The global sea level rise projections from 2011 (Figure 2.7) are, at the time of writing this report, over thirteen (13) years old. Since these projections were published, significant advancements have been made

with regards to global sea level rise projections, and local understanding of land subsidence, thereby resulting in significant changes to both global and local relative sea level rise projections. The principles in Table 2.8 are still applicable and are considered in this study.

Local relative sea level rise (SLR) is a combination of both global sea level changes due to climate change and local vertical land movements. Global SLR is the result of changes in glacier and ice-sheet mass loss, changing ocean circulation conditions, thermal expansion of the oceans, and human caused changes in land water storage. Local vertical land movements are the result of tectonic uplift or subsidence, isostatic rebound due to glacial retreat, and sediment consolidation. Local relative SLR is therefore the change in ocean height relative to land and is the apparent sea-level change experienced by coastal communities and ecosystems. Local relative SLR is also the parameter adopted for design purposes.

Natural Resources Canada (NRCan) developed an advanced dataset of projected relative sea-level rise to the year 2100 across Canada (James, 2021). The projections are based on the Intergovernmental Panel on Climate Change's Fifth Assessment Report (IPCC AR5) for the following Representative Concentration Pathways (RCP)¹³:

- RCP 2.6 – Low emissions: Sever mitigation measures are taken to reduce emissions immediately.
- RCP 4.5 – Intermediate emissions: Emissions peak around 2040 and decline after.
- RCP 8.5 – High emissions: Emissions continue to rise until roughly 2100.

NRCan is presently in the process of updating relative SLR projections for Canada based on the IPCC AR6 report, but results are not yet publicly available. AR6 projections are available through the [CAN-EWLAT](#)¹⁴ online tool (Greenan, 2022) for small craft harbours and tide gauge locations. For the Vancouver Harbour tidal station, CAN-EWLAT provides a projection of 0.52 m relative to year 2020 for the median high-emissions scenario (SSP5-8.5), which is approximately analogous to the AR5 RCP8.5 mean projection.

To compare the various sea level rise scenarios, from the earliest 2011 Provincial Guidelines to the most recent AR6 projections, the relative sea level rise projections for Vancouver are adjusted to a common reference point of 2023 as depicted in Figure 2.8 and summarized in Table 2.9. It should be noted that all projections are relative sea level rise projections and thus include local annual land subsidence. It is noted that the 2011 sea level rise guidelines are conservative relative to the latest IPCC scientific projections and guidance, which has been assessed locally by NRCan.

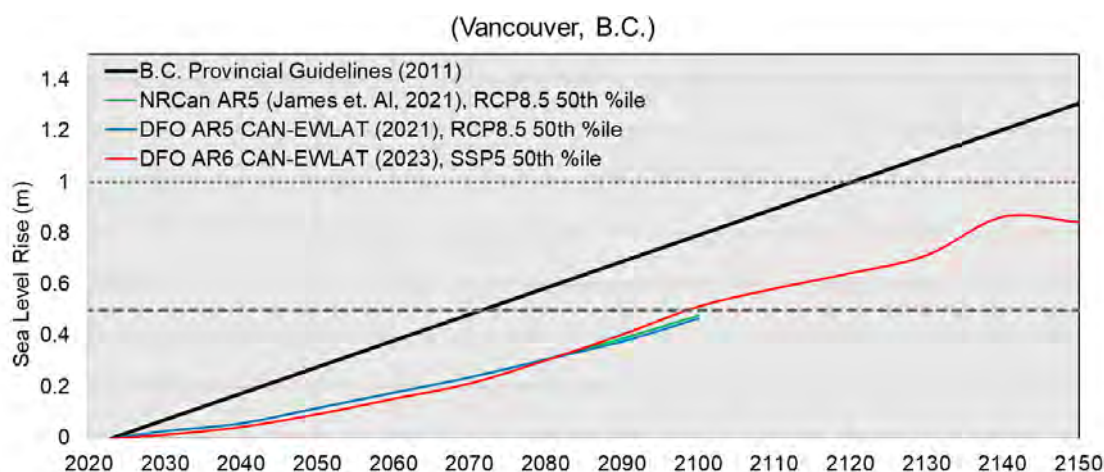


Figure 2.8 Comparison of Local Sea Level Rise projections in Vancouver

¹³ <https://climatedata.ca/>

¹⁴ <https://gis.dfo-mpo.gc.ca/portal/apps/experiencebuilder/experience/?id=760c4e0033ef4023ba395127a406d3a7&locale=en>

The latest scientific models and projections indicate a relative sea level rise at Vancouver of no more than 0.50 m between 2023 and 2100, and a relative sea level rise less than 1.0 by 2150 (and in fact slightly declining). It is therefore proposed to adopt future sea level rise scenarios of 0.50 m and 1.0 m, for mapping purposes.

In summary, two (2) future sea level rise scenarios are presented in this study:

- **Half a meter (0.50 m) of sea level rise** to demonstrate near-term flood impacts in the coming century associated with climate change.
- **One-meter (1.0 m) of sea level rise** to be adopted by DNV for FCL mapping purposes. This scenario can be used to update coastal flood hazard maps and used to provide general information about coastal processes and flood hazards to coastal property owners and occupants in the project area.

In summary, the 1.0-meter sea level rise target should be formally adopted by DNV, stakeholders and all parties referring to this document.

These recommendations are aligned with guidance in Table 2.8 (Ausenco Sandwell, 2011a) which indicates that a 0.50 m SLR allowance is appropriate for short to medium term - life of 25 to 50 years, and 1.0 m SLR allowance is appropriate for longer term - life of up to 2100. As sea level rise science and projections continue to evolve, the guidance offered by mapping 0.50 m and 1.0-meter sea level rise estimates can be used relative to the latest scientific consensus, to provide a robust basis for informed planning decisions along the DNV coastline. At this time, a 2.0-meter increase in relative SLR is highly unlikely to occur by 2100 and is likely to fall well outside the long-term planning timelines of DNV. A 2.0-meter relative SLR projection is therefore discarded as part of this assessment. If required, this SLR scenario can be considered for future study and mapping projects.

Table 2.9 Relative Sea Level Change (m) for Various Climate Projections

Year	B.C. Provincial Guidelines (2011)	ECCC (2021)	CAN-EWLAT AR5 (2021)	CAN-EWLAT AR6 (2023)
Scenario	Recommended Sea Level Rise Policy in B.C.	AR5 RCP 8.5 (median)	AR5 RCP 8.5 (median)	AR6 SSP5 8.5 (median)
2023	0.00	0.00	0.00	0.00
2030	0.07	0.03	0.03	0.01
2040	0.18	0.06	0.06	0.04
2050	0.28	0.12	0.12	0.09
2060	0.38	0.18	0.18	0.15
2070	0.48	0.24	0.24	0.21
2080	0.59	0.31	0.31	0.30
2090	0.69	0.39	0.38	0.40
2100	0.79	0.48	0.47	0.51

2.6 Tsunami Hazard

Although the likelihood and severity of such events may vary, Burrard Inlet is susceptible to the effects of tsunamis. Tsunamis in the region can be generated by seismic activity along “nearby” fault lines (Cascadia

subduction zone), submarine landslides within the inlet or adjacent coastal areas, or other geological events. While Burrard Inlet may not be directly exposed to the open ocean, tsunamis originating from the Pacific could potentially propagate into Burrard Inlet, albeit with reduced energy compared to coastal areas directly facing the ocean.

The tsunami alert zoning map of British Columbia (BC, 2022) places Burrard Inlet in Zone E (along with the entire Strait of Georgia) and is accompanied by the following description:

"Tsunamis are rare but serious events. Many areas of coastal B.C. may be threatened in the event of a tsunami. However, it is generally accepted by scientific and technical experts that Victoria, eastern Vancouver Island, Vancouver, and the lower mainland are low-risk areas."

Clague et. Al (Clague, 2005) concluded that the likelihood of North or West Vancouver being struck by a damaging tsunami is very low. Clague notes that it is difficult to quantify "very low," but the absence of tsunami evidence in geological archives bordering the southern Strait of Georgia and spanning more than 4,000 years suggests that the annual probability of a tsunami with waves greater than 2.5 metres high is no greater than 1 in 1,000 (i.e., one (1) tsunami every 1,000 years, on average) and more likely 1 in 5,000 or less (one (1) tsunami every 5,000 years). The primary tsunami risk to Deep Cove comes from local, landslide-triggered events in Howe Sound and Indian Arm. Given these findings, and the low risk posed by tsunamis, they are not considered within the scope of the present study.

3 Regional Numerical Modelling of Coastal Processes

The following chapter describes the development of a regional MIKE by DHI MIKE21 Flexible Mesh (FM) Hydrodynamic (HD) and Spectral Wave (SW) model of the Burrard Inlet and the Indian Arm for the purposes of supporting the coastal flood inundation mapping and the wave runup assessment to derive Flood Construction Levels (FCLs) along the DNV shoreline.

3.1 Hydrodynamic Hindcast Model

A hydrodynamic model of the Burrard Inlet and Indian Arm was developed to characterize total water levels, and the total water level gradient along the entire DNV shoreline for a 0.5% AEP (200-year return period). There are only three (3) water level monitoring stations in Burrard Inlet and Indian Arm which are relevant to the project. To develop a seamless total water level surface between these three (3) observations stations, a continuous long-term hourly total water level hindcast can be used to fill this gap. DHI therefore developed a high-resolution long-term hydrodynamic hindcast from 1970 to present day, which provides hourly total water level outputs at any location along the DNV shoreline. The model has been extensively calibrated and validated to local observations and provides a strong basis for establishing the 200-year total water levels along the DNV shoreline for mapping purposes.

The MIKE by DHI MIKE 21 Flexible Mesh (FM) Hydrodynamic (HD)¹⁵ model has been used to develop the total water level hindcast. These models are considered industry standard and well suited to investigate coastal processes for the purposes of flood hazard mapping. MIKE21 FM HD is a modelling system based on a flexible mesh approach and provides two-dimensional (2D) free-surface depth-averaged flows. The model is based on the numerical solution of the 2D shallow water equations – the depth-integrated incompressible Reynolds averaged Navier-Stokes equations. Details of the model's capabilities, characteristics of the numerical mesh, the configuration used, and model calibration are presented in Appendix C.3.

3.1.1 Simulation Scenarios

The hydrodynamic model was run from 1970 to 2023, using total water levels from the Point Atkinson tidal station. Thus, both harmonic and atmospheric effects were considered in the forcing water levels (Table 3.1). Model configuration, including a detailed sensitivity analysis, are presented in Appendix C.3.

Table 3.1 Hydrodynamic Model Scenario

HD Scenario	Date Range	Water Levels
Long-term Hindcast	01/01/1970 – 12/31/2023	Total Water Level from Point Atkinson

3.1.2 Modeling Results

The results of the maximum total water level observed for the duration of the 53-year hindcast, are depicted in Table 3.1. A map of the maximum surge residual (i.e., atmospheric component) observed for the duration of the 53-year hindcast is derived by removing tidal harmonic effects from the modeled water level series.

In general, the surge values vary only slightly (Figure 3.2) between 0.95 and 1.05 m above the water level along the Inlet. This indicates that surge is predominantly driven by processes within the

¹⁵Version 2024 was used: https://manuals.mikepoweredbydhi.help/2024/Coast_and_Sea/MIKE_FM_HD_2D.pdf

Salish Sea and Pacific Ocean, and that locally generated surge is relatively modest within the Burrard Inlet and Indian Arm. The maximum surge values, occur at the terminal points of the fjords at Port Moody and Indian Arm.

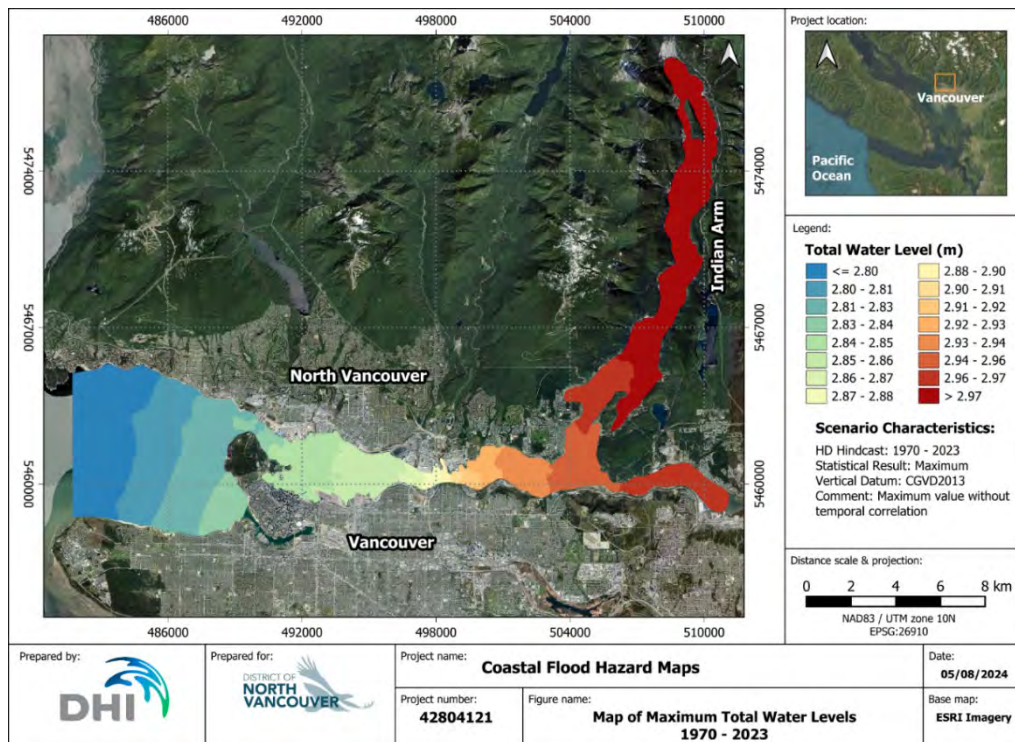


Figure 3.1 Maximum total water level variations along the inlet obtained from the 53 years of hindcast

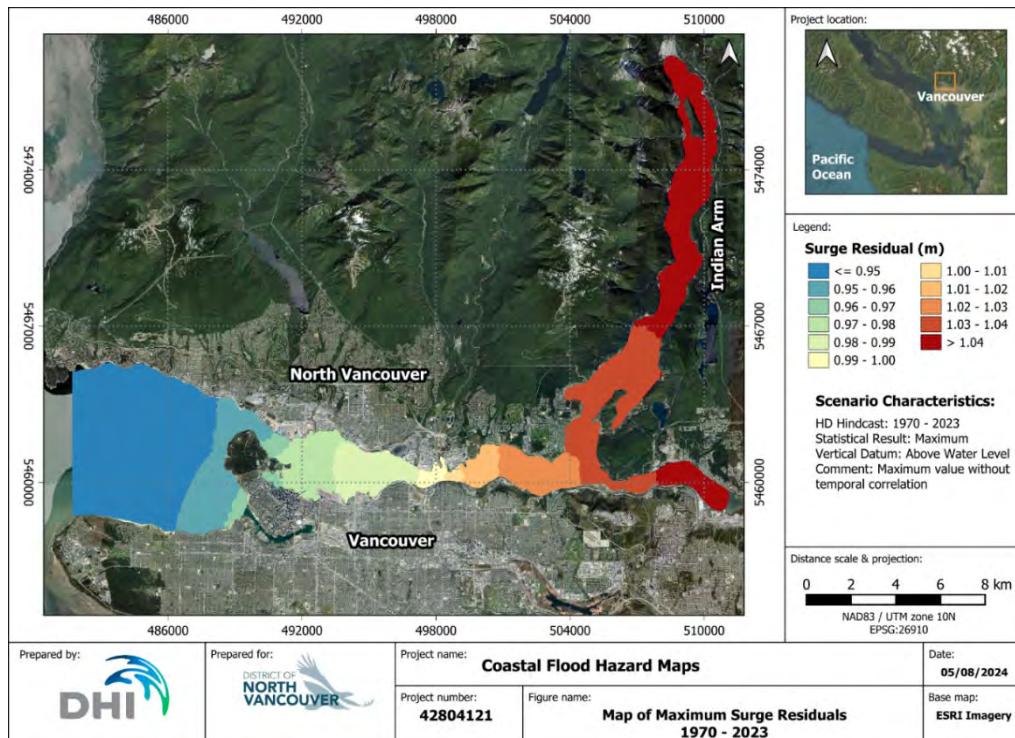


Figure 3.2 Surge residual variations along the inlet obtained from the 53 years of hindcast

3.1.3 Total Water Levels for Flood Mapping

To determine the annual exceedance probability (AEP) for total water levels for a 1- to 200-year event (100% and 0.5% respectively), an extreme value analysis (EVA¹⁶) of the 53-year total water level hindcast data was completed. Extreme values with associated long return periods are estimated by fitting a probability distribution to historical data. Several distributions, data selection and fitting techniques are available for estimation of extremes, where the estimated extremes are often sensitive to the choice of method. However, it is not possible to choose a preferred method only on its superior theoretical support or widespread acceptance within the industry. Hence, it is common practice to test several approaches and to make the final decision based on goodness of fit (refer to Appendix C.3.4 for details).

The main objective in determining an appropriate extreme distribution function is to derive the best possible estimates of extreme conditions at desired return periods. Often the data must be extrapolated to probabilities beyond the record length to match design return periods (USACE, 2006). There are large uncertainties associated with extreme value analyses, and the uncertainties generally increase for higher return periods. Ideally, time series that are long compared to the desired return periods should be available to reliably extract return values. In practice, however, the opposite is true and return values corresponding to return periods much longer than the length of recorded data are needed. Intuitively, the further away from the data one has to extrapolate, the larger the uncertainties of the resulting estimates will be.

As a rule of thumb, for example, the ISO standard ISO 19901-1 (ISO, 2020) recommends not using return periods more than a factor of three to four times beyond the length of the data set when deriving return values for design (Vanem, 2015). Therefore, for the assessment of a 0.5% AEP, one would need a continuous time series of over 50-65 years. In this instance, we have over 53 years of data, which provides a satisfactory approximation for the 200-year event.

To derive representative TWLs for the different parts of the Inlet, time series were extracted at various points (Figure 3.3). The results for the central fit at some of these points are depicted in Table 3.2 and Figure 3.4, while the remaining results, along with the complete list of figures for these main points, can be reviewed in Appendix C.3.4. The total water levels with a 200-year return period were estimated to range between 2.98 and 3.02 mCGVD2013, between the points of Maplewood Flats and Bishop Creek.

Given the low variability of the estimated water levels along the entirety of the DNV shoreline, a static water level of 3.0 mCGVD2013 is considered for the wave modeling. Further, it is assumed that a joint occurrence of extreme total water level and high winds generating the 200-year waves, will occur concurrently.

¹⁶ The Extreme Value Analysis (EVA) is a fit of data to predict extreme events reoccurrence.

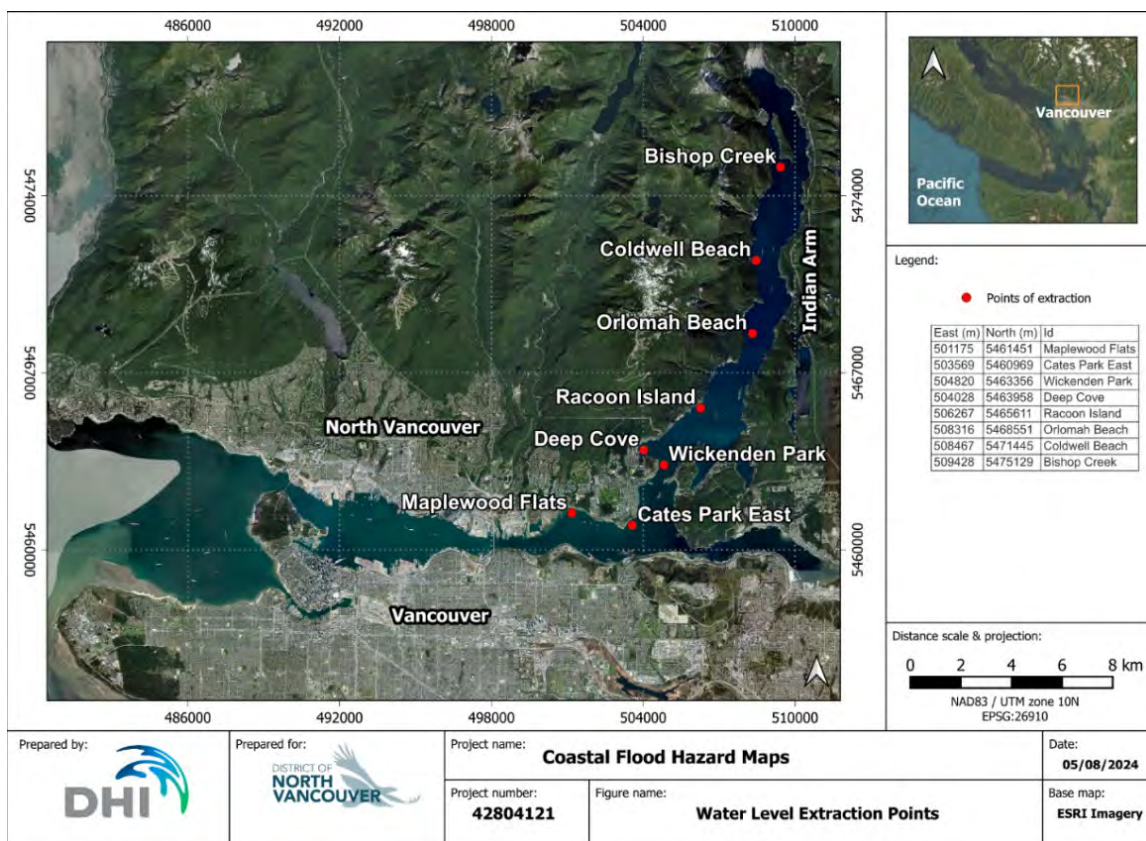


Figure 3.3 Water Level Extraction Points Locations and Coordinates

Table 3.2 AEPs for Total Water Level – Central Estimation

Annual Exceedance Probability (AEP)	Total Water Level (m, CGVD 2013)	
	Maplewood Flats	Bishop Creek
100% (Annual)	2.47	2.50
50% (1-in-2 years)	2.55	2.58
20% (1-in-5 years)	2.64	2.68
10% (1-in-10 years)	2.71	2.74
5% (1-in-20 years)	2.77	2.81
2% (1-in-50 years)	2.85	2.89
1% (1-in-100 years)	2.92	2.96
0.5% (1-in-200 years)	2.98	3.02

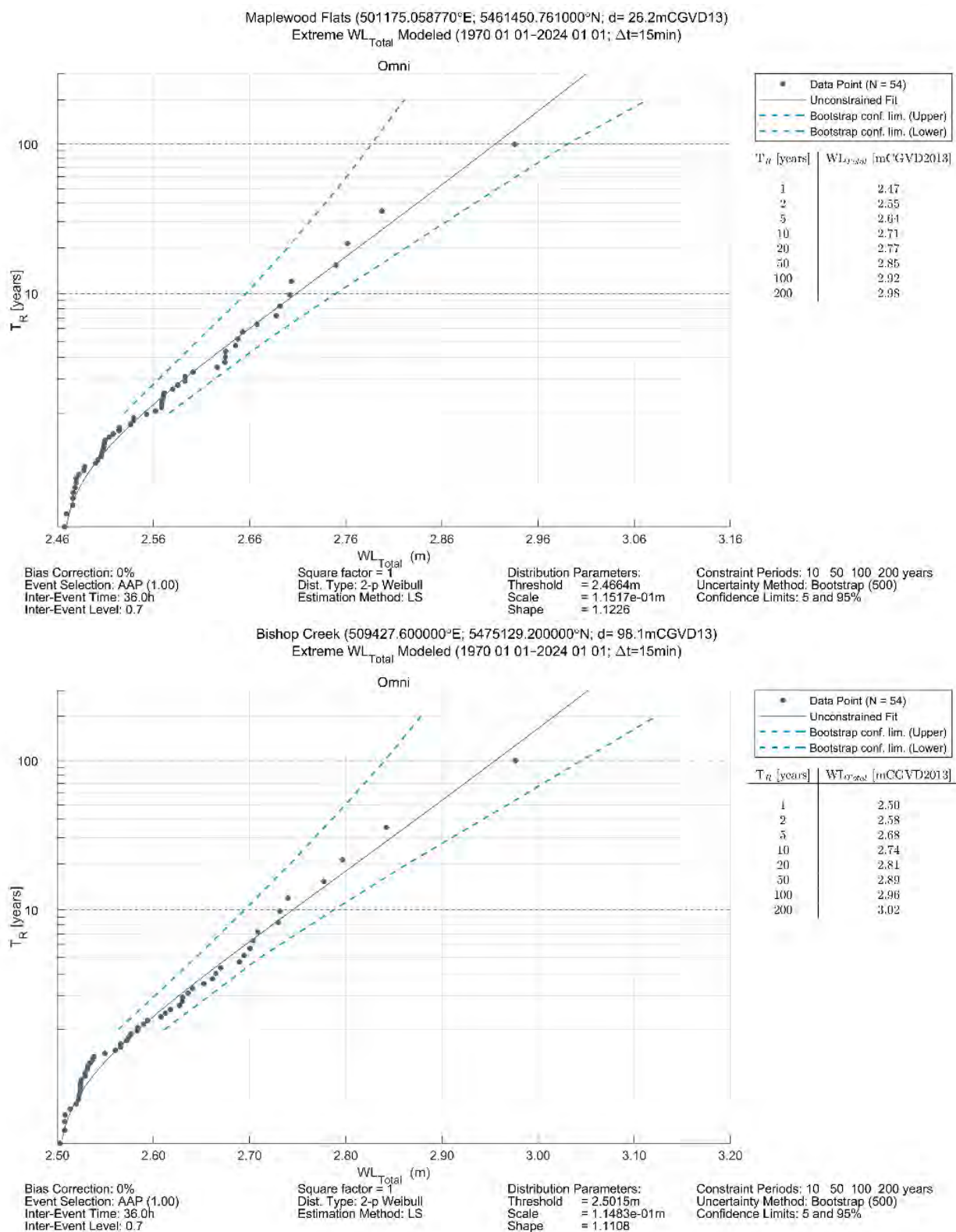


Figure 3.4 Total Water Level Extreme Value Analysis at Maplewood Flats (top) and Bishop Creek (bottom) – 1970 to 2023

3.2 Spectral Wave Modelling

A 2D spectral wave model of the Burrard Inlet and Indian Arm has been developed to simulate the 0.5% AEP or 200-year return period wave conditions throughout the study area for prevailing wind conditions from all directions, at 15° intervals, using the rationale described in Section 2.3 (Characterization of Local Atmospheric Conditions). The 2D spectral wave model will consider nearshore wave conditions for both the 200-year total water level, as well as sea level rise (0.50 m and 1.0 m) conditions. Results from the wave model will inform the wave runup assessment and subsequent derivation of FCLs.

3.2.1 Model Overview

The spectral wave modelling was performed using the industry-standard MIKE by DHI MIKE 21 FM Spectral Waves (SW)¹⁷ model. The model simulates the growth, decay and transformation of wind-generated waves and swells in offshore and coastal areas. Details of the model capabilities, mesh characteristics, and the configuration are outlined in Appendix C.4.

3.2.2 Simulation Scenarios

To analyze extreme wave events along the fetch of the Burrard Inlet and Indian Arm, discrete simulation scenarios were developed for the 0.5% AEP or 200-year return period wave condition. These scenarios, combined with total water levels presented in Section 3.1.3 (Total Water Levels for Flood Mapping), will be used as input to the wave runup assessment and subsequent derivation of FCLs.

As previously noted, the wave assessment considers omni-directional wind magnitude only. The rationale is that this assumption is valid, given the short fetches along which waves are generated within Indian Arm and Burrard Inlet. As described in Section 2.3 (Characterization of Local Atmospheric Conditions), sustained wind magnitudes at Point Atkinson and YVR, have been scaled to wind magnitudes observed within Indian Arm and Burrard Inlet, and subsequently applied in the MIKE21 FM SW model as an omni-directional wind magnitude in 15° intervals. This methodology strikes a balance between assessing a reasonable magnitude of wind-generated waves within the fjords of the DNV, while still ensuring that the analysis is representative and sufficiently conservative to assess wave hazards along the shoreline. When selecting the 200-year wave parameters for the runup assessment, DHI considered the orientation of the profile used to conduct the runup assessment, relative to the direction of prevailing waves obtained throughout the domain at 15° intervals, as further detailed in Section 4.1.1 (Reach and Profile Delineation).

The model scenarios are summarized in Table 3.3. Additional scenarios including Sea Level Rise effects were also evaluated and are presented in Appendix C.4.2.

Table 3.3 Wave Model Scenarios, including Winds and Water Levels.

SW Scenario	AEP (%)	Wind Direction (deg)	Wind Speed (m/s)	Water Level (m CGVD13)
200-year RTP ¹⁸	0.5	0 – 345 / Δ15°	19.8	3

¹⁷Version 2024 was used: https://manuals.mikepoweredbydhi.help/2024/Coast_and_Sea/MIKE21SW.pdf

¹⁸ The return period is the inverse of the exceedance probability of a specific event in any given year. It quantifies the expected frequency of occurrence of an event of a given magnitude. For example, a return period of 50 years means there is a 1/50 (2%) chance that an event of this magnitude or larger will occur in any given year.

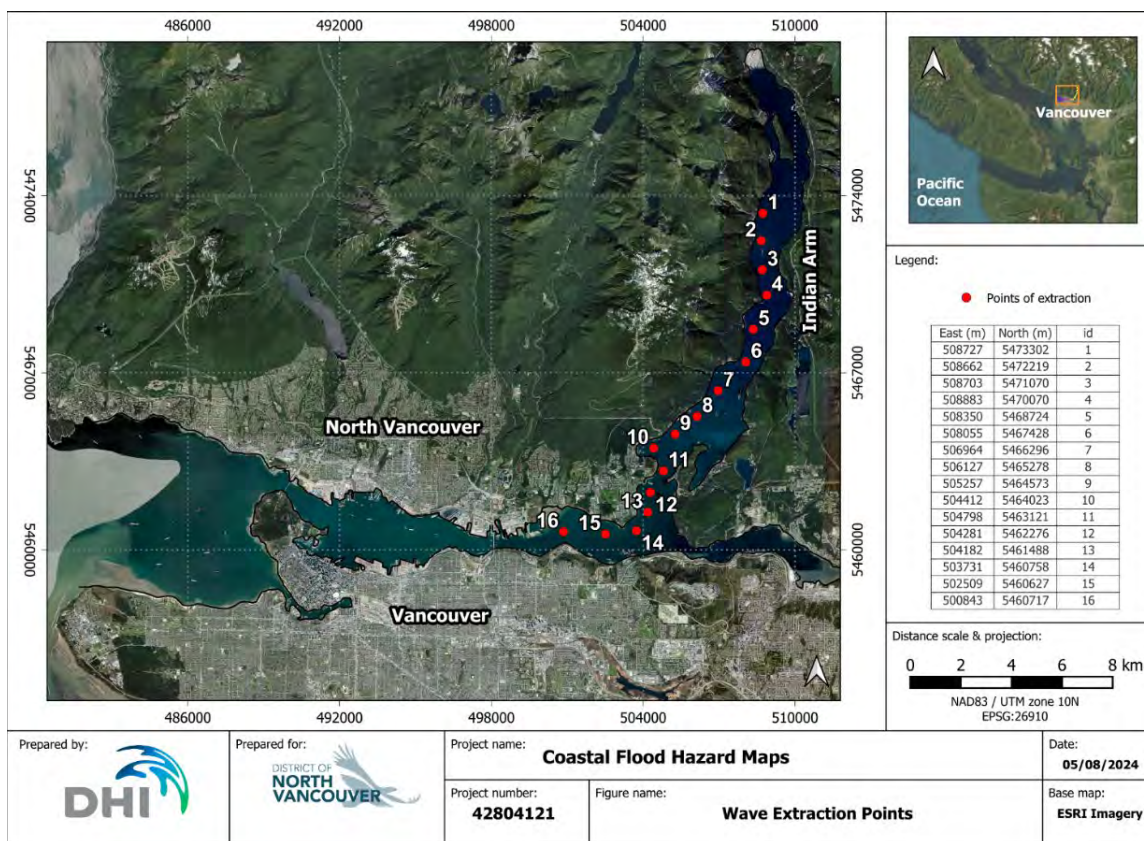


Figure 3.5 Wave Extraction Points Locations and Coordinates

The model results were extracted at 16 points along the Inlet, starting from the most northern point in the Indian Arm to the eastern area of the Second Narrows, as illustrated in Figure 3.5.

3.2.3 Spectral Wave Model Results

Model outputs for discrete extreme wave conditions are plotted for two governing scenarios (winds blowing from the south and east) for a 200-year return period (RTP) event at 200-year TWL, without sea level rise. In Figure 3.6 and Figure 3.7, the primary plot presents the wave results across the entire domain. The three (3) inset plots are zoomed in to different sections of the Inlet to illustrate local wave behavior in greater detail for illustrative purposes.

The model results depicted in Figure 3.6 shows that under the 0.5% AEP condition, wind-waves from a perpendicular fetch (points 14 to 16 in Figure 3.5) can result in waves heights along the shoreline in excess of 0.6 m, arriving obliquely in some areas. The southerly winds depicted in Figure 3.6 also demonstrate that over a larger unobstructed body of water such as English Bay, wave growth is greater than within a narrow-enclosed body of water such as Indian Arm where variable shoreline orientation interrupts wave growth. Figure 3.7 provides a snap-shot of prevailing winds from the east, where wave growth along the narrow Indian Arm is very limited relative to larger fetches along Burrard Inlet and Indian Arm. Collectively, these snap-shots demonstrate the sensitivity to prevailing wind direction on wave generation and magnitude along the shoreline.

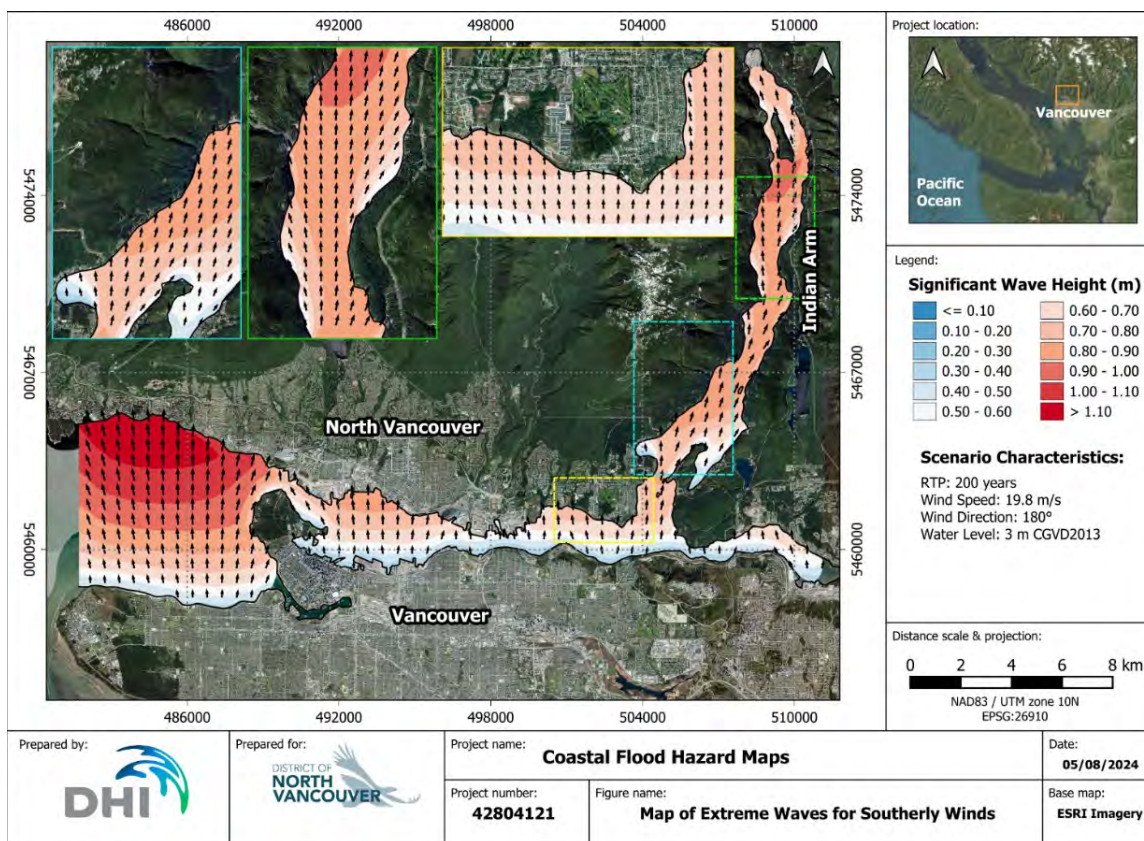


Figure 3.6 Snapshot of spectral wave model output for a 200-year return period extreme event with prevailing winds from the south (180°) and water level scenario.

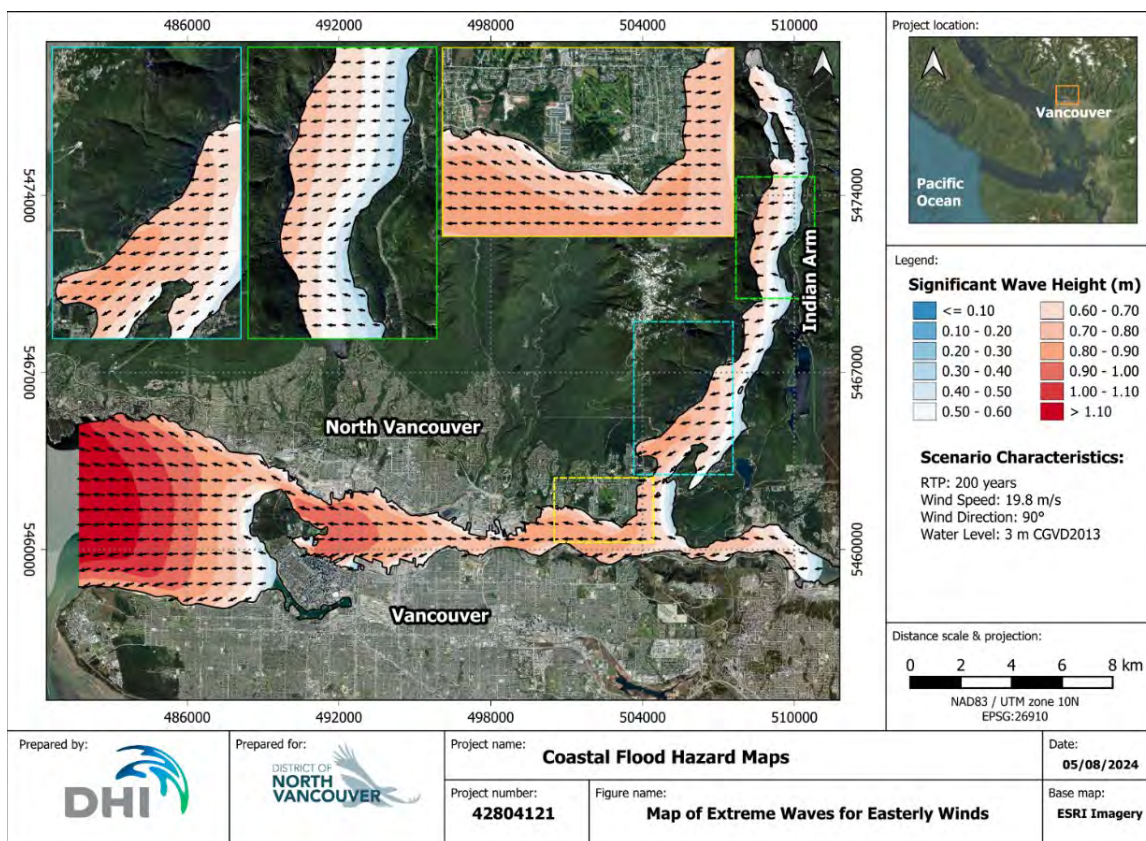


Figure 3.7 Snapshot of spectral wave model output for a 200-year return period extreme event with prevailing winds from the east (90°) and water level scenario.

Table 3.4 and Table 3.5 summarize the results for significant wave height and period at selected extraction stations. These reflect the range of wind directions and variations in coastline orientation across the study area. The results illustrate a variation in height from 0.4 to 0.9 m and changes in peak periods of up to 3.5 seconds. Along the upper Indian Arm (points 1-5) which is orientated on a north-south axis, the most consequential waves generated along the shoreline are from the north (0°-30°) and the south (180°-210°), which can be explained by the longest uninterrupted fetch along these axes. As the shoreline orientation rotates clockwise to the northeast (points 7 – 13), the governing wave directions shift by approximate 30° with governing waves coming from the northeast (30°-60°) and southwest (210°-240°) respectively. Point 15 is representative of the shoreline along the Burrard Inlet, where the largest incoming waves are governed by eastern (90°-120°) and western (240°-270°) fetch limitations. Given the relatively short fetch throughout the study region, the short (i.e. low energy) wave periods (2.0-3.5 seconds) are aligned with expectations.

Table 3.4 Significant wave height obtained from the spectral wave model for a 200-year RTP event

Significant Wave Height (m)		Extraction Points							
		1	3	5	7	9	11	13	15
Direction (°)	0	0.70	0.89	0.74	0.75	0.75	0.84	0.79	0.56
	30	0.75	0.88	0.75	0.82	0.89	0.93	0.86	0.58
	60	0.76	0.76	0.71	0.77	0.88	0.86	0.82	0.68
	90	0.73	0.64	0.65	0.71	0.83	0.70	0.74	0.79
	120	0.74	0.67	0.62	0.69	0.74	0.59	0.71	0.78
	150	0.81	0.71	0.71	0.78	0.73	0.69	0.72	0.71
	180	0.88	0.74	0.80	0.89	0.79	0.80	0.75	0.63
	210	0.80	0.69	0.83	0.91	0.80	0.79	0.73	0.69
	240	0.60	0.55	0.74	0.82	0.73	0.69	0.69	0.80
	270	0.41	0.45	0.55	0.66	0.60	0.56	0.63	0.86
	300	0.41	0.57	0.49	0.51	0.49	0.50	0.57	0.81
	330	0.56	0.76	0.64	0.58	0.52	0.64	0.65	0.68

Table 3.5 Peak period obtained from the spectral wave model for a 200-year RTP event

Peak Period (s)		Extraction Points							
		1	3	5	7	9	11	13	15
Direction (°)	0	2.8	3.3	3.0	3.0	3.2	3.2	3.1	2.2
	30	2.9	3.3	2.9	3.1	3.3	3.5	3.3	2.3
	60	2.8	3.0	2.8	2.9	3.2	3.3	3.1	2.9
	90	2.6	2.4	2.5	2.6	3.0	3.0	2.6	3.0
	120	2.6	2.6	2.3	2.6	2.8	2.3	2.7	3.0
	150	3.0	2.8	2.8	2.9	2.6	2.8	2.7	2.6
	180	3.2	2.9	3.2	3.2	3.0	3.0	2.7	2.4
	210	3.2	3.0	3.3	3.3	3.0	3.0	2.8	2.5
	240	2.6	2.0	3.3	3.2	2.8	2.8	2.7	3.0
	270	1.8	1.9	2.0	2.9	2.5	2.4	2.5	3.2
	300	1.8	2.3	2.1	2.0	2.1	2.1	2.2	3.0
	330	2.5	3.1	2.5	2.3	2.0	2.6	2.6	2.7

The spectral wave model has not been calibrated to locally observed wave conditions as these are not publicly available along the DNV shoreline. Collecting wave data for model calibration is beyond the scope of this study. DHI has reliably applied its models, using regionally tuned settings and parameters, to simulate extreme wave conditions for regional flood hazard mapping purposes. It is therefore anticipated that the spectral wave model developed for this study will provide robust and reliable wave inputs for the purposes of this investigation. The complete set of results for all points is provided in Appendix C.4.2.

In conclusion, the wave model provides a robust basis to support the wave runup modelling and subsequent assessment of FCLs along the DNV shoreline. The model results verify the fetch-limited nature

of wave generation in the fjord system and align with theoretical estimates of maximum wave growth potential. The omni-directional approach to assess wave growth from all directions removes uncertainty associated with localized wind phenomena and ensures that the most representative wave parameters are used to inform flood hazard mapping. At each transect the greatest incoming wave height, perpendicular to the shoreline, resulting in the greatest wave runup will be selected on a transect-by-transect basis using the model output.

3.3 Input to Coastal Flood Inundation Mapping

Numerical modelling of total water levels and wave conditions throughout Burrard Inlet and Indian Arm are foundational to the wave runup assessment (See Section 4), derivation of the Flood Construction Level (See Section 5.1), and mapping of the Designated Flood Level (See Section 5.2 – Mapping Procedure) and FCL (See Section 5.2 – Mapping Procedure). The ensuing sections demonstrate the value and ability of the MIKE21 FM HD and SW models to provide output at any location throughout the Burrard Inlet and Indian Arm. Additionally, the model outputs can be used for other planning and policy activities, and can support shoreline development applications and permitting as required.

4 Wave Runup Assessment

The following Chapter describes the process of characterizing wave runup at 98 transects along the DNV shoreline using both numerical modelling (FUNWAVE-TVD) and empirical (EurOtop 2018) methods, to derive wave runup, which is essential for establishing the Flood Construction Levels (FCLs) along the DNV shoreline.

4.1 Applied Approach

Wave runup was assessed along the DNV shoreline using a multi-step approach. In summary, this approach can be broken down at a high level into the following steps:

1. Segmenting the shoreline into reaches, where for each reach, a characteristic profile was selected based on topography, bathymetry, shoreline orientation, geology and substrate, as well as exposure to prevailing waves.
2. Wave parameters were selected at the offshore end of the profiles from the MIKE21 FM SW model described in section 3.2 (Spectral Wave Modelling).
3. The selected profiles were further simplified into a series of straight-line segments, for the purpose of the runup assessment.
4. With the established offshore wave parameters, waves were propagated towards the nearshore to assess wave runup. This propagation was performed using the FUNWAVE-TVD numerical model, as described by Shi et al. (2012). The model accurately transforms waves from intermediate depths to the nearshore and accounts for key behaviors like wave interactions, breaking, set-up, and run-up/overtopping. Utilizing the FUNWAVE-TVD model, the waves at the toe for each profile were derived and used to assess wave runup.
5. Wave runup assessment was conducted using two (2) methodologies:
 - o (EurOtop, 2018), which provides empirical formulas and guidelines for estimating wave runup, and
 - o Extracting direct wave runup results from the FUNWAVE-TVD simulations.
6. The two (2) methodologies were used as the baseline for assessing wave runup at each profile. This involved an iterative process of analyzing the runup values and the flooding extents for each reach and determining whether the EurOtop or FUNWAVE-TVD results were best suited to establish the wave runup R2% value for each transect.

Each step in the above approach is discussed in greater detail in the ensuing sections starting with the process for selecting the reach extents and positioning the representative profile for the runup assessment within that reach.

4.1.1 Reach and Profile Delineation

The delineation of shoreline reaches and the placement of transects within each reach to assess wave runup, requires a strong understanding and detailed interpretation of the DNV shoreline and its exposure to wave and water level hazards. The DNV shoreline has significant variability in shoreline types, from shallow inter-tidal flats, to beaches, embankments, built shoreline infrastructure, alluvial materials, and rock embankments or cliffs. To facilitate the wave runup assessment, the DNV shoreline was discretized into reaches, as depicted in Appendix D using visual evidence collected from the site visit (Appendix E),

combined with interpretation of the DTM (Section 2.2.4 – Digital Terrain Model), shoreline classification, prevailing wave conditions (Section 3.2.3 – Spectral Wave Model Results), and various DNV GIS layers (Section 2.2 – Mapping Layers).

The extent and position of each reach was determined using the following key considerations:

- The shoreline type and composition, whether a low-lying alluvial fan, steep bluff or bed-rock cliff, or built infrastructure such as revetments and/or seawalls.
- Intersection of property lines for both private and public properties, where reach lines within the bounds of private property were avoided.
- Wave exposure and open fetch along the reach extent.
- Topographic and bathymetric features including shallow (large intertidal extents) and/or deepwater directly in front of the reach.
- Ability to extract a profile for the wave runup assessment within the reach which is uniformly representative of that reach.
- Presence of critical municipal assets or infrastructure within the reach.
- Vulnerability of private properties and residences within the reach.

In total 98 reaches were selected using the above selection criteria. The number of transects ensures the required level of detail to perform a localized assessment of flood risk to facilitate accurate flood hazard mapping and subsequent planning and shoreline management decisions. All extracted profiles for each reach are presented in Appendix D.1.

4.1.2 Wave Runup Characterization

Wave induced runup corresponds to the maximum onshore elevation, with respect to the total “still” water level (tide, surge, wind setup, sea level rise, etc.), generated by the waves. It includes both the wave set-up¹⁹ and the swash uprush²⁰. Figure 4.1 outlines the components of wave runup and other relevant water levels that contribute to wave runup, which were considered as part of this study.

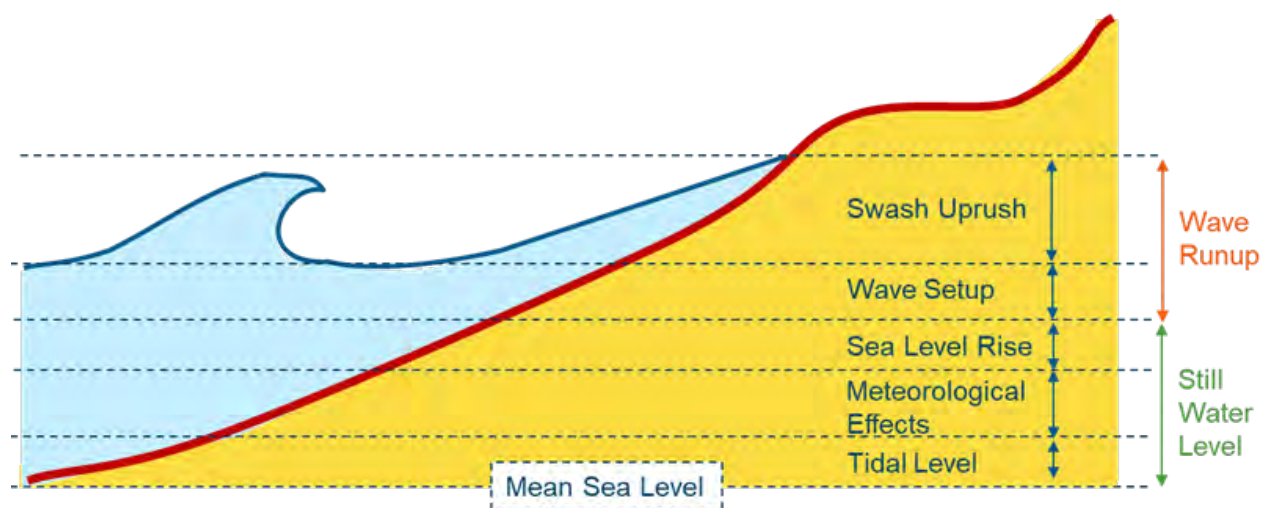


Figure 4.1 Schematic Figure of Wave Runup

¹⁹ Elevation of the mean water level at the shoreline due to wave breaking in the surf zone.

²⁰ Up and down propagation of bores formed after the collapse of waves on the beach. Swash is the decelerating uprush phase and backwash is the accelerating down-rush phase.

Runup is a complex phenomenon that depends on the incident wave characteristics and its transformation to the nearshore, the local water depths, the bathymetric profile, and the characteristics of coastal structures, if present. The most commonly used parameters to describe wave runup are R_{mean} , R_{max} , and $R_{2\%}$, where:

- R_{mean} is the mean runup elevation. It is calculated by averaging all individual runup events.
- R_{max} is the largest elevation obtained by a single runup event.
- $R_{2\%}$ is a statistical measure of the elevation that is exceeded by only 2% of the incoming waves.

The runup 2% ($R_{2\%}$) was used in this investigation, as it has historically been considered the most suitable parameter for describing the whole runup series and is the most commonly applied metric for describing wave runup. Additionally $R_{2\%}$ is cited for use by (Ausenco Sandwell, 2011a) (Ausenco Sandwell, 2011b) (Ausenco Sandwell, 2011c) in Provincial Coastal Flood Mapping. The $R_{2\%}$ parameter has an origin from experiments in physical models conducted in the Netherlands (see EurOtop 2018, section 5.2.1), with the idea that if only 2% of the wave runup reached the crest of coastal defenses, such as dikes or embankments, this defense would need minimal protection measures (EurOtop 2018, section 5.2.2). The value of $R_{2\%}$ has widely been adopted as the wave runup parameter to be used for flood hazard studies covering not only coastal structures but also natural beaches, shoreline, and municipal infrastructure.

4.2 Wave Runup Assessment Methodologies

Wave runup has been assessed for 96 profiles using the empirical methods outlined in EurOtop (2018) and the numerical model FUNWAVE-TVD (Shi et al. 2012). A summary of these methods is provided below.

4.2.1 Empirical Methods (EurOtop, 2018)

EurOtop (2018) provides guidance on analysis and/or prediction of wave runup and overtopping for flood defenses subject to wave action. It is regarded as an industry standard when performing assessments for coastal structures and some natural coastal features. Moreover, in 2023 EurOtop (2018) became an accepted methodology within the FEMA Coastal Flood Hazard Guidelines (FEMA, 2023).

The manual includes a series of workflows specifically tailored for different coastal structures and shoreline types subject to a variety of wave characteristics. Each workflow provides a series of empirical formulas, which are generally based on measurements conducted in wave flumes, where structures and bathymetry are idealized and modelled at scale. The application of these empirical formulations to real-world cases requires extensive analysis and schematization of site-specific profiles in addition to careful consideration of the local wave conditions.

A key concept used in the EurOtop (2018) methodology is the idea of the “toe of the structure”, which corresponds to the location of the separation between the gently sloping sea bottom and the coastal structure or feature (see Figure 4.2).

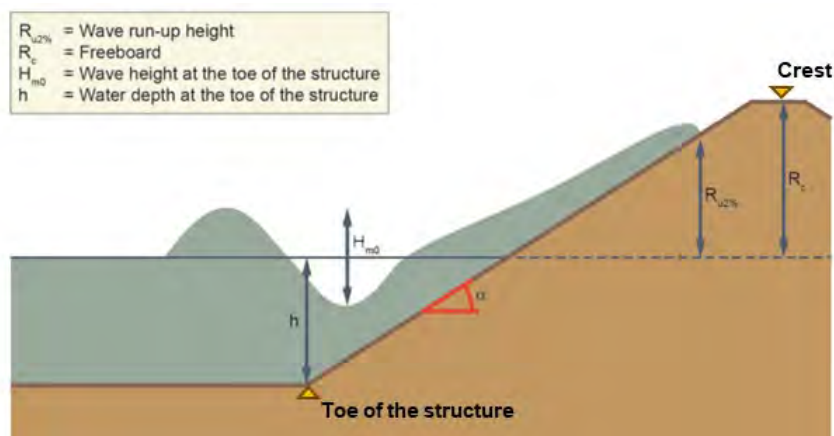


Figure 4.2 Schematic Profile Outlining Key EurOtop Features
(Modified from EurOtop, 2018)

EurOtop (2018) requires wave conditions to be determined at the toe of the structure, prior to their use of the formulas for runup. Other relevant concepts include the crest level, which could be represented by the crest of a coastal structure or a location at a natural crest along the shoreline profile, and the profile slope.

As the empirical formulas in EurOtop (2018) are developed from measurements conducted in wave flumes, the bathymetric profiles used to derive the formulas are generally idealized with simple slopes and are limited in their capabilities of representing complex geometries. As nearly 100 locations along the DNV shoreline were investigated using the empirical equations in EurOtop (2018), the complex geometry of the DNV shoreline was simplified into a series of straight lines as demonstrated in Figure 4.3. The toe of the structure was defined as the starting point of the line segment that intersects with the static water level (circled in red in Figure 4.3).

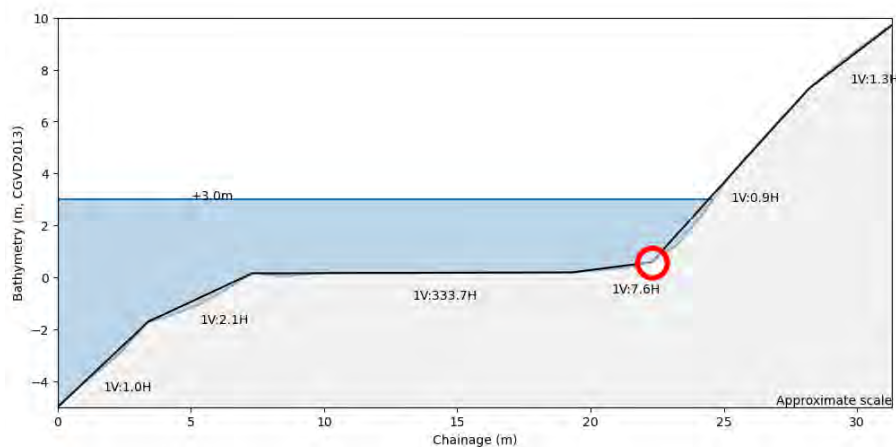


Figure 4.3 Example Profile Simplification

4.2.2 Numerical Model (FUNWAVE-TVD)

The numerical model FUNWAVE-TVD (Shi et al. 2012) was used to propagate the offshore waves to the nearshore and to compliment the empirical methods outlined in EurOtop (2018) to assess wave runup for

this study. FUNWAVE-TVD is a fully nonlinear, phase-resolving²¹ Boussinesq-type wave model. The model is capable of resolving many coastal processes, such as:

- Nearshore wave propagation and transformation;
- Refraction, diffraction, reflection and nonlinear shoaling;
- Wave-induced nearshore circulation;
- Nonlinear wave-wave and wave-current interactions;
- Wave breaking with runup and overtopping;
- Partially absorbing/reflecting inner boundaries to avoid wave reflections and distortion generated by the model boundaries;
- Harbor resonance and infragravity waves; and
- Vessel-generated waves and related sediment transport with morphology change.

The FUNWAVE-TVD model uses an internal wave-maker to generate waves in the model domain. The results from the MIKE21 SW model detailed in section 3.2 were used to define the internal wave-maker properties such as the significant wave height, peak wave period, and spectral shape parameter.

The FUNWAVE-TVD model outputs water surface elevation at each point in the domain for a specified output frequency. With the water surface elevation, the waves at the toe of structure can be assessed by processing the water surface elevation time history. The wave runup can be determined by tracking the water surface elevation within the swash zone (as illustrated by the red circle in Figure 4.6, Figure 4.8, and Figure 4.10).

4.2.3 Limitations of Assessment Methodologies

Each methodology for assessing wave runup presented above has its own set of distinct considerations, efficiencies, strengths, and limitations. Empirical formulas remain the most straightforward method for calculating wave runup when the bathymetry profiles are simple and there is a clear indication of where the toe of the structure is, as presented in Figure 4.2. Their application falls short in handling complex bathymetric profiles such as those presented in Figure 4.4, for which the toe of the structure and slope are difficult to interpret, given the shallow foreshore.

²¹ Phase-resolving models resolve individual waves and individual wave processes, unlike phase-averaged models that predict average wave conditions over time and space.

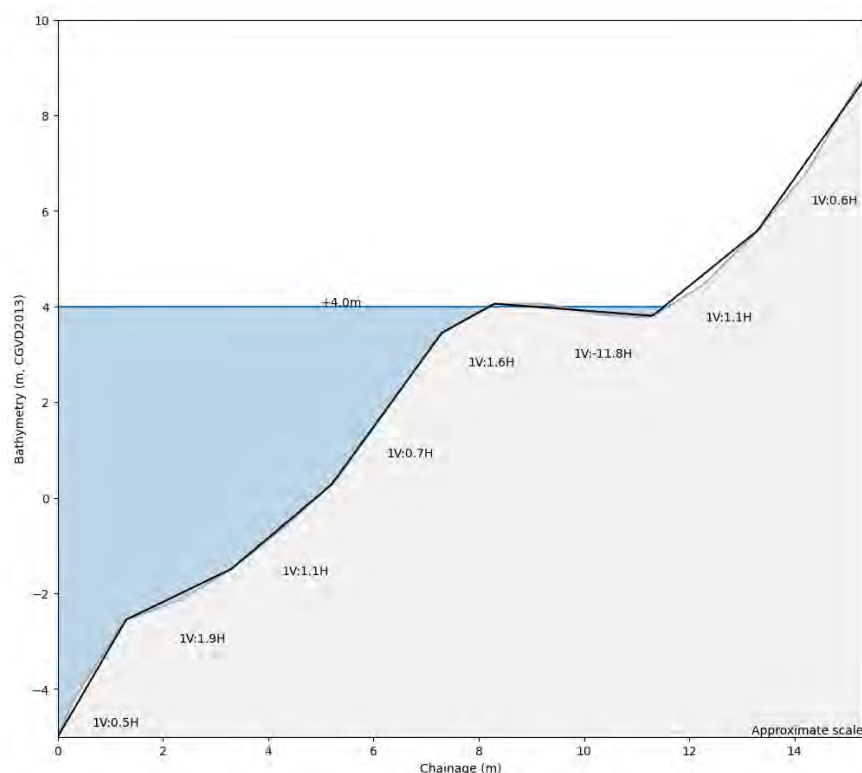


Figure 4.4 Example Complex Profile

The application of empirical formulas requires user interpretation and decisions regarding the toe location or determining the representative slope. In contrast, the FUNWAVE-TVD model is a powerful tool for analyzing wave runup across a broad spectrum of bathymetries and coastal profiles, as no assumption of the toe location or simplification of the profile is required. Nevertheless, there are limitations with the FUNWAVE-TVD model. The model is not as responsive and suitable for addressing shorter wave periods and very steep slopes. Additionally, the model can also be very computationally expensive— requiring both significant time and computational resources to resolve wave-surface interactions. It is important to note that validation of these methods has not been evaluated in this study, as no collection or comparison with actual wave runup measurements were available or undertaken. Given the strong body of research, literature and industry-application of the wave runup methods and models applied in this study, in addition to DHI's extensive experience applying these tools and methodologies, it is reasonable to assume that the results presented herein are fit-for-purposes to assess wave runup and FCLs.

4.3 Wave Runup Results

Appendix D.2 depicts the projection of the 0.5% (200-year return period) flood level onto each of the assessed profiles. The results for three (3) varying sample profiles, including a gently sloping, steep, and shallow foreshore profile, are presented below.

4.3.1 Gently Sloping Profile

Profile 24, depicted in Figure 4.5, represents a gently sloping profile with a mild slope of approximately 6H(Horizontal):1V(Vertical). From the MIKE21 SW model results, the offshore wave conditions have a significant wave height of approximately 0.7 m and a peak wave period of approximately 2.6 s. This profile is considered an ideal profile to model using FUNWAVE-TVD and also to apply the empirical formulas

outlined by EurOtop (2018) to calculate runup. This is due to the mild slope of the profile and the clear indication of where the toe of the structure is located (circled in red on Figure 4.5).

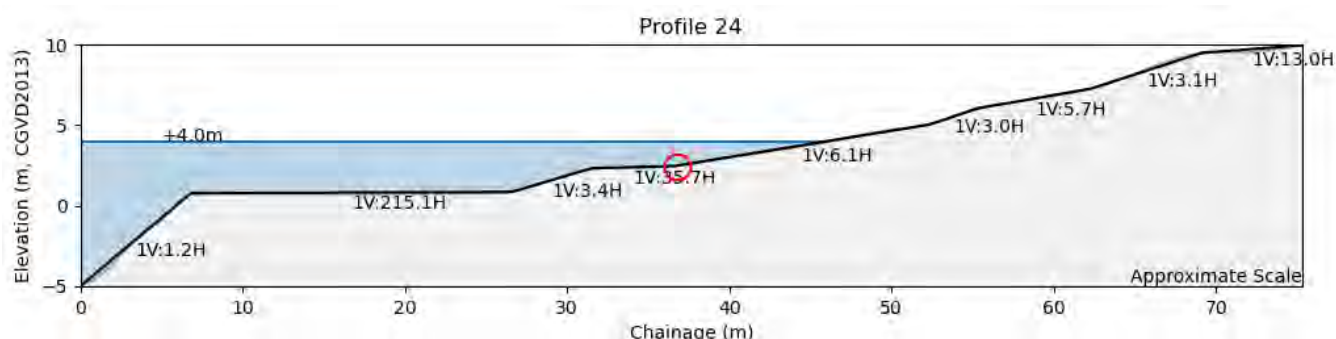


Figure 4.5 Gently Sloping Profile – Profile 24

The offshore waves are transformed to the toe of the structure using FUNWAVE-TVD, which results in a significant wave height and mean wave period at the toe approximately equal to 0.45 m and 2.8 s, respectively. Following the wave runup guidelines outlined in EurOtop (2018), the resultant $R_{2\%}$ runup is +0.67 m. Figure 4.6 outlines the $R_{2\%}$ runup result from the FUNWAVE-TVD model, which is +0.65 m. This result demonstrates that for gently sloping profiles with clear toe locations, both EurOtop (2018) and FUNWAVE-TVD give similar wave runup results.

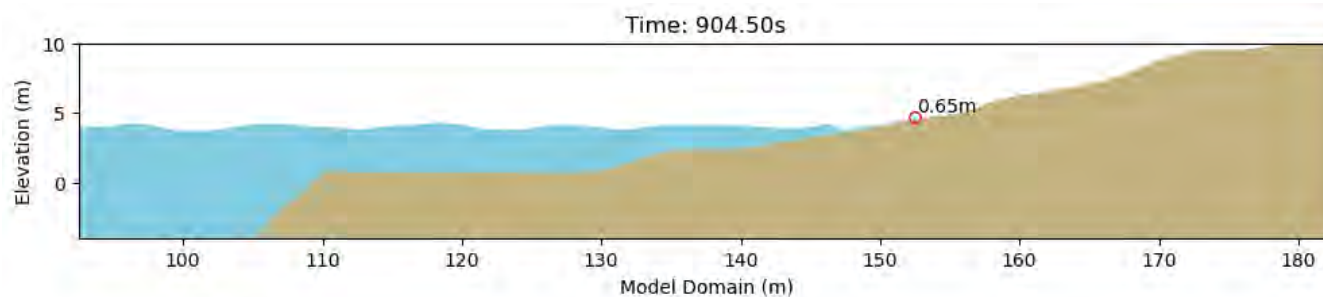


Figure 4.6 Gently Sloping Profile – Profile 24 $R_{2\%}$ FUNWAVE-TVD Result

4.3.2 Steep Profile

Profile 7, depicted in Figure 4.7, represents a steep sloping profile with a slope of approximately 2H:1V. From the MIKE21 SW model results, the offshore wave conditions have a significant wave height of approximately 0.8 m and a peak wave period of approximately 3.0 s. This profile is considered a difficult profile to model using FUNWAVE-TVD, as generally steep slopes require very high model resolution to accurately capture wave runup. However, this profile is simple for applying the EurOtop (2018) empirical formulas, as there is a clear representative slope, similar to the slopes used in laboratory experiments to derive the empirical equations upon which EurOtop (2018) is based. The toe of the structure is circled in red in Figure 4.7.

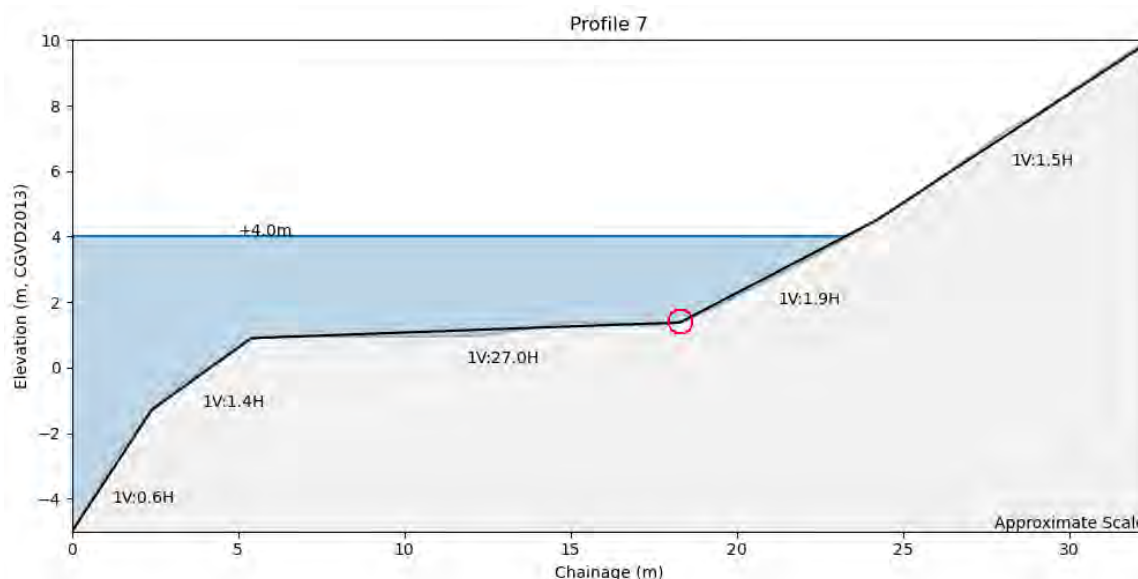


Figure 4.7 Steep Sloping Profile – Profile 7

The offshore waves are transformed to the toe of the structure using FUNWAVE-TVD, which results in a significant wave height and mean wave period at the toe approximately equal to 0.80 m and 3.1 s, respectively. Following the wave runup guidelines outlined in EurOtop (2018), the resultant $R_{2\%}$ runup is +2.56 m. Figure 4.8 outlines the $R_{2\%}$ runup result from the FUNWAVE-TVD model, which is +1.14 m. This result further enforces that the model has a limitation in capturing runup for very steep profiles, where resolution is limited to maintain computational efficiency.

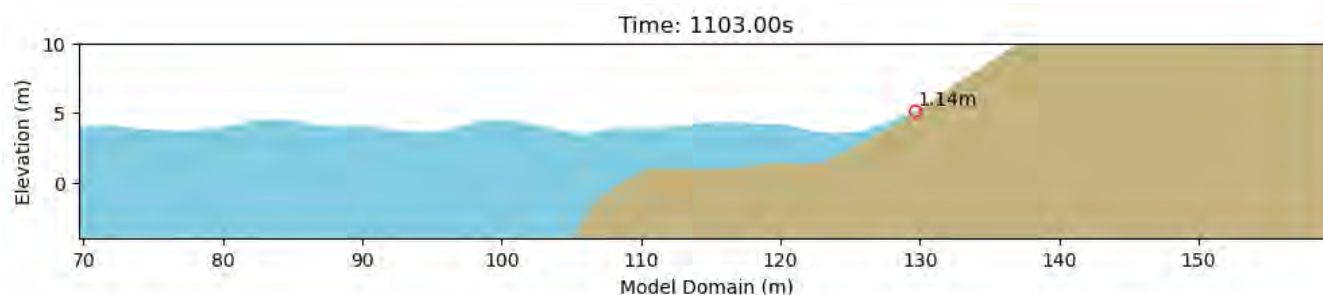


Figure 4.8 Steep Sloping Profile – Profile 7 $R_{2\%}$ FUNWAVE-TVD Result

4.3.3 Shallow Foreshore Profile

Profile 66, depicted in Figure 4.9, represents a shallow foreshore profile with a slope of approximately 112H:1V. From the MIKE21 SW model results, the offshore wave conditions have a significant wave height of approximately 0.8 m and a peak wave period of approximately 3.0 s. This profile is considered a straightforward profile to model using FUNWAVE-TVD but is a complex profile to apply the empirical formulas outlined EurOtop (2018), as these empirical formulations were not developed for shallow foreshore slopes. Further, given that EurOtop (2018) requires a location of the toe, it is difficult to apply EurOtop (2018) as the location of the toe is difficult to distinguish.

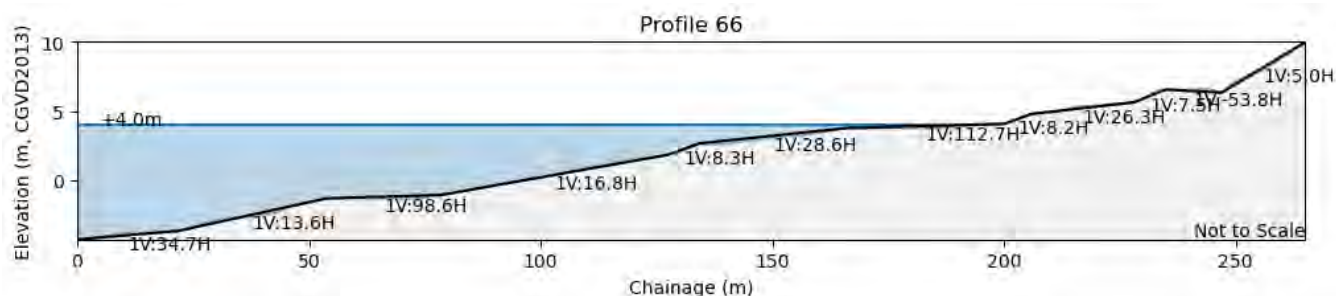


Figure 4.9 Shallow Foreshore Profile – Profile 66

The offshore waves are transformed to the toe of the structure using FUNWAVE-TVD, which results in a significant wave height and mean wave period at the toe approximately equal to 0.41 m and 3.0 s, respectively. Following the wave runup guidelines outlined in EurOtop (2018), the resultant $R_{2\%}$ runup is +0.17 m. Figure 4.10 outlines the $R_{2\%}$ runup result from the FUNWAVE-TVD model, which is +0.22 m. This result demonstrates that the numerical model tends to predict larger wave runup for shallow foreshore profiles when compared to EurOtop (2018).

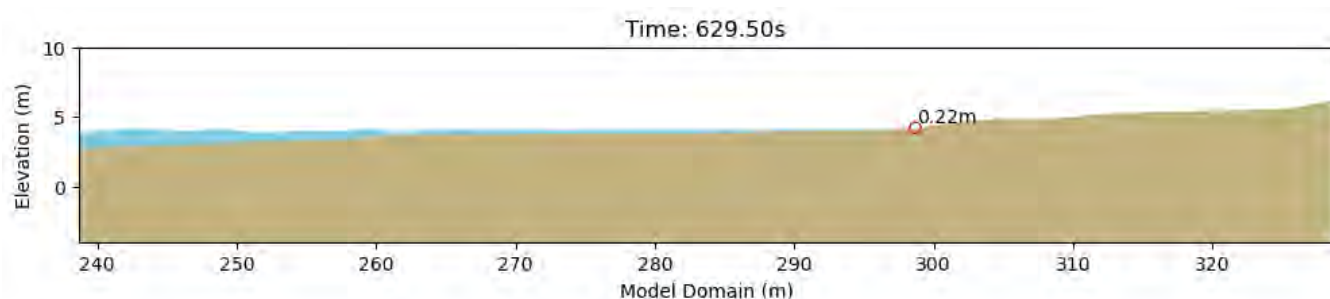


Figure 4.10 Shallow Foreshore Profile – Profile 66 $R_{2\%}$ FUNWAVE-TVD Result

5 Mapping of Coastal Flooding

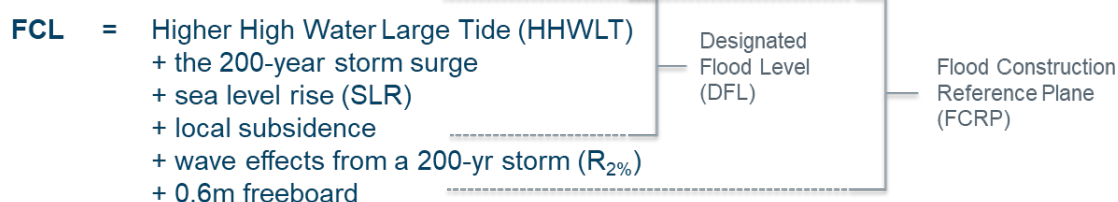
The following chapter describes the process of combining the data and information developed in previous chapters, such as total water levels, relative sea level rise projections, and profile specific wave transformation and runup, to establish and map the Designated Flood Level (DFL) and Flood Construction Level (FCL) along the DNV shoreline. Results are provided for 98 reaches and mapped for presentation purposes.

5.1 Flood Construction Levels

The following project was initiated with DNV's desire to obtain a comprehensive database, map set, and digital archive which maps the Designated Flood Level (DFL) and Flood Construction Level (FCL) along the entire DNV shoreline. In British Columbia, a selection of guidelines and documentation ((APEGBC, 2017) (Ausenco Sandwell, 2011b) (Ausenco Sandwell, 2011a) (Ausenco Sandwell, 2011c)) exist to offer practitioners guidance on establishing the DFL and FCL for coastal regions of British Columbia. In general, two (2) methodologies exist, the additive approach and probabilistic approach (Figure 5.1).

The key difference between the two (2) approaches is that the probabilistic approach combines tidal and storm surge phenomena into a joint total water level, whereas the additive approach treats these components separately. In the absence of long-term observations and numerical modelling tools, it is sometimes necessary to use the simpler additive approach. However, this approach is frequently more conservative and is not fully representative of the joint occurrence of tides and storm surge. Combining the Higher High Water Large Tide (HHWLT) with the 200-year storm surge is unlikely to be representative of a 200-year return period total water level. An assessment of the total water level indicates that the probability of a HHWLT coinciding with a peak storm surge event is statistically lower than 0.5%, and thus combining these components independently is conservative. Along the shorelines of DNV there can be significant variability in nearshore wave propagation, wave runup and storm surge impacts, depending on the stage of the tide, which varies more than 5 meters. Given that sufficient long-term observational data is available within Burrard Inlet and Indian Arm, and that a long-term numerical modeling hindcast approach was adopted by DHI, the more robust and accurate probabilistic approach can be applied here.

Additive Approach



Probabilistic Approach

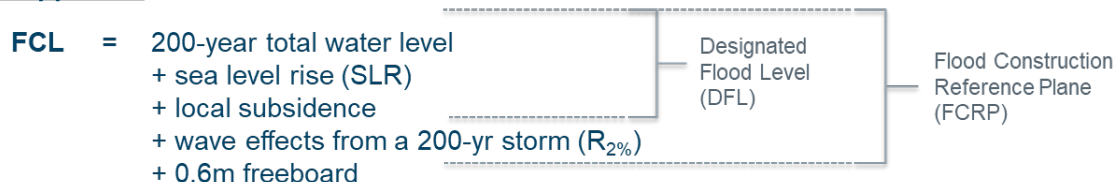


Figure 5.1 Methodologies to define the FCL, DFL and FCRP including key components of each

As illustrated in Figure 5.1, the DFL is the combination of the 200-year total water level, and sea level rise including local adjustments for land-subsidence. The FCL is the DFL inclusive of the 200-year wave effects (defined by $R_{2\%}$) and a 0.60-meter freeboard, which is a standard safety margin presented in Provincial guidance.

For each of the 98 reaches defined along the DNV shoreline, a FCL is defined for the 0.5 m and 1.0 m sea level rise scenario, relative to CGVD2013.

For reference, the FCL values for each reach are presented in a tabular format in Appendix D.3. The reach delineation and position of the profiles at which the FCL has been calculated are presented in the maps in Appendix D.2. These maps also depict the Digital Terrain Model (DTM) upon which FCL and DFL values are projected.

As part of this project, DNV has received Geographic Information System (GIS) compatible shapefiles which delineate the reaches, profiles and associated FCL values for the entire DNV shoreline.

5.2 Mapping Procedure

Three (3) map sets were developed depicting total water levels (Appendix F.2) and the FCL (Appendix F.3 and Appendix F.4), where the 47 km DNV shoreline was divided into 25 map sheets (as depicted in Figure 5.2). Map sheets are presented at a 1:4000 scale for user readability, in accordance with BC flooding guidelines (APEGBC, 2017). The maps utilize the NAD 1983 UTM Zone 10N projection coordinate system and the CGVD 2013 vertical datum.

Each map sheet is comprehensive, including a mapping overview, technical definitions, mapping limitations, data sources, and disclaimers. The set of three (3) map series is included in Appendix E of this report are detailed below:

1. **Total Water Levels:** This series displays the total water levels under baseline conditions as well as under 0.5 m and 1.0 m sea level rise scenarios.
2. **Designated and Flood Construction Levels for 0.5 m Sea Level Rise:** This series illustrates the DFL and FCL inundation limits for a 0.5 m sea level rise across 98 reaches along the DNV shoreline.
3. **Designated and Flood Construction Levels for 1.0 m Sea Level Rise:** This series depicts the DFL and FCL inundation limits for a 1.0 m sea level rise across the same 98 reaches along the DNV shoreline.

All GIS files used to generate the map sets have been transmitted to DNV including relevant metadata and supporting descriptions of data format, type, limitations and usage considerations. A description of how these map sets can be applied is provided in Section 7.1 (Application of the Information Presented in this Report).

One-meter (1.0 m) of sea level rise should be adopted by DNV and qualified professionals for FCL mapping purposes. This sea level rise projection can be used to update coastal flood hazard maps and used to provide general information about coastal processes and flood hazards to coastal property owners and occupants in the project area.

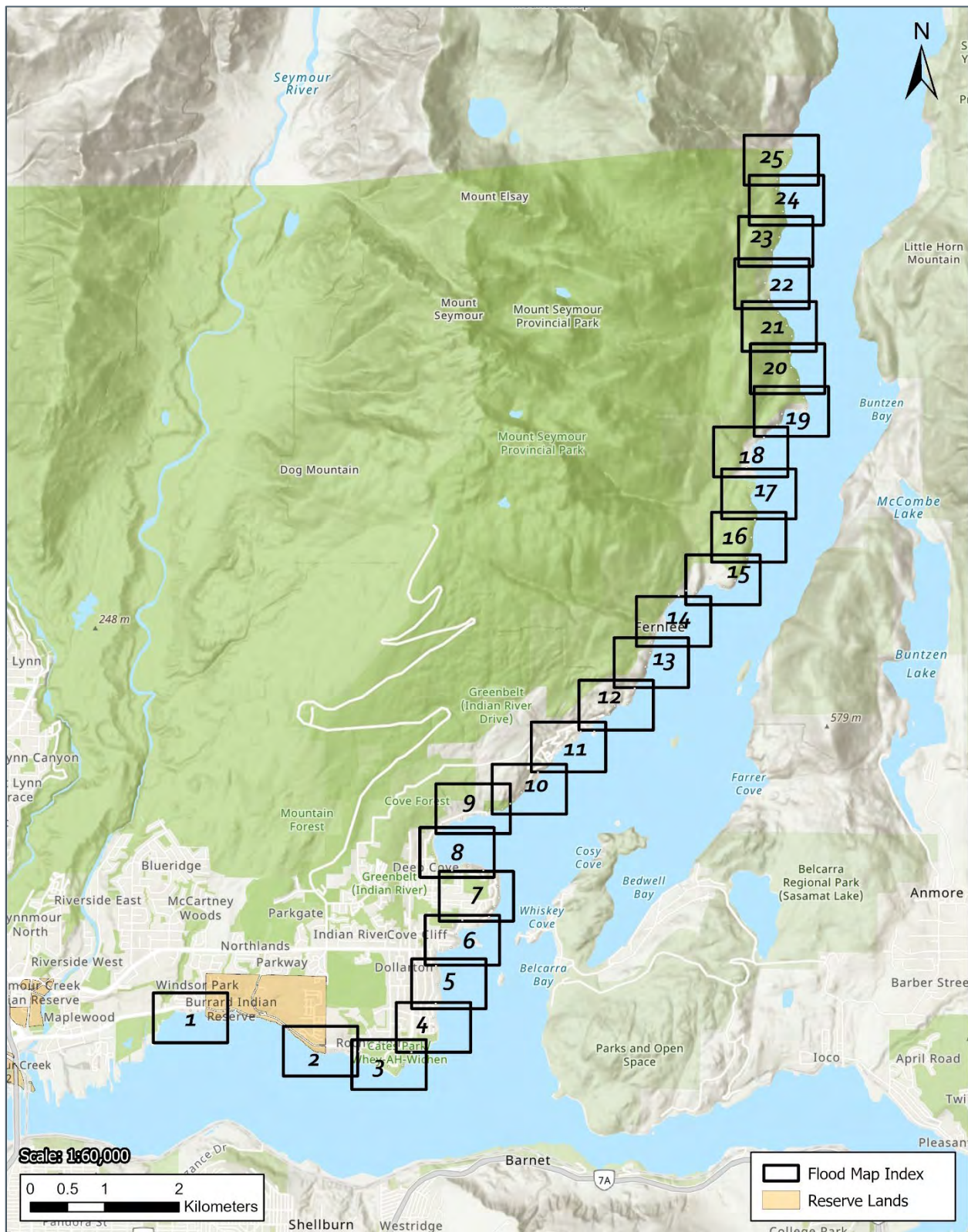


Figure 5.2 Flood Inundation Map Inserts – DNV

5.3 Interpretation of the Mapping Product

A snapshot of the one-meter (1.0 m) SLR FCL mapping product provided in Appendix E is depicted in Figure 5.3, where the following should be noted:

- The designated flood level (DFL) for the 1.0 m SLR scenario is depicted in light blue, where the seaward (i.e., offshore) limit is taken as the elevation of the LLWLT (Table 2.7), denoted by the blue arrow in Figure 5.3. The landward limit of the DFL is projected on the DTM as a contour, denoted by the yellow arrow in Figure 5.3, and is representative of a combination of the 200-year total water level, sea level rise, and local adjustments for land-subsidence.
- The flood construction level (FCL) for the 1.0 m SLR scenario is depicted in light green, where the seaward (i.e., offshore) limit is taken as the landward DFL contour. The landward limit of the FCL, denoted by the red arrow in Figure 5.3, is projected on the DTM as a contour which includes wave effects and freeboard of 0.60 m.
- The shoreline has been segmented into reaches, where reach lengths vary depending on specific shoreline criteria outlined in Section 4.1.1 (Reach and Profile Delineation). Each reach boundary is denoted by light green reach break lines which extend across the FCL polygon starting at the offshore limit of the FCL and extending inland to the landward limit of the FCL.
- The FCL value for each reach is provided in a box between reach lines and is denoted as an elevation in meters (CGVD2013).
- Property boundaries and building footprints are depicted for reference from the DNV GIS database.

Using the mapping products, building set-back and land-use decisions should be made relative to the landward contour of the light green FCL polygon for the 1.0 m sea level rise scenario. This contour is denoted by the red arrow in Figure 5.3. The FCL number demarked in the white boxes for each reach can be applied on an updated and detailed land survey, as required, to further refine the FCL contour relative to a local vertical datum (CGVD2013).

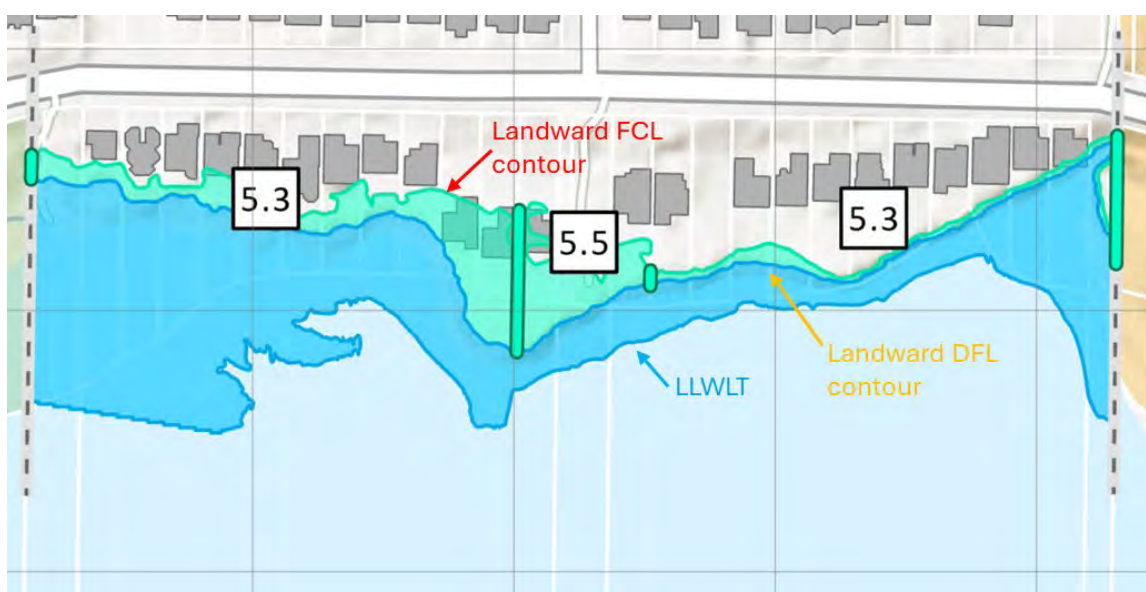


Figure 5.3 Snapshot of the Flood Mapping Product

6 Shoreline Characterization & Erosion Vulnerability within the Context of Flood Mapping

The following chapter provides a qualitative overview and identification of shoreline reaches within the DNV which may be prone to shoreline erosion and instability, within the context of the flood hazard mapping and wave runup assessment completed under this scope of work. A combination of resources, together with anecdotal evidence from DNV staff, were used as lines of evidence to inform the identification of shoreline reaches vulnerable to erosion and shoreline instability. Resources referenced as part of this exercise include literature, historical air photos, imagery collected from site visits, past shoreline classification, the DTM developed as part of this project, and the wave runup assessment. It should be noted that the assessment presented herein is qualitative in nature and that no sediment transport modelling, detailed sediment budgets, or geomorphology analysis were undertaken as part of this scope of work. Vulnerable areas are identified within the context of the flood hazard maps generated under this scope of work. More detailed shoreline erosion risk assessments and quantification of shoreline recession and erosion should be completed on a site-by-site basis.

6.1.1 Geologic History of the Shoreline

The Georgia Depression (i.e., the Salish Sea region) was first formed through a series of large-scale geologic processes and was further modified by successive glacial advances and retreats. With each glaciation, the immense weight of the ice deformed the earth's crust, leading to a rise in sea level relative to the land elevations. These glacial cycles were accompanied by extensive erosion and the deposition of various sediments, including glacial, glaciofluvial, and glaciomarine deposits (Bednarski, 2014). During the intervening periods, the landscape was influenced by fluvial, mass wasting, and marine processes.

The last major glaciation– the Fraser Glaciation– began approximately 26,000 before present (BP), resulting in an extensive ice sheet across the North Vancouver area (Bednarski, 2014). The Fraser Glaciation resulted in extensive deposits of sediments in the study area, including glacial till. Deglaciation occurred around 12,500 BP, leading to the inundation of the North Shore to an elevation of approximately 200 m during the early post-glacial sea period. Deltas formed at valley mouths due to the influx of sediment-laden meltwater from retreating glaciers, but as sea levels fell, these deltas were gradually incised.

The slow rebound of tectonic plates from the glacial weight caused sea levels to drop below their present levels, with sea levels falling to approximately 10 m above present levels by 10,000 BP. Subsequent global scale eustatic effects caused sea levels to rise again within a few meters of present-day levels (Wyatt, 2015).

6.2 Qualitative Interpretation of Shoreline Erosion Risk along the DNV Shoreline

Using the information gathered as part of the coastal flood inundation mapping and wave study, supplemented with additional background data and literature, a qualitative interpretation of shoreline erosion risk is presented in Table 6.1. The potential for shoreline erosion is strongly linked to the shoreline character (sediment size and shape, slope, elevation, orientation, etc.), presence of structures and historical infrastructure development, as well as shoreline exposure to higher-energy waves and storm surges. Historical air photos, background information on coastal processes (as described in the preceding sections), site observations, and the site history are reviewed and coupled to develop a qualitative understanding of potential shoreline erosion risk along the DNV shoreline. The following sources and

references of information were considered as lines of evidence to inform the identification of shoreline reaches vulnerable to erosion and shoreline instability:

- Flood inundation limits under present day and 1.0 m sea level rise scenario (as the FCL) for the 200-year water level;
- Historical airphotos provided by DNV as an orthomosaic for the years 1930, 1946, 1959, 1978, 1989, 1996, 2013 and 2022, as depicted in (Appendix D.1);
- Coastal surface geology information as presented by (Bednarski, 2014);
- Shoreline classification from the Physical Shore-Zone Mapping System (Appendix E.2), developed by the BC Ministry of Environment (Howes, Owens, & Harper, 1995). This system was designed to provide standardized documentation of the physical characteristics of the BC coastline, supporting a variety of resource management applications such as planning, impact assessment, and oil spill response. The methodology employed involves a detailed subdivision of the shoreline into alongshore units and across-shore components, characterized by morphology, substrate, and dynamic physical processes. This approach allows for systematic recording and analysis of shoreline features. This database (CRIMS, 2018) includes attributes such as wave exposure, sediment transport, and shoreline change, facilitating the classification of shore units into 34 standard Shoreline Types based on substrate, sediment, width, and slope.;
- Photos taken along the entirety of the DNV shoreline by DHI during its January 24th, 2024, site-visit (Appendix E.2).; and
- Assessment of satellite imagery and regional mapping products.

Table 6.1 Qualitative Interpretation of Shoreline Erosion Risk along the DNV Shoreline

Map Sheet	Transects	FCL (+1.0 m SLR, CGVD2013)	Shoreline classifications supplemented by observations (Appendix E.2)	Surface Geology (Bednarski, J.M. 2014)	Historical Evolution of the Shoreline based on Air Photo Record (Appendix E.1)	Qualitative Interpretation of Shoreline Erosion Risk
1	87, 88, 89	5.3 m to 5.5 m	- Sand & Gravel Beach - Built Structures	- Intertidal deposits: mostly fine-grained sands, silts, and clays deposited in tidal flats, exposed between mean low water and high-water lines. - Till Blanket: >2 m thick, continuous till cover forming undulating topography that locally obscures underlying units.	Prior to the late 1980s to early 1990s, there was extensive infilling of the intertidal and armouring of the shoreline, especially in the vicinity of the Maplewood Flats. These changes are expected to have rapidly changed sediment transport patterns and sediment availability downdrift along the DNV shoreline. Development in the coastal zone has largely ceased since then, and erosion rates since then are expected to be indicative of those that can be anticipated in the future. The present-day shoreline has some shoreline protection along low-lying areas mainly consisting of rip-rap, revetments and woody debris.	The shore-zone appears to be undergoing slow, chronic erosion, which pre-dates the earliest airphotos. Erosion of the beach face may be slowing due to the remaining beach material being relatively coarse and stable under the mild wave climate. Erosion of fine materials along the shoreline is likely to continue if unprotected.
2	84, 85, 86	5.4 m to 5.5 m	- Sand & Gravel Beach - Sand & Gravel Flat - Built Structures	- Intertidal deposits: mostly fine-grained sands, silts, and clays deposited in tidal flats, exposed between mean low water and high-water lines. - Beach deposits: sand to sandy loam, up to 2 m thick, deposited by waves and currents at the present shoreline. - Till Blanket: >2 m thick, continuous till cover forming undulating topography that locally obscures underlying units. - Anthropogenic deposits. - Outwash terrace deposits: 1 to 10 m thick, forming terraces, perched above modern fluvial deposits.	Air photos indicate that from the 1940s to the 1990s, there was some infilling and construction of jetties along the shoreline for industrial activities. Removal of jetties occurred in the late 2010s accompanied by the installation of shoreline protection (rip-rap and revetment) at Cates landing. Development in the coastal zone has largely been unchanged in the 2020s.	Cates Landing is anticipated to become more vulnerable with rising sea levels. The existing revetment along Cates Landing is anticipated to mitigate shoreline erosion directly at the property, although consequently it may reduce sediment supply downdrift thereby destabilizing the shoreline at Cates Park. The natural shore-zone appears to be undergoing slow, chronic erosion, which pre-dates the earliest airphotos. Erosion of the beach face may be slowing due to the remaining beach material being relatively coarse and stable under the mild wave climate. Erosion of fine materials along the shoreline is likely to continue if unprotected.

Map Sheet	Transects	FCL (+1.0 m SLR, CGVD2013)	Shoreline classifications supplemented by observations (Appendix E.2)	Surface Geology (Bednarski, J.M. 2014)	Historical Evolution of the Shoreline based on Air Photo Record (Appendix E.1)	Qualitative Interpretation of Shoreline Erosion Risk
3	76, 77, 78, 79, 80,81, 82, 83, 84, 85	5.3 m to 6.0 m	- Sand & Gravel Beach - Sand & Gravel Flat - Built Structures	- Intertidal deposits: mostly fine-grained sands, silts, and clays deposited in tidal flats, exposed between mean low water and high-water lines. - Beach deposits: sand to sandy loam, up to 2 m thick, deposited by waves and currents at the present shoreline. - Till Blanket: >2 m thick, continuous till cover forming undulating topography that locally obscures underlying units. - Anthropogenic deposits. - Outwash terrace deposits: 1 to 10 m thick, forming terraces, perched above modern fluvial deposits.	The Cates Park shoreline has remained largely unchanged since the 1960s and 1970s. Since this time the shoreline has experienced mild erosion which has been mitigated with deposits of sand and gravel materials that were placed at two (2) locations within the intertidal area of Cates Park to protect the upland shoreline and headland from erosion.	The southern tip and western shoreline of Cates Park are low lying and vulnerable to inundation, wave action, and high-water levels as demonstrated in the FCL mapping. The shoreline displays signs of chronic erosion and scour at the shoreline embankment caused by wave action. The Cates Park shoreline is amongst the most vulnerable segments of shoreline to erosion in the DNV and will continue to erode at a mild to moderate rate without intervention and maintenance.
4	73, 74, 75, 76, 77, 78, 79	4.9 m to 5.8 m	- Sand & Gravel Beach - Sand & Gravel Flat - Built Structures	- Intertidal deposits: mostly fine-grained sands, silts, and clays deposited in tidal flats, exposed between mean low water and high-water lines. - Till Blanket: >2 m thick, continuous till cover forming undulating topography that locally obscures underlying units.	The shoreline transitioned from industrial activities in the 1930 to urbanization in the 1950s, with significant construction of overwater structures and docks from the 1970s onwards. Shoreline hardening and armouring has continued through to present-day along this stretch of DNV shoreline with relatively little change from the 1990s onwards. This is considered a highly urbanized and hardened shoreline.	FCL values indicate inundation and wave hazards just north of Cates Park along the DNV shoreline. Continuous shoreline protection structures such as revetments and seawalls prevent erosion along most of the shoreline, although local wave induced damages are feasible. For those areas where there is still natural shoreline, it is anticipated that slow, chronic erosion may continue, although likely very mild due to the remaining beach material being relatively coarse and stable.
5	71, 72, 73	5.5 m to 5.7 m				

Map Sheet	Transects	FCL (+1.0 m SLR, CGVD2013)	Shoreline classifications supplemented by observations (Appendix E.2)	Surface Geology (Bednarski, J.M. 2014)	Historical Evolution of the Shoreline based on Air Photo Record (Appendix E.1)	Qualitative Interpretation of Shoreline Erosion Risk
6	64, 65, 66, 67, 68, 69, 70	4.8 m to 5.7 m	- Sand & Gravel Flat - Rock Cliff - Gravel Beach - Built Structures	- Intertidal deposits: mostly fine-grained sands, silts, and clays deposited in tidal flats, exposed between mean low water and high-water lines. - Till Blanket: >2 m thick, continuous till cover forming undulating topography that locally obscures underlying units. - Fluvial Terrace Deposits: >2 m thick, forming inactive terraces above the modern floodplain. - Floodplain deposits: sorted gravel, sand, silt, and organic detritus >1 m thick; channel fill and overbank sediments forming active floodplains. - Mesozoic diorite, granodiorite, and associated rock types of the Coast Crystalline Complex.	The shoreline transitioned from industrial activities in the 1930 to urbanization in the 1950s, with significant densification from the 1980s to the 2010s. Significant presence of overwater structures and docks from the 1970s onwards. Shoreline hardening and armouring has continued through to present-day with relatively little change from the 2010s onwards. Some greenspace maintained at Banbury and Strathcona Lookout Park.	Erosion risk along this stretch of DNV shoreline is generally anticipated to be low to very low, given the relatively sheltered configuration of the shoreline, and the various reaches of bedrock and rocky shoreline. Adjoining shoreline segments with sand and gravel beaches have been hardened with rock revetments and seawalls and are generally not anticipated to erode further. Strathcona Lookout Park is vulnerable to flooding, as indicated in the FCL mapping, due to the low-lying fluvial deposits. Erosion may be occurring locally at Strathcona Lookout Park from both coastal and fluvial processes where some bank protection may be required in the future.
7	97, 96, 95, 61, 62, 98, 63, 64, 65, 66	5.3 m to 7.8 m	- Sand & Gravel Flat - Rock Cliff - Gravel Beach - Built Structures	- Mesozoic diorite, granodiorite, and associated rock types of the Coast Crystalline Complex. - Outwash terrace deposits: 1 to 10 m thick, forming terraces, perched above modern fluvial deposits.	The shoreline remained relatively undeveloped through to the 1960s, at which point urbanization occurred into the 1990s, after which little has changed along the shoreline. Shoreline development opportunities have been limited due to the steep terrain, hard shoreline, and lack of space along the shoreline to develop infrastructure.	Although relatively exposed, erosion risk along this stretch of DNV shoreline is generally anticipated to be very low to negligible, given the elevated rocky shoreline and presence of gravel beaches.

Map Sheet	Transects	FCL (+1.0 m SLR, CGVD2013)	Shoreline classifications supplemented by observations (Appendix E.2)	Surface Geology (Bednarski, J.M. 2014)	Historical Evolution of the Shoreline based on Air Photo Record (Appendix E.1)	Qualitative Interpretation of Shoreline Erosion Risk
8	92, 93, 57, 58, 59, 69, 94	5.2 m to 5.5 m	- Sand & Gravel Flat - Rock Cliff - Rock with Gravel Beach - Built Structures	- Intertidal deposits: mostly fine-grained sands, silts, and clays deposited in tidal flats, exposed between mean low water and high-water lines. - Outwash terrace deposits: 1 to 10 m thick, forming terraces, perched above modern fluvial deposits. - Mesozoic diorite, granodiorite, and associated rock types of the Coast Crystalline Complex.	The community of Deep Cove had some coastal development through the 1930s to the 1950s with an increase in overwater structures, jetties, docks, and other marina infrastructure becoming more prominent through the 1970s to 1990s. Since the early 2000s the shoreline and overwater infrastructure at Deep Cove has not significantly changed.	The gravel beaches, seawall infrastructure and other shoreline protection measures, in addition to the configuration of the cove at Deep Cove, result in a relatively stable shoreline configuration where erosion is anticipated to be very low. Flooding may cause localized damages along the shoreline, although this is anticipated to be relatively minor, as the site is sheltered from higher wave energy found in Indian Arm.
9	54, 55, 56, 92, 94, 57	5.2 m to 6.4 m	- Sand & Gravel Flat - Rock with Gravel - Built Structures	- Intertidal deposits: mostly fine-grained sands, silts, and clays deposited in tidal flats, exposed between mean low water and high-water lines. - Outwash terrace deposits: 1 to 10 m thick, forming terraces, perched above modern fluvial deposits. - Mesozoic diorite, granodiorite, and associated rock types of the Coast Crystalline Complex.	The north shore of Deep Cove began to develop in the 1950s, with significant expansion of marina infrastructure and overwater jetties from the 1970s onwards. Since the early 2000s the shoreline and overwater infrastructure along this section of shoreline has not significantly changed.	The shoreline has considerable development, including many vertical seawalls, as well as natural features such as gravel beaches and rocky outcrops. Together these features are not prone to erosion, and therefore erosion risk in this area is very low. Rising sea levels and projected FCLs may result in some local damages during storm events but are not anticipated to significantly increase erosion risk given the extent of existing shoreline hardening.
10	51, 52, 53, 54	5.6 m to 6.9 m	- Sand & Gravel Flat - Rock with Gravel - Built Structures	- Intertidal deposits: mostly fine-grained sands, silts, and clays deposited in tidal flats, exposed between mean low water and high-water lines. - Mesozoic diorite, granodiorite, and associated rock types of the Coast Crystalline Complex.	This segment of shoreline remained relatively undeveloped until the 1980s when residential properties and shoreline infrastructure such as jetties were introduced along the shoreline. Shoreline development has continued to present-day with some light shoreline protection along low-lying areas mainly consisting of rip-rap, revetments and woody debris.	The bedrock and gravel beaches found along this shoreline appear to be stable. There is little to no evidence of shoreline recession and erosion. Therefore, erosion risk is relatively low. Rising sea levels and projected FCLs may result in some local damages during storm events but are not anticipated to significantly increase erosion risk.

Map Sheet	Transects	FCL (+1.0 m SLR, CGVD2013)	Shoreline classifications supplemented by observations (Appendix E.2)	Surface Geology (Bednarski, J.M. 2014)	Historical Evolution of the Shoreline based on Air Photo Record (Appendix E.1)	Qualitative Interpretation of Shoreline Erosion Risk
11	46, 47, 91, 48, 49, 59, 90,51	5.0 m to 5.9 m	- Sand & Gravel Flat - Rock with Gravel - Built Structures	Bednarski, J.M. (2014) mapping product not available. It is estimated that the shoreline consists of the following surface geology: Intertidal deposits: mostly fine-grained sands, silts, and clays deposited in tidal flats, exposed between mean low water and high-water lines.	Residential development at the Indian River Road wharf has existed since the 1930s (earliest air photo record available for this study) and has increased in density along the shoreline to present day. There is an increased presence of overwater structures and docks from the 1970s onwards. Shoreline protection along low-lying areas mainly consisting of rip-rap and woody debris.	Shoreline erosion risk is very low along the stretches of shoreline with rock outcrops and gravel beaches. There is an outwash and alluvial fan at Indian River Road Wharf consisting of coarse sands and gravels may become mobile at higher water levels, with wave exposure, during storm events. Future FCLs at this location indicate that some local damages and shoreline erosion is feasible occur extreme events that coincide with high water levels.
12	42, 43, 44, 45, 46, 47	5.6 m to 6.8 m	- Rock with Gravel - Rock Cliff	- Mesozoic diorite, granodiorite, and associated rock types of the Coast Crystalline Complex. - Outwash terrace deposits: 1 to 10 m thick, forming terraces, perched above modern fluvial deposits.	Some residential development from the 1950s onward, with more significant shoreline development at Sunshine Falls Ln from the 1960s onwards, including overwater structures and docks, and shoreline protection along low-lying areas consisting of rip-rap and woody debris.	Shoreline erosion risk is very low along the stretches of shoreline with rock outcrops and gravel beaches. There is an outwash and alluvial fan at the end of Sunshine Falls Ln consisting of coarse sands and gravels which may experience some mobility with wave exposure, during storm events at high tide.
13	39, 40, 41, 42	5.6 m to 6.8 m	- Rock with Gravel - Rock Cliff - Sand with Gravel Beach	Bednarski, J.M. (2014) mapping product not available. It is estimated that the shoreline consists of the following surface geology: - Intertidal deposits: mostly fine-grained sands, silts, and clays deposited in tidal flats, exposed between mean low water and high-water lines. - Mesozoic diorite, granodiorite, and associated rock types of the Coast Crystalline Complex.	Air photos indicate that shoreline remains largely undeveloped throughout the 1950s to 1980s. Presently a few properties sit along the shoreline, although these are situated on higher ground given the steep terrain and rocky bluffs along the shoreline.	Shoreline erosion risk can be considered very low to negligible due to the presence of natural rocky cliffs, rocky outcrops, and small gravel pocket beaches that extend along the shoreline.

Map Sheet	Transects	FCL (+1.0 m SLR, CGVD2013)	Shoreline classifications supplemented by observations (Appendix E.2)	Surface Geology (Bednarski, J.M. 2014)	Historical Evolution of the Shoreline based on Air Photo Record (Appendix E.1)	Qualitative Interpretation of Shoreline Erosion Risk
14	33, 34, 36, 38, 39	5.2 m to 7.2 m	- Rock with Gravel - Rock Cliff - Sand with Gravel Beach - Sand and Gravel flat	Bednarski, J.M. (2014) mapping product not available. It is estimated that the shoreline consists of the following surface geology: - Intertidal deposits: mostly fine-grained sands, silts, and clays deposited in tidal flats, exposed between mean low water and high-water lines. - Mesozoic diorite, granodiorite, and associated rock types of the Coast Crystalline Complex. - Outwash terrace deposits: 1 to 10 m thick, forming terraces, perched above modern fluvial deposits.	The air photo record for only partially covers this stretch of shoreline and indicates that there was no significant development at Fernlee prior to the 1960s. At present, there is a small community at Fernlee established on an outwash terrace, with some overwater structures and docks, and shoreline protection along low-lying areas consisting of rip-rap and woody debris.	There is a high degree of shoreline variability within this stretch of shoreline from rocky cliffs to sandy and gravel beaches. There is little evidence of shoreline recession and erosion, and the shoreline can be considered stable. Rising sea levels and projected FCLs may result in some local damages during storm events at Fernlee but are not anticipated to significantly increase erosion risk.
15	30, 31, 32, 33	6.2 m to 7.2 m	- Rock Cliff - Sand and Gravel flat	Bednarski, J.M. (2014) mapping product not available. It is estimated that the shoreline consists of the following surface geology: - Mesozoic diorite, granodiorite, and associated rock types of the Coast Crystalline Complex. - Outwash terrace deposits: 1 to 10 m thick, forming terraces, perched above modern fluvial deposits.	There are no historical air photos of the community at the end of Sasamat Ln. At present this low-lying community sits on an alluvial fan and outwash terrace deposit. One (1) large wharf and several smaller docks have been built along the shoreline. The rest of the shoreline consist of steep rocky cliffs with a vertical face.	Along the rock cliffs of the shoreline there is no shoreline erosion risk. the community at the end of Sasamat Ln. is vulnerable to future sea level rise and flooding as indicated by the FCL analysis, where the sand and gravel beach may experience some mobility with wave exposure, during storm events at high tide. Vegetation further upland may experience inundation, damages and localized erosion during extreme conditions.
16	27, 28, 29, 30	5.2 m to 7.0 m	- Rock with Gravel - Rock Cliff	Bednarski, J.M. (2014) mapping product not available. It is estimated that the shoreline consists of the following surface geology: Mesozoic diorite, granodiorite, and associated rock types of the Coast Crystalline Complex.	There are no historical air photos of this region. At present, there is no shoreline development in this region.	There is no evidence of historical shoreline erosion and/or mobility. The shoreline consists predominantly of static rocky cliffs and rock outcrops.

Map Sheet	Transects	FCL (+1.0 m SLR, CGVD2013)	Shoreline classifications supplemented by observations (Appendix E.2)	Surface Geology (Bednarski, J.M. 2014)	Historical Evolution of the Shoreline based on Air Photo Record (Appendix E.1)	Qualitative Interpretation of Shoreline Erosion Risk
17	25, 26, 27	5.1 m to 6.5 m	- Rock with Gravel Beach - Gravel Beach - Sand and Gravel flat	Bednarski, J.M. (2014) mapping product not available. It is estimated that the shoreline consists of the following surface geology: - Mesozoic diorite, granodiorite, and associated rock types of the Coast Crystalline Complex. - Outwash terrace deposits: 1 to 10 m thick, forming terraces, perched above modern fluvial deposits.	There are no historical air photos of this region. Camp Jubilee is situated on an outwash terrace and has been there since 1935. The foreshore consists of a gravel beach and has one (1) large dock structure to service the camp.	Camp Jubilee is vulnerable to compound alluvial and coastal flooding. The gravel beach and general shoreline configuration appears to be relatively stable. The gravel beach may experience some mobility with wave exposure, during storm events at high tide.
18	21, 22, 23, 24	6.6 m to 5.3 m	- Sand and Gravel flat - Rock Cliff		There are no historical air photos of this region. The community at Thwaytes Landing is situated on an outwash terrace and consists of less than a dozen small buildings and structures, with a few small jetties and docks. The foreshore consists of a sand and gravel beach.	The community at Thwaytes Landing is vulnerable to coastal flooding. The sand and gravel beach appears to be relatively stable and may experience some mobility with wave exposure, during storm events at high tide.
19	17, 18, 19, 20, 21	5.8 m to 6.2 m	Rock Cliff	Bednarski, J.M. (2014) mapping product not available. It is estimated that the shoreline consists of the following surface geology: Mesozoic diorite, granodiorite, and associated rock types of the Coast Crystalline Complex.	There are no historical air photos of this region. At present, there is very little development (i.e., <10 structures) along the shoreline.	There is no evidence of historical shoreline erosion and/or mobility. The shoreline consists predominantly of static rocky cliffs and rock outcrops.
20	14, 15, 16, 17	5.6 m to 7.2 m			There are no historical air photos of this region. At present, there is no shoreline development in this region.	
21	11, 12, 13	6.9 m to 8.2 m	- Gravel Beach - Rock Cliff	Bednarski, J.M. (2014) mapping product not available. It is estimated that the shoreline consists of the following surface geology: - Mesozoic diorite, granodiorite, and associated rock types of the Coast Crystalline Complex. - Outwash terrace deposits: 1 to 10 m thick, forming terraces, perched above modern fluvial deposits.	There are no historical air photos of this region. There is a small collection of cabins situated on an outwash terrace, with a few small jetties and docks. The foreshore consists of a gravel beach.	The shoreline consists predominantly of static rocky cliffs and rock outcrops which are not mobile. The gravel beach in front of the cabins appears to be stable and may experience some mobility with wave exposure, during storm events at high tide.
22	8, 9, 10	6.5 m to 7.0 m				

Map Sheet	Transects	FCL (+1.0 m SLR, CGVD2013)	Shoreline classifications supplemented by observations (Appendix E.2)	Surface Geology (Bednarski, J.M. 2014)	Historical Evolution of the Shoreline based on Air Photo Record (Appendix E.1)	Qualitative Interpretation of Shoreline Erosion Risk
23	6, 7, 8	6.5 m to 7.2 m	Rock Cliff	Bednarski, J.M. (2014) mapping product not available. It is estimated that the shoreline consists of the following surface geology: Mesozoic diorite, granodiorite, and associated rock types of the Coast Crystalline Complex.	There are no historical air photos of this region. At present, there is no shoreline development in this region.	There is no evidence of historical shoreline erosion and/or mobility. The shoreline consists predominantly of static rocky cliffs and rock outcrops.
24	3, 4, 5	6.4 m to 6.8 m				
25	1, 2, 3	7.2 m to 6.4 m				

7 Application of Flood Hazard Maps

This chapter provides guidance on the application of the mapping products and FCL data developed as part of this study. Provincial Guidelines are referenced to illustrate how FCL and mapping products developed as part of this study can be used to inform building setbacks, land use planning strategies, and land use management. Additionally, the 2020 North Shore Sea Level Rise Risk Assessment and Adaptive Management Strategy (KWL, 2020) is referenced to identify which specific objectives and recommendations from the strategy document are satisfied by this study.

7.1 Application of the Information Presented in this Report

The following section briefly outlines how the FCL values mapped along the DNV shoreline can be interpreted and broadly applied by DNV to support sea level rise planning. The guidance is broadly adapted from the B.C. Ministry of Environment Guidelines for Management of Coastal Flood Hazard Land Use (Ausenco Sandwell, 2011b). **The one-meter (1.0 m) sea level rise scenario should be adopted by DNV for FCL mapping purposes. This scenario should be used to update the official DNV coastal flood hazard maps to inform initial planning of building setbacks, land use strategies, and zoning.**

For the year 2100 it is recommended to establish requirements for new buildings to meet FCL and setbacks in accordance with Provincial Guidelines (Ausenco Sandwell, 2011b), or to meet flood protection requirements as established by Qualified Professionals.

7.1.1 Building Setbacks from the Sea

As stated in Provincial Guidelines (Ausenco Sandwell, 2011b), SLR will have the long-term effect of moving the Natural Boundary²² landward in un-diked areas. As sea levels rise, the landward migration of the Natural Boundary will have significant implications for both infrastructure and ecosystems along the DNV shoreline. Low-lying areas and gently sloping shorelines will be particularly vulnerable to increased coastal erosion and habitat shifts. This could lead to the loss of important ecological buffers, reducing their ability to absorb storm surge impacts and protect inland areas. For infrastructure, the gradual encroachment of the sea may increase the frequency of coastal flooding, damage roadways, and compromise underground utilities in exposed areas. In the absence of dikes or engineered protections, drainage systems may become overwhelmed, requiring upgrades to stormwater infrastructure, outfalls, and potential drainage pump stations to manage inland water levels.

Given these challenges, DNV will need to consider a long-term adaptation strategy, balancing setback requirements, nature-based solutions (e.g., living shorelines, wetland restoration), and potential hard engineering options such as dikes or seawalls in highly vulnerable areas. A feasibility study could assess whether engineered interventions—such as managed retreat, elevated infrastructure, or selective dike construction—are necessary to mitigate long-term risks while preserving natural coastal dynamics.

It is noted that the Natural Boundary is an established concept in BC law— and reflects a change in vegetation and soil based on effects of the sea. All of the DNV is un-diked, and therefore the natural

²² Means the visible high watermark of any lake, river, stream or other body of water where the presence and action of the water are so common and usual and so long continued in all ordinary years as to mark upon the soil of the bed of the lake, river, stream or other body of water a character distinct from that of the banks thereof, in respect to vegetation, as well as in respect to the nature of the soil itself (Land Act, Section 1). In addition, the natural boundary includes the best estimate of the edge of dormant or old side channels and marsh areas. For coastal areas, the natural boundary shall include the natural limit of permanent terrestrial vegetation.

boundary will continue to move landward along the entire DNV shoreline. This effect is more pronounced on gently sloping shorelines or low coastal benches than in steeper shoreline terrain or where bedrock is present. Where lands are to remain un-diked, setbacks for buildings from the sea must anticipate Sea Level Rise (SLR) for the lifespan of the building. Building Setback should be established as **‘the greater of 15 m from the Future Estimated Natural Boundary²³ or a distance to where the native land elevation equals the Flood Construction Level’**. This setback would apply to non-erodible bedrock cliffs as well as other shoreline types.

Although the Natural Boundary can be used as a measure to define building setbacks, it is often difficult to quantify. In coastal areas, the Natural Boundary reflects a snapshot historical record of tide, storm surge and wave runup effects, which may be the mark of a recent storm in an ordinary year, or it may be the mark of the most severe storm in recent times. **Therefore, it is recommended to avoid use of the Natural Boundary, and to instead adopt the FCL to establish building setbacks within the DNV.** There is a more consistent methodology and greater technical basis to apply the FCL consistently. Although the FCL values in each reach can be used as a basis for establishing building setbacks, it is strongly recommended to verify the FCL contour using an updated site-specific survey and interpretation of the FCL by a qualified professional on a case-by-case basis. Applicant supported studies by Qualified Professionals should be used to customize building “setback” based on coastal risk assessments that consider how SLR combined with wave action and coastal geomorphology may alter shoreline locations, shape and backshore erosion. Guidelines for location of buildings should be based on these planning studies and the expected life of the at-risk asset.

7.1.2 Land Use Planning Strategies

Beyond concerns about individual buildings, the long-term nature of SLR provides an opportunity to minimize risks and impacts by land use planning strategies. During planning for land use and development, mapping and planning strategies for SLR Planning Areas can minimize costs and hazards for both public and private landowners/insurers. To facilitate land use planning for SLR it is important to establish the future FCL allowances for Year 2100 using the FCL lines on detailed contour maps developed as part of this study. **The SLR Planning Area lines will be, in effect, contour lines representing allowances for the FCL levels in Year 2100. These have been defined as part of this study.**

Development should occur outside the SLR Planning Area, to avoid risks associated with SLR. Increases in SLR will gradually move the natural boundary landward. Land use in the area that will be inundated in the future should be managed to adjust to the change in shoreline and to the increased risk of sea flooding during the Designated Storm²⁴. Uses such as agriculture, parks, open space and limited industrial or short-term uses would be preferred. Where coastal defenses or existing rock geology stops the shoreline from moving, intertidal areas and their associated ecosystems are at risk of being squeezed out. SLR Planning should consider what areas of land should be set aside to allow migration of coastal ecosystems, or to support ecosystem restoration or habitat banking. Land managers may decide to protect some parts of a SLR Planning Area by building a new dike or placing landfill to meet FCLs. If dikes are used as protection, such areas must meet the requirements of the “Sea Dike Guidelines 2010” (Ausenco Sandwell, 2011c).

In general, the recommended planning approach is to set an FCL based on a precautionary principle and a reasonably long building lifespan (i.e., 100 years) and then allow those applicants that need to challenge these FCLs to commission studies by a qualified professional to consider the

²³ The Future Estimated Natural Boundary (FENB) is the predicted location of the future Natural Boundary as the result of sea level rise. Setbacks for future new buildings should move inland with the Future Estimated Natural Boundary to preserve the protection that exists at the shoreline. Provincial guidelines suggest that calculation of the Future Estimated Natural Boundary can be based on the Flood Construction Level minus the Freeboard allowance.

²⁴ A storm, which may occur in any given year, of such a magnitude as to equal a storm having the designated annual exceedence probability (AEP) of 0.50%.

science and site conditions and recommend a site-specific and structure-specific FCL. In these cases, a covenant on the Land Title of the property would provide notice on the allowances and restrictions on the land and its structures. Additionally, the covenant would give notice that future FCL levels may vary depending on future SLR projections.

7.1.3 Land Use Management Tools

Tools that the DNV can use to apply land use strategies include:

- Official Community Plans- hazard land identification and SLR Planning Area designation;
- Zoning bylaws - “risk zoning”;
- Section 910 Flood Plain Bylaw;
- Official Community Plan Development Permit Area for Protection of Development from Hazardous Conditions- guidelines and requirements for developing in hazard areas;
- Restrictive covenants;
- Public education- about the hazards and ways that individuals can address them; and
- Early warning and emergency preparedness programs.

7.2 North Shore Sea Level Rise Strategy

The wave study and mapping effort presented herein inform and support the recommendations presented in the 2020 North Shore Sea Level Rise Risk Assessment and Adaptive Management Strategy (KWL, 2020). The strategy provides six (6) action items, where this report supports four (4) of these, including:

- **Action 2: Continue to Build Knowledge about the Impacts of Sea Level Rise**
 - o This study supports several of the recommended additional monitoring, studies, and analysis outlined in the strategic document, including but not limited to:
 - Wave modelling to address knowledge gaps;
 - Local sea level rise and wave monitoring; and
 - Shoreline erosion screening assessment to identify areas with highest vulnerability to sea level rise and vessel traffic.
- **Action 3: Establish Comprehensive Adaptation Plans in Collaboration with Partners**
 - o This study provides a technical basis to inform future adaptation plans and strategies within the DNV to manage the risks associated with sea level rise. The data and maps presented herein are of sufficient detail and quality to inform risk assessments, adaptive management strategies, schematic design of adaptation measures, and indicative financial planning and costing of adaptation measures.
- **Action 4: Integrate Findings from this Strategy into Community-wide Flood Management Initiatives**
 - o This study provides updated coastal flood construction levels (FCLs) and setbacks which can be incorporated into future floodplain regulation tools such as floodplain bylaws or development permit areas (DPAs).
 - o The information in this study can be used to support the following recommendations from the strategy:
 - Revise long-term avoid and retreat approaches into land-use planning as part of official community plan and local area plan updates;

- Incorporate findings and adaptation measures into asset management (water, wastewater, drainage) and/or natural asset management plans;
 - Update climate change adaptation strategies;and
 - Incorporate coastal flood mapping (current sea level) into emergency management and response plans.
- **Action 5: Continue to Build Public Awareness about Coastal Flooding and Sea Level Rise**
 - o This study provides information that can be used to support engagement with public and key community groups within DNV about sea level rise risks and adaptation planning. The strategy suggests that ongoing engagement should aim to build community understanding of sea level rise impacts and refine an understanding of the key values and priorities that inform the development of tailored adaptation approaches within each community.

8 Study Conclusions

This chapter outlines key recommendations and next steps for managing coastal flood risks in the District of North Vancouver based on the findings of the study. Key recommendations include reviewing sea level rise projections and flood construction levels every ten years, integrating updated FCLs into floodplain regulations, land-use planning, asset management, and emergency response plans. The study's limitations note that the data is for planning purposes only and does not account for fluvial or pluvial flooding, erosion, or localized site-specific factors. Site-specific assessments are recommended for critical infrastructure and new developments. The findings support DNV's coastal resilience efforts, including the 2020 North Shore Sea Level Rise Risk Assessment, and provide essential data for flood hazard management and community engagement.

8.1 Proposed Next Steps

Based on the outcomes and findings of this study, it is recommended to consider the following next steps:

- SLR projections and related FCL requirements should be reviewed every 10 years at a minimum. The guidelines and requirements in SLR Planning Areas will need to be reviewed in these same intervals, with a focus on updating FCL elevation requirements, which may move up or down as projections for SLR become more accurate.
- Use the existing study to incorporate updated coastal flood construction levels (FCLs) and setbacks for future development into floodplain regulation tools such as floodplain bylaws or development permit areas (DPAs).
- Consider incorporating long-term avoid and retreat approaches into land-use planning as part of official community plan and local area plan updates.
- Incorporate FCL values developed as part of this study into asset management (water, wastewater, drainage) and/or natural asset management plans.
- Update climate change adaptation strategies to reflect the findings from this study.
- Incorporate the coastal flood mapping developed in this report into emergency management and response plans.
- Use the information presented in this report to inform and support stakeholder engagement and dialogue with the community, partners and government.

8.2 Study Limitations

The following should be noted by DNV when using the data supplied by DHI as part of this study:

- This data was prepared for DNV for the purposes outlined in this document. The material and information in the document reflect the opinion and best judgment of DHI Water & Environment, Inc. based on the information available at the time of preparation. Any use of this document, the data provided under this study, or reliance on its content by third parties is the responsibility of the third party. DHI Water & Environment, Inc. accepts no responsibility for any damages suffered as a result of third-party use of this document or for uses other than the intended purposes stated herein.
- Inundation limits are based on consideration of coastal processes only and do not incorporate flooding from pluvial and fluvial sources.

- Users must note the dates of base mapping, aerial photography, ground or bathymetric surveys and issue of mapping relevant to dates of development in the map area. Subsequent developments or changes within the floodplain or channel will affect flood levels and render site-specific map information obsolete.
- Under the provisions of the Flood Hazard Statutes Amendment Act, 2003 (Bill 56), local governments have the role and responsibility for making decisions about local floodplain development practices, including decisions about floodplain bylaws within their communities. Information on floodplain management guidelines can be found in the BC Flood Hazard Area Land Use Management Guidelines.
- The accuracy of the location of a floodplain boundary as shown on this map is limited by the base topography.
- The floodplain limits are not established on the ground by legal survey. A site survey is required to reconcile property location, ground elevations and designated flood level information.
- Erosion, riverine hazards and overland flood effects are not included.
- Results and mapping are appropriate and applicable on a reach-scale, for planning purposes only. Detailed site specific (i.e. lot level) FCL studies are highly recommended, as required, on a case-by-case basis to refine FCL limits for infrastructure specific purposes.
- It is important and necessary to conduct site-specific studies for critical infrastructure or new developments, and to establish dedicated FCL values for these sites using locally collected and new data and analysis. This process will address site-specific risks pertinent to critical or new infrastructure not addressed as part of this regional study.

8.3 Closing

This report outlines the development of coastal flood inundation maps that include wave effects. The maps are intended to be a reference document for the DNV and qualified professionals to establish, or assist in establishing, site-specific FCLs and setbacks to help ensure the risks associated with coastal flooding and erosion are mitigated in the design and construction of new development.

A set of 25 map sheets was developed with 98 individual shoreline reaches at which the DFL and FCL were characterized for the 0.5 m and 1.0 m sea level rise scenarios. The mapping results were combined with existing literature, air photos, and site surveys, which allowed for a comprehensive characterization of shoreline erosion vulnerability within the flood mapping context. The work presented in this report feeds into a broader program and initiative by DNV to obtain foundational knowledge about coastal flooding and erosion risks along the DNV shoreline, advance multiple recommendations in the 2020 North Shore Sea Level Rise Risk Assessment and Adaptive Management Strategy, and to inform coastal property owners and occupants about the wave modeling study's purpose and the updated flood hazard maps.

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Appendix A. Digital Data Transfer

As part of this project, DHI delivered a comprehensive data package in GIS format for DNV to map the Total Water Level, DFL and FCL along the DNV shoreline. Table A.1 summarizes the GIS data files, all of which were processed and developed in ArcGIS Pro 3.2.0. The project uses NAD 1983 UTM Zone 10N as the coordinate system and CGVD 2013 as the vertical datum for all delivered data. The data package includes additional datasets sourced from the DNV open data portal²⁵.

Table A.1 A Summary of the GIS Data Delivery

Data Product Name	Data Description	Data Projection	File Name & Type
Buildings	Detailed footprints of all buildings within the study area.	NAD 1983 UTM Zone 10N	Buildings (Polygon Shapefile)
Mapping Extent	Lines to mark the extent of the water levels mapped in this study.	NAD 1983 UTM Zone 10N	Mapping Extent (Line Shapefile)
Park Lands	Geographic boundaries and extents of parklands within the study area.	NAD 1983 UTM Zone 10N	Park Lands (Polygon Shapefile)
Property Lines	Delineations of property boundaries.	NAD 1983 UTM Zone 10N	Property Lines (Line Shapefile)
Reach Lines	Reach lines mark the extent of inundation limits where Flood Construction Levels (FCL) and Designated Flood Levels (DFL) are applicable along the shoreline. For additional information please consult the accompanying DHI report and reported FLC and DFL values per reach. The process to identify the reach lines, and their extents, is described in Chapter 4.1.1.	NAD 1983 UTM Zone 10N	Reach Lines (Line Shapefile)
Reserve Lands	Boundaries and extents of reservation lands.	NAD 1983 UTM Zone 10N	Reserve Lands (Polygon Shapefile)
Total Water Level 200-year	The Total Water Level 200-Year Shapefile delineates the inundation boundaries for a 200-year return period total water level, with extents of the polygon from the Lowest Low Water Large Tide (LLWLT) offshore to the upper inundation limits. This shapefile provides a spatial representation of potential flood extents under varying sea level conditions.	NAD 1983 UTM Zone 10N, CGVD2013	Total Water Level 200-year CGVD2013 (Polygon Shapefile)
Total Water Level 200-year for 0.5 m Sea Level Rise	The Total Water Level 200-Year for 0.5 m Sea Level Rise Shapefile delineates the inundation limits for a 200-year return period total water level, under 0.5 m sea level rise, providing a spatial representation of potential flood extents with sea level rise.	NAD 1983 UTM Zone 10N, CGVD2013	Total Water Level 200-year for 0.5 m Sea Level Rise CGVD2013 (Polygon Shapefile)
Total Water Level 200-year for 1.0 m Sea Level Rise	The Total Water Level 200-Year for 1.0 m Sea Level Rise Shapefile delineates the inundation limits for a 200-year return period total water level, under 1.0 m sea level rise, providing a spatial representation of potential flood extents with sea level rise.	NAD 1983 UTM Zone 10N, CGVD2013	Total Water Level 200-year for 1.0 m Sea Level Rise CGVD2013 (Polygon Shapefile)
Designated Flood Levels	The Designated Flood Levels Shapefile comprises a polygon delineating inundation limits from the Lowest Low Water Large Tide (LLWLT) offshore to the upper extents of the Designated Flood Level (DFL).	NAD 1983 UTM Zone 10N, CGVD2013	Designated Flood Levels CGVD2013 (Polygon Shapefile)

²⁵ <https://geoweb.dnv.org/data>

Data Product Name	Data Description	Data Projection	File Name & Type
Flood Construction Levels for 0.5 m Sea Level Rise	The Flood Construction Levels for 0.5 m Sea Level Rise Shapefile consists of polygon delineating inundation limits from the offshore Lowest Low Water Large Tide (LLWLT) to the upper extents of inundation. This shapefile identifies the upper extent of inundation for 98 reaches along the DNV shoreline. Each reach has an associated specific Flood Construction Level (FCL), determined by the local wave dynamics. For additional information please consult the accompanying DHI report and reported FLC and DFL values per reach.	NAD 1983 UTM Zone 10N, CGVD2013	Flood Construction Levels for 0.5 m Sea Level Rise CGVD2013 (Polygon Shapefile)
Flood Construction Levels for 1.0 m Sea Level Rise	The Flood Construction Levels for 1.0 m Sea Level Rise (SLR) Shapefile comprises polygons that outline the inundation limits from the offshore Lowest Low Water Large Tide (LLWLT) to the upper extents of inundation for 1.0 m SLR scenario. For additional information please consult the accompanying DHI report and reported FLC and DFL values per reach.	NAD 1983 UTM Zone 10N, CGVD2013	Flood Construction Levels for 1.0 m Sea Level Rise CGVD2013 (Polygon Shapefile)
GIS Data Layer Package	The "GIS Data Transfer - District of North Vancouver" is an ArcGIS Pro layer package file. This comprehensive package includes all the above-mentioned GIS files for mapping.	-	GIS Data Transfer - District of North Vancouver (*.lpx file)

Appendix B. Bathymetric Data

Appendix B.1 Bathymetric Data Sources

Bathymetric data is sourced from the Canadian Hydrographic (CHS) non-navigational (NONNA) data repository, complemented with publicly available bathymetric and topographic LiDAR datasets from the Government of British Columbia. Details on each dataset are described in Table B.1 and the coverage illustrated in Figure B.1.

Table B.1 Model Bathymetry sources, Datums and Resolution

*Only to fill in the Maplewood flats area

Name	Date of Survey	Source	Vertical & Horizontal Datum	Resolution (m)
NONNA	No specific date available.	Gathered from NONNA's website	Chart Datum & WGS84	10
*LiDAR-BC	2016	Gathered from LiDAR BC website	CGVD2013 & NAD83 UTM 10N	1

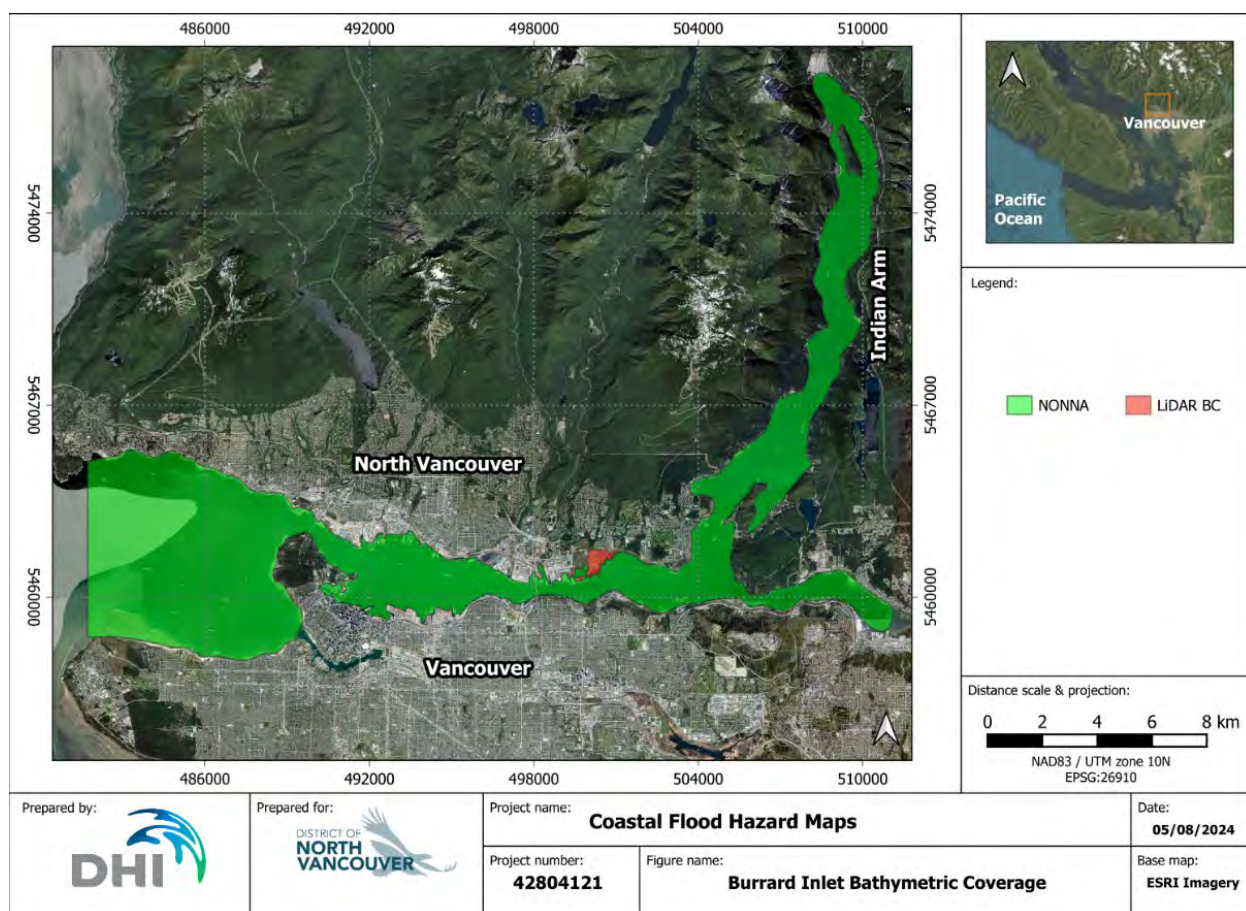


Figure B.1 Bathymetric Coverage Data Sources

Appendix B.2 Datum Correction and Bathymetric Interpolation

The tide stations and the vertical distance of the benchmarks to the different datums are presented in Table B.2, while their locations within Burrard Inlet are illustrated in Figure B.2. The differences between the GPS-H conversion and the benchmarks do not exceed 1 cm.

The final bathymetry map and the datum correction for CGVD28 and CGVD2013, are presented in Figure B.3.

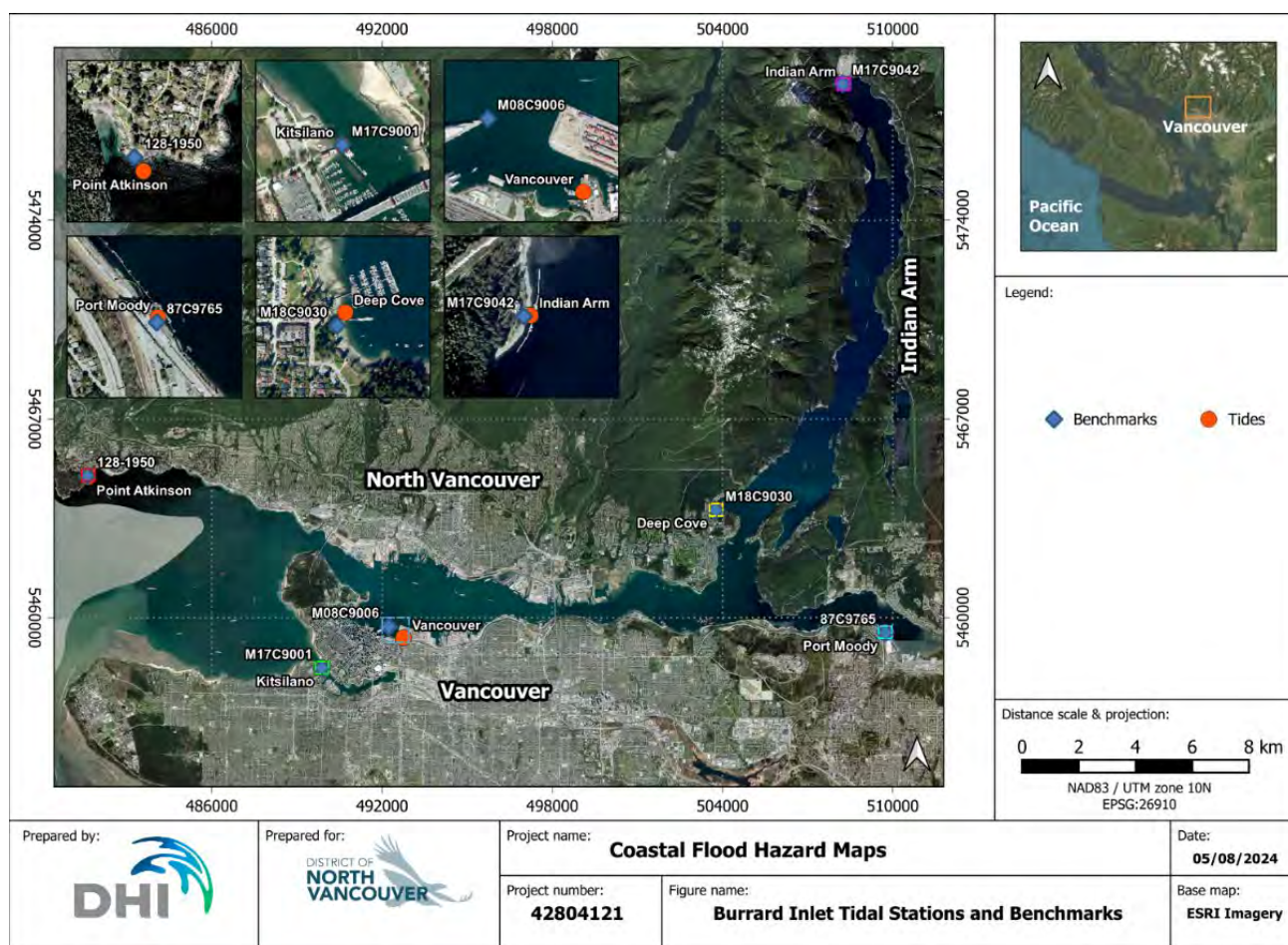


Figure B.2 Tidal Stations and Benchmarks for Datum Corrections

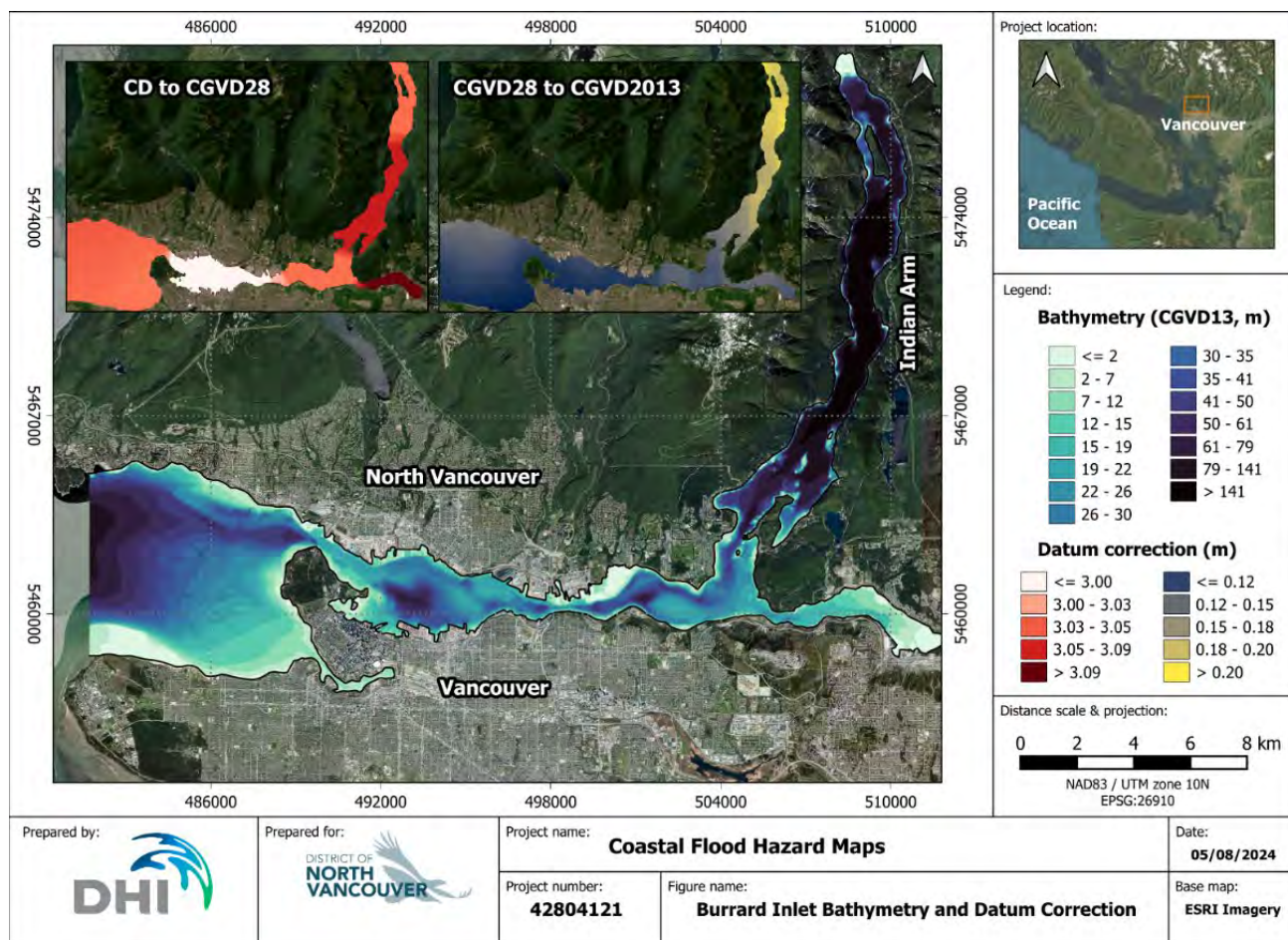


Figure B.3 Bathymetric Interpolation and Maps of Datum Corrections

Table B.2 Tidal Stations, Datums and Corrections
Coordinates in UTM 10N NAD83

Station	Coordinates (m)	CGVD2013 (m)	CGVD28 (m)	CD (m)	CGVD28-2013 (m)	GPS-H (m)
Point Atkinson	481620E 5464950N	4.44	4.28	7.34	0.16	0.17
Kitsilano	489871E 5458225N	3.68	3.56	6.61	0.11	0.12
Vancouver	492750E 5459288N	4.13	4.02	7.02	0.12	0.13
Port Moody	509744E 5459481N	3.19	3.05	6.17	0.14	0.15
Deep Cove	503778E 5463809N	2.75	2.60	5.69	0.15	0.16
Indian Arm	508254E 5478800N	3.66	3.46	6.51	0.20	0.20

Appendix C. Regional Numerical Modelling of Coastal Processes

Appendix C.1 Characterization of Local Atmospheric Conditions

The following appendix outlines the development of a long-term wind record for use in the study. An extreme-value-analysis is conducted for application in the numerical modelling of waves and wave runoff.

Appendix C.1.1 Meteorological Stations

A summary of the meteorological stations considered for the study is presented in Table C.1.

Table C.1 Wind Data Sources
Coordinates in UTM 10N NAD83

Data Name	Coordinates	Resolution	Date	Source
Point Atkinson - 844	480744E 5464180N	1 hr	1996 - 2024	CCCS
YVR - 51442	486884E 486884N	1 hr	1953 – 2024	CCCS
IMAPLE25	500000E 5461917N	5 min	2022 – 2024	Wunderground
INORTH193	508710E 5469706N	5 min	2020 – 2024	Wunderground
INORTH428	503634E 5461919N	5 min	2022 – 2024	Wunderground

Appendix C.1.2 Adapted Long-term Wind Record for Use in the Study

To generate a sufficiently long wind time series to derive extreme conditions for use in the wave model, the YVR measurements were merged with those from Point Atkinson and adjusted to standardize them to 10 m, making them comparable (Figure C.1). This dataset provides an adequate long-term regional description and record of atmospheric conditions, under the assumption that all the strong winds captured by the Point Atkinson station are also captured by the YVR station due to their relative proximity.

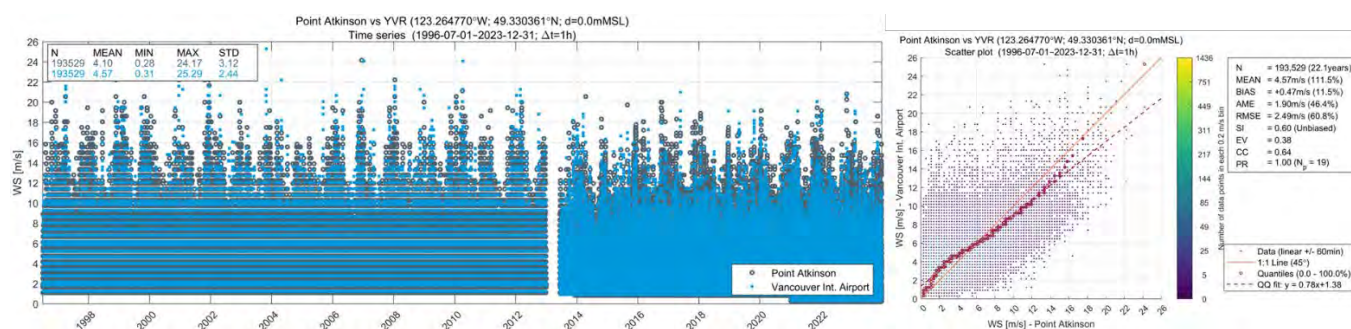


Figure C.1 Wind speed comparison between Point Atkinson station and height corrected Vancouver International Airport station (YVR)

Considering the variability of the winds within the Inlet and after analyzing the local observations (section 2.3.1 – Wind Variability within Burrard Inlet & Indian Arm), it was decided to use the INORTH193 station as representative of the Inlet, due to its higher wind intensities and a less sheltered location compared to the

other two stations analyzed (IMAPLE25 and INORTH428), which results in a more conservative and thus a more appropriate scenario.

A scaling factor was applied to the long-term regional record of atmospheric conditions described previously, to derive conditions representative of Indian Arm. This was achieved by reducing the energy from the long-term station by approximately 30%. As a result of this adjustment, the bias decreased from 1.07 m/s to 0.10 m/s. The result of the adjustment is depicted in Figure C.2, where the lower panel depicts the original comparison between wind magnitudes at Point Atkinson and INORTH193, while the upper panel illustrates the scaled Point Atkinson wind magnitude, which more closely correlates with wind magnitudes observed at INORTH193. For the purposes of this study, the final dataset is referred to as the long-term Indian Arm wind timeseries.

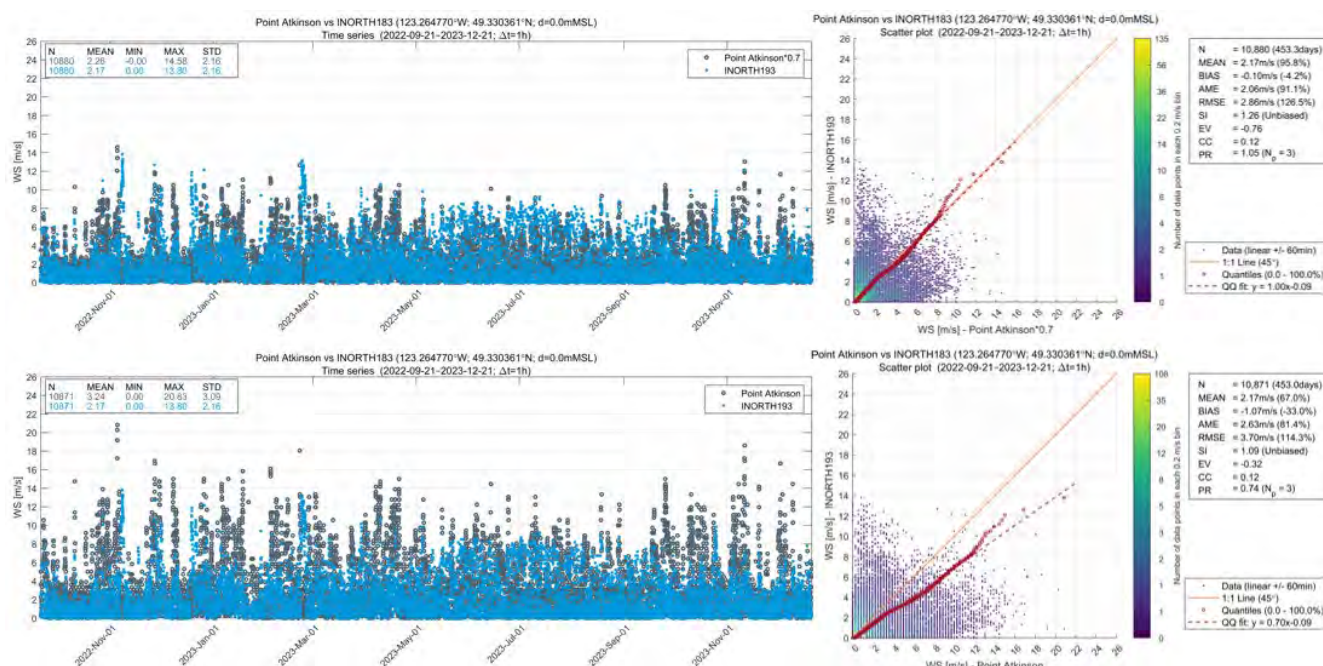


Figure C.2 Wind speed comparison between corrected Point Atkinson station and INORTH193 station (top), and the uncorrected (bottom)

Appendix C.1.3 Extreme Value Analysis – Additional Results

Following the approach of the extreme value analysis carried out on water levels (Section 2.4 – Characterization of Water Levels), projections were also estimated for different return periods for the wind, using the long-term Indian Arm wind timeseries (i.e., scaled Point Atkinson winds). The result of the omnidirectional analysis is presented in Table C.2, while the distribution and fitting are shown in Figure C.3.

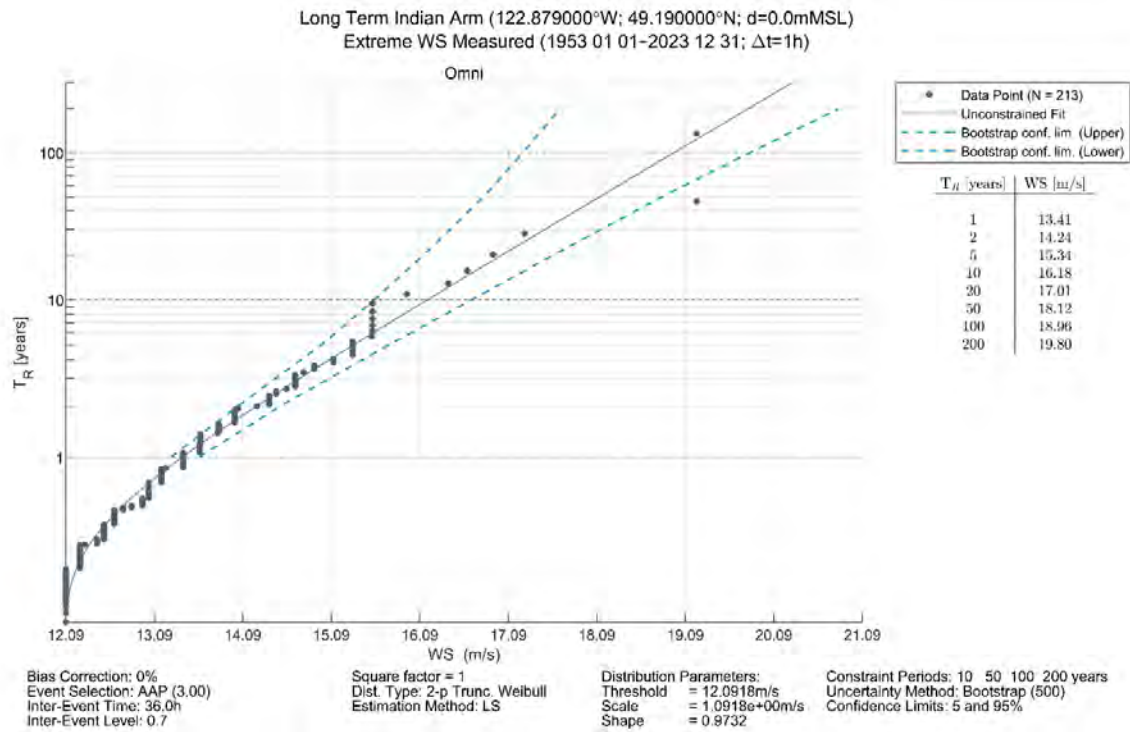


Figure C.3 Omni-Directional Wind Speed Extreme Value Analysis at Indian Arm 1953 to 2023

Table C.2 Omni-Directional Extreme Value Analysis and Confidence Limits at Indian Arm 1953 to 2023

WS (m/s)	Return Period (Years)							
	1	2	5	10	20	50	100	200
Omni Lower bnd	13.46	3.96	14.55	15.04	15.48	15.99	16.35	16.69
Omni Central Est.	13.66	14.28	15.08	15.67	16.26	17.02	17.58	18.14
Omni Upper bnd	13.90	14.59	15.44	16.08	16.71	17.54	18.15	18.78

Appendix C.2 Characterization of Water Levels

Appendix C.2.1 Tidal Stations

The full list of stations used in the analysis and modelling is indicated in Table C.3 while the utilization of this data is described below. Point Atkinson water levels were used to force the model boundaries. Given the proximity between Point Atkinson (PA) and Sandy Cove (SC), the latter was employed to check and correct gaps in the PA record. Indian Arm Head (IAH), Port Moody (PM) and Vancouver (VA) were used to calibrate/validate water levels in the model. It should be noted that none of the records presented in the table exhibit absolute continuity, as they contain gaps on various days/months/years.

Table C.3 Water Level Stations
Coordinates in UTM 10N NAD83

Data Name	Type	Resolution	Coordinates	Date	Source
7786 Sandy Cove	WL	1 min	483147E 5465390N	2009 – 2024	DFO
7735 Vancouver	WL	1 min / 1 hr	492728E 5459255N	1909 – 2024	DFO
7755 Port Moody	WL	1 min / 1 hr	509744E 5459481N	1962 – 2024	DFO
7795 Point Atkinson	WL	1 min / 1 hr	481560E 5465010N	1914 – 2024	DFO
7774 Indian Arm Head	WL	1 min	508254E 5478800N	2018 – 2024	DFO

Appendix C.3 Hydrodynamic Hindcast Model

Appendix C.3.1 Model Description and Configuration

The MIKE by DHI MIKE 21 Flexible Mesh (FM) Hydrodynamic model (HD)²⁶ is a modelling system based on a flexible mesh approach and provides two-dimensional (2D) free-surface depth-averaged flows. The model is based on the numerical solution of the 2D shallow water equations – the depth-integrated incompressible Reynolds averaged Navier-Stokes equations.

The MIKE 21 Flow Model FM is composed of the following modules:

- Hydrodynamic Module;
- Transport Module;
- MIKE ECO Lab/Oil Spill Module;
- Particle Tracking Module;
- Mud Transport Module; and
- Sand Transport Module.

The Hydrodynamic module is the basic computational component of the entire MIKE21 suite, providing the hydrodynamic basis for all the other modules.

The model for Burrard Inlet was constructed using a triangular finite element mesh, featuring coarser resolutions toward the boundaries, and slightly improved along the Narrows. The model domain extends from the limits of the Strait of Georgia and Burrard Inlet, near the Point Atkinson lighthouse location, up to the innermost areas along the Indian Arm and Port Moody. To optimize computational cost without compromising mesh accuracy, a water level calibration process was carried out, as detailed in Appendix C.3.2. The size of the elements varies from 380 m in the outer areas to less than 80 m in the narrower areas, resulting in a total of 6,686 elements and 3,769 calculation nodes (Figure C.4).

²⁶Version 2024 was used: https://manuals.mikepoweredbydhi.help/2024/Coast_and_Sea/MIKE_FM_HD_2D.pdf

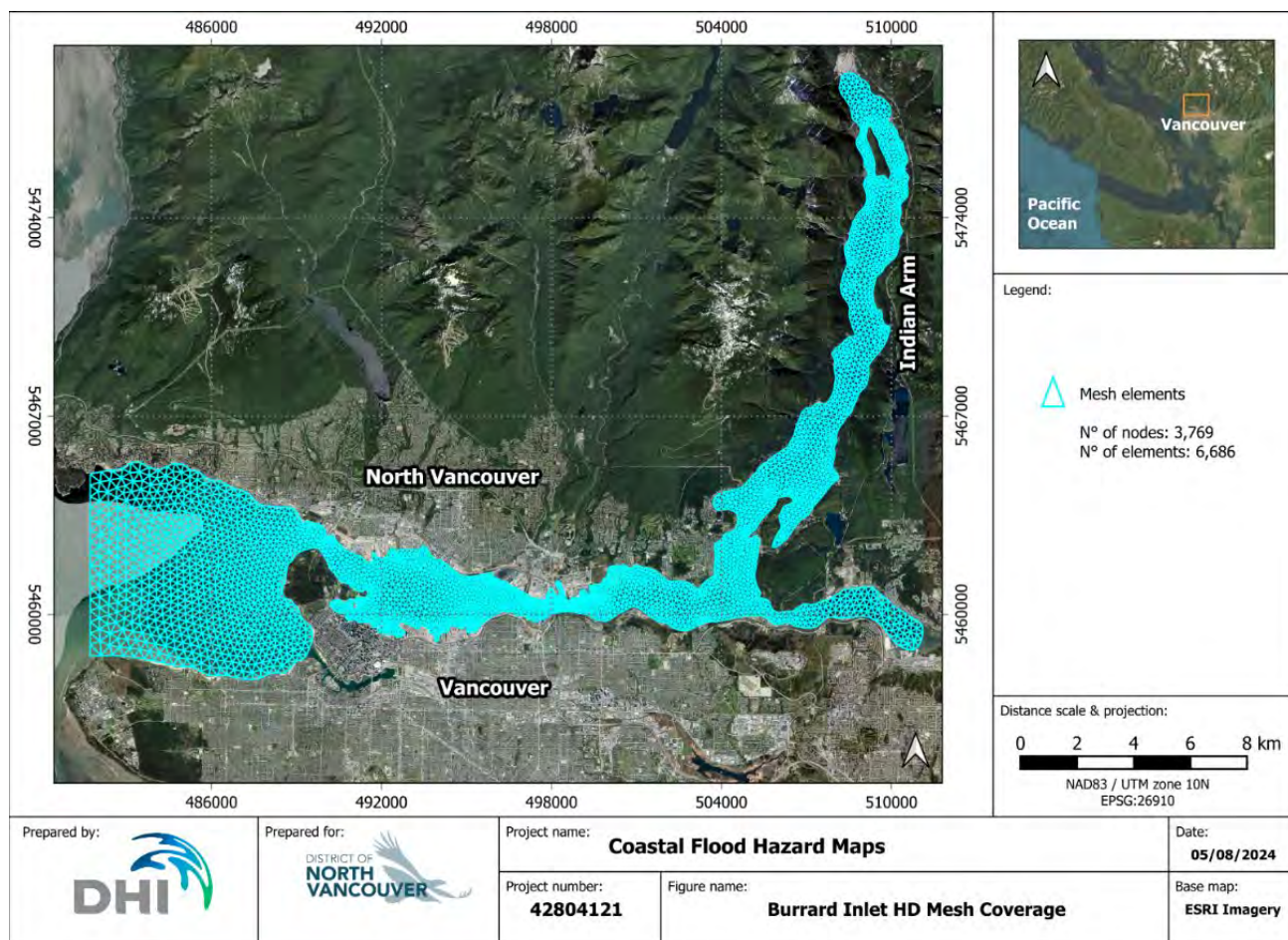


Figure C.4 MIKE HD Model Mesh Overview for Burrard Inlet

Table C.4 SW Model Parametrization for Wind-Waves Assessment
Coordinates in UTM 10N NAD83

Setting	HD _{DNV}
Date Range	1970 - 2023
Solution Technique	Low order
Min/Max Time Step	0.01 s / 900 s
Type of Riemann Solver	HLLC / factor 1
Eddy Viscosity	Smagorinsky formulation
Bed Resistance	Manning 32 m ⁴ (1/3)/s
Wind Forcing	No local wind
Water Level	Total Water Level (Harmonic + Surge)
Density	Barotropic

Appendix C.3.2 Calibration

The calibration process was conducted over a modelling window spanning from January 2022 to December 2023, capturing the highest recorded events in late 2022. The comparisons between water levels at Vancouver, Port Moody and Indian Arm are illustrated in Figure C.5. From these comparisons, it can be concluded that the model satisfactorily resolves the water levels within Burrard Inlet, maintaining a significant similarity not only in the tidal phase but also in the amplitudes throughout the area spanning from Point Atkinson to Indian Arm. Consequently, it is expected that the water levels along the coast of interest will also be well represented.

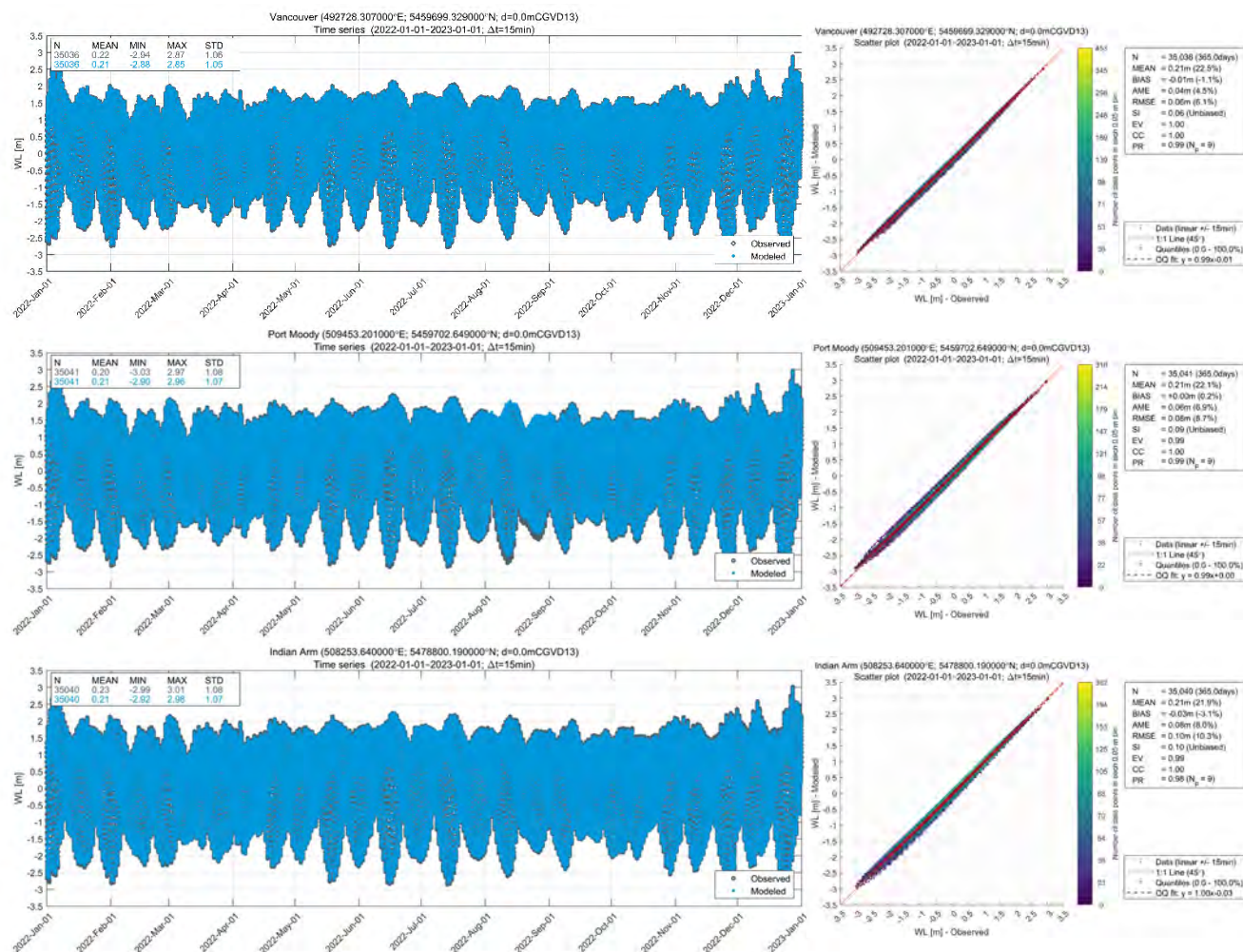


Figure C.5 Timeseries of measured and predicted water levels at Vancouver, Port Moody, and Indian Arm tidal stations for 2022

Appendix C.3.3 Validation

The model validation was conducted using the full period available from the three (3) tidal stations. As depicted in Figure C.6, the model satisfactorily represents the water levels throughout the duration of the assessed period, both in phase and amplitude, with slight biases of up to 1 cm.

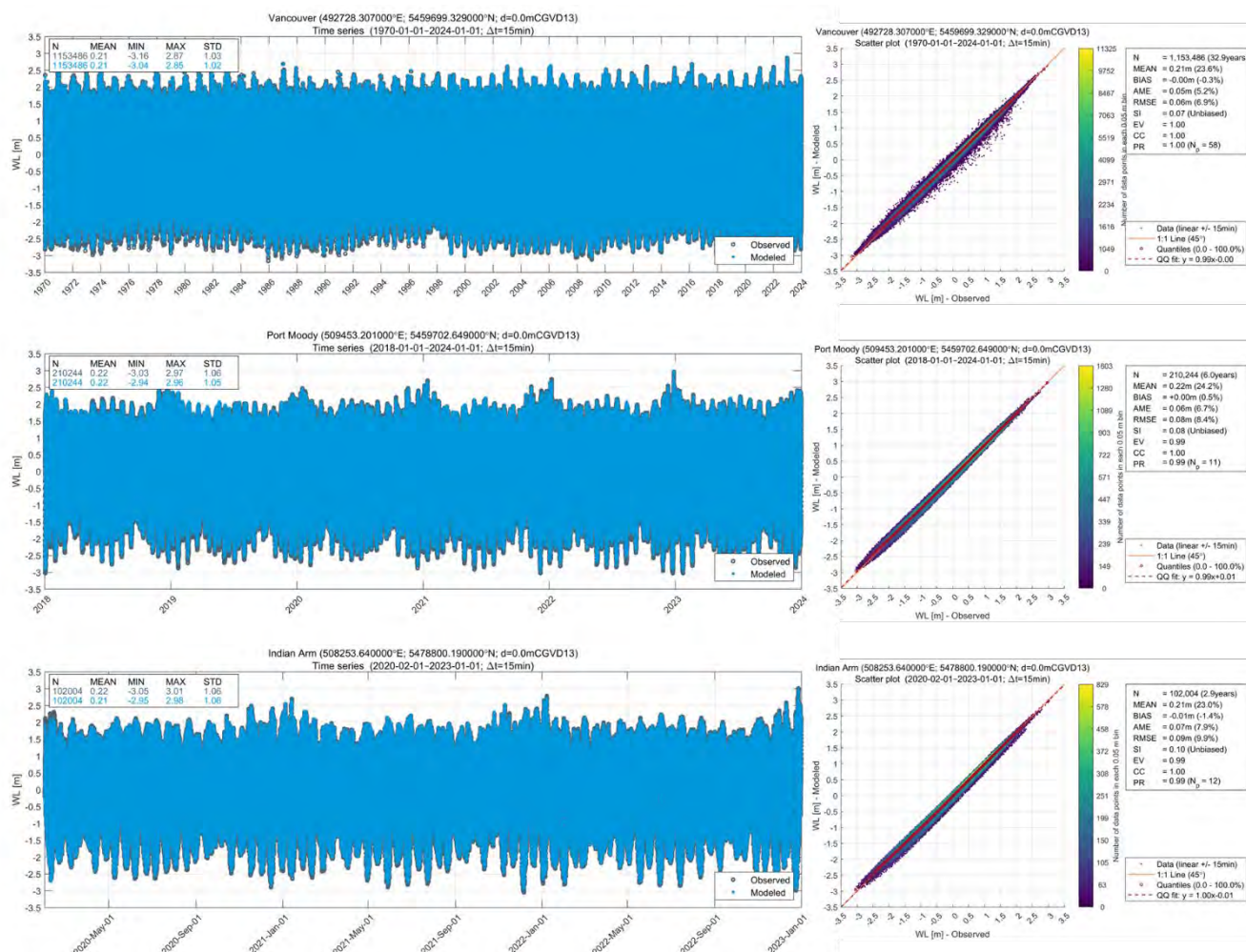


Figure C.6 Timeseries of measured and predicted water levels at Vancouver, Port Moody, and Indian Arm tidal stations for 2022

Appendix C.3.4 Extreme Value Analysis – Additional Results

The sensitivity analysis presented in Figure C.7 indicates that the preferred extreme value distribution is the least squares 2p-Weibull distribution, as it remains consistent regardless of the number of events per year. The complete results of the extreme value analysis are presented for all points of interest along the stretch connecting Maplewood Flats with Bishop Creek (Table C.5), along with the corresponding descriptive figures (Figure C.8 to Figure C.15).

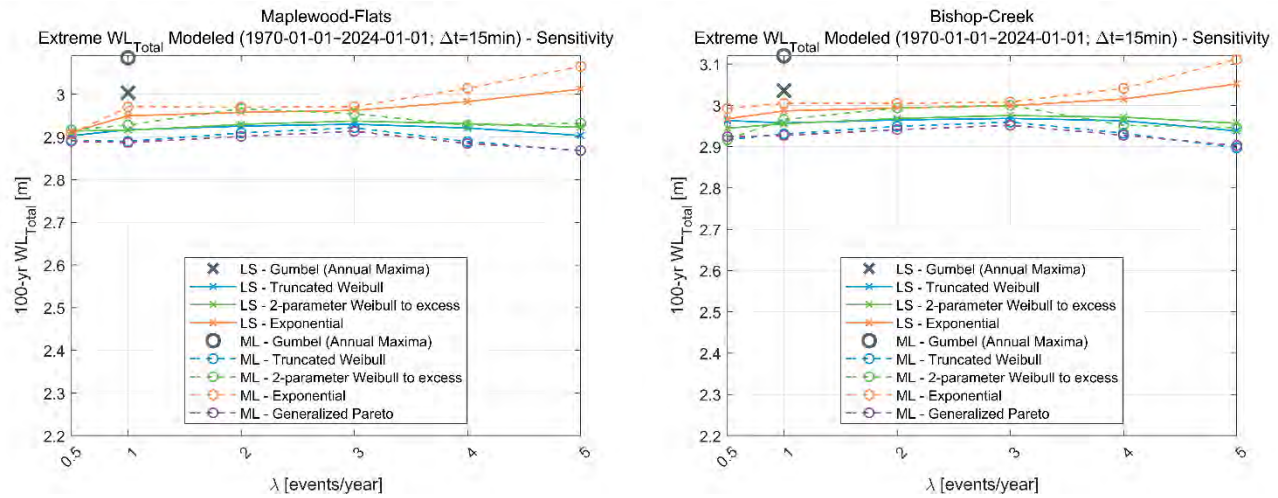


Figure C.7 Sensitivity analysis 100-year, estimated using different distributions for varying peak events (from 1 to 5 events per year)

Table C.5 AEPs for Total Water Level in All Points of Interest – Central Estimation

100%: Annual; 50%: 1-in-2 years; 10%: 1-in-10 years; 5% 1-in-20 years; 2%: 1-in-50 years; 1%: 1-in-100 years; 0.5%: 1-in-200 years

Total Water Level (m, CGVD 2013)	Annual Exceedance Probability (AEP)							
	100%	50%	20%	10%	5%	2%	1%	0.5%
Maplewood Flats	2.47	2.55	2.64	2.71	2.77	2.85	2.92	2.98
Cates Park East	2.48	2.56	2.65	2.72	2.78	2.87	2.93	2.99
Wickenden Park	2.49	2.57	2.67	2.73	2.80	2.88	2.94	3.00
Deep Cove	2.49	2.58	2.67	2.74	2.80	2.88	2.94	3.00
Racoon Island	2.50	2.58	2.67	2.74	2.80	2.89	2.95	3.01
Orlomah Beach	2.50	2.58	2.68	2.74	2.81	2.89	2.95	3.01
Coldwell Beach	2.50	2.58	2.68	2.74	2.81	2.89	2.95	3.02
Bishop Creek	2.50	2.58	2.68	2.74	2.81	2.89	2.96	3.02

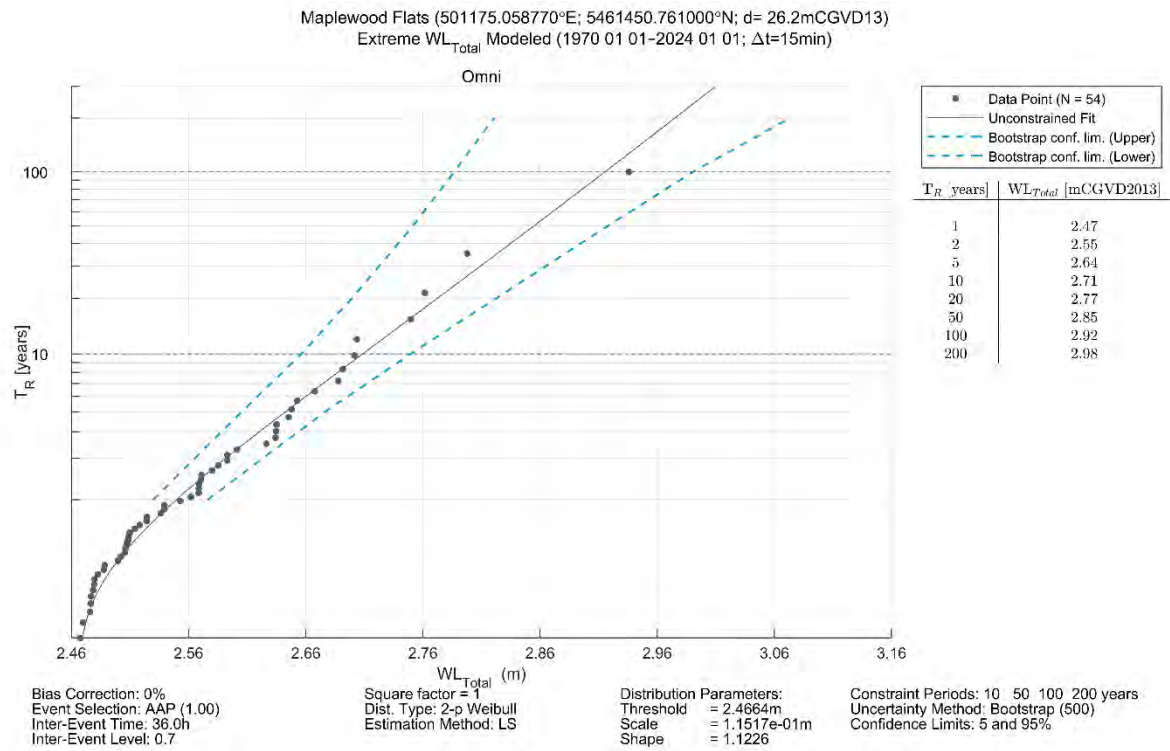


Figure C.8 Total Water Level Extreme Value Analysis at Maplewood Flats – 1970 to 2023

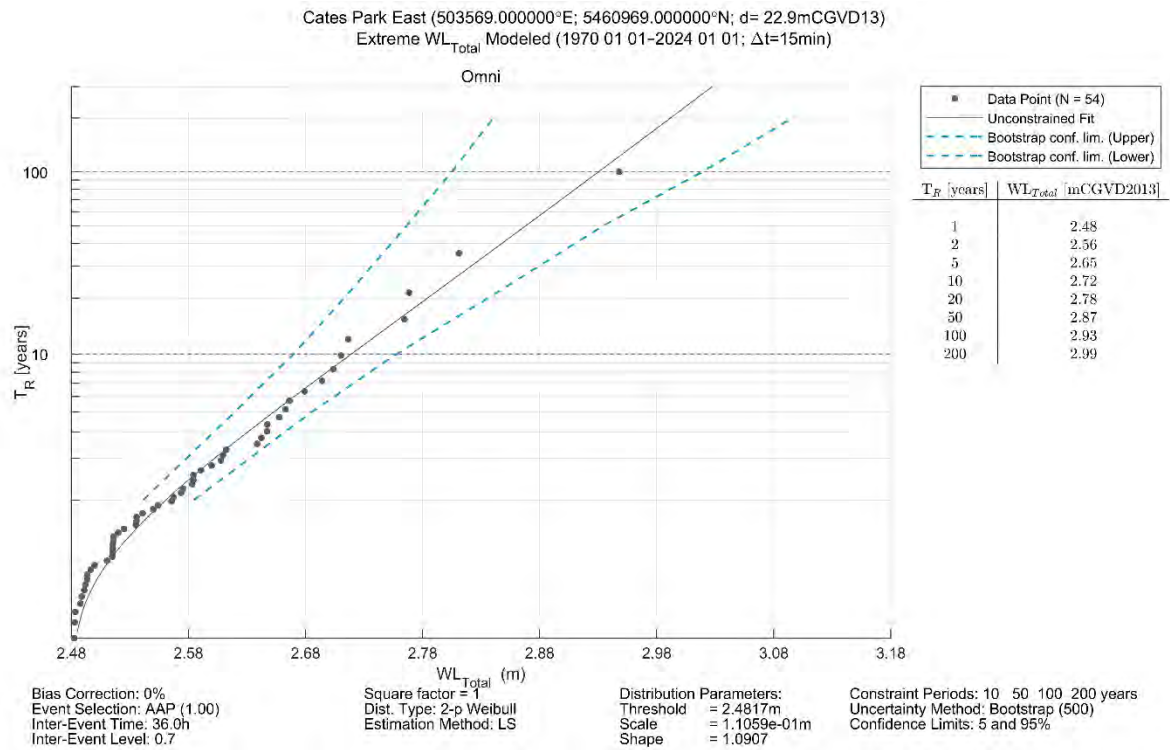


Figure C.9 Total Water Level Extreme Value Analysis at Cates Park East – 1970 to 2023

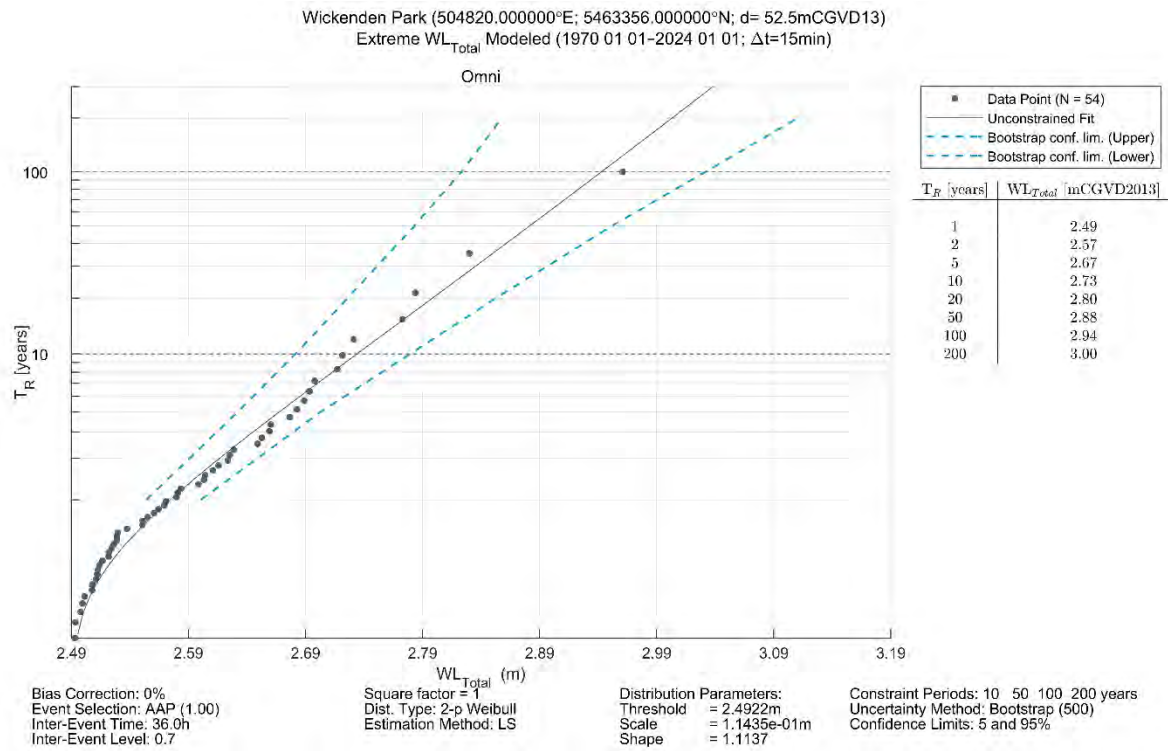


Figure C.10 Total Water Level Extreme Value Analysis at Wickenden Park – 1970 to 2023

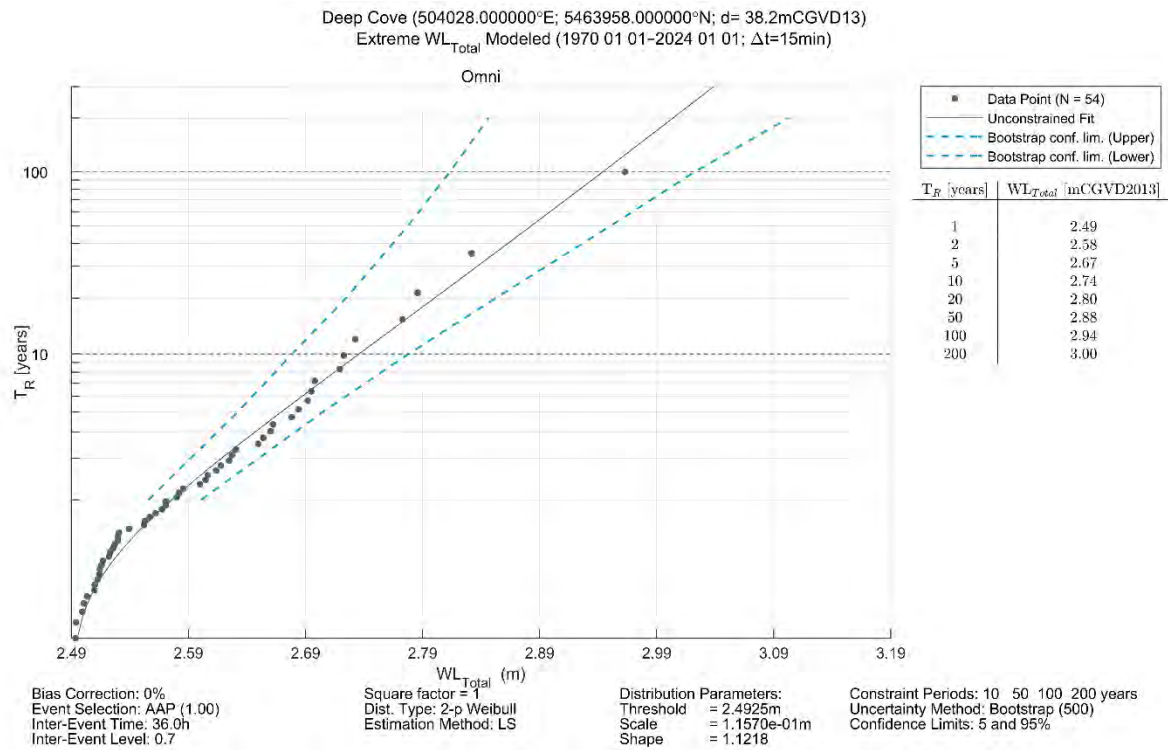


Figure C.11 Total Water Level Extreme Value Analysis at Deep Cove – 1970 to 2023

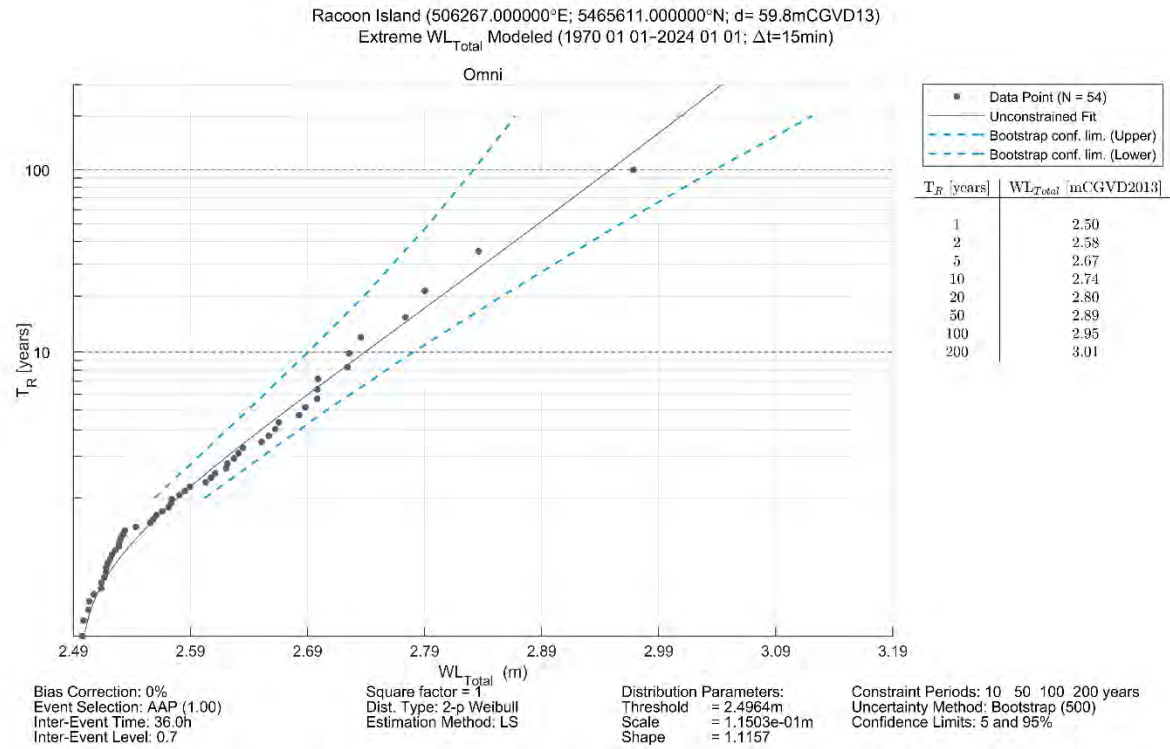


Figure C.12 Total Water Level Extreme Value Analysis at Raccoon Island – 1970 to 2023

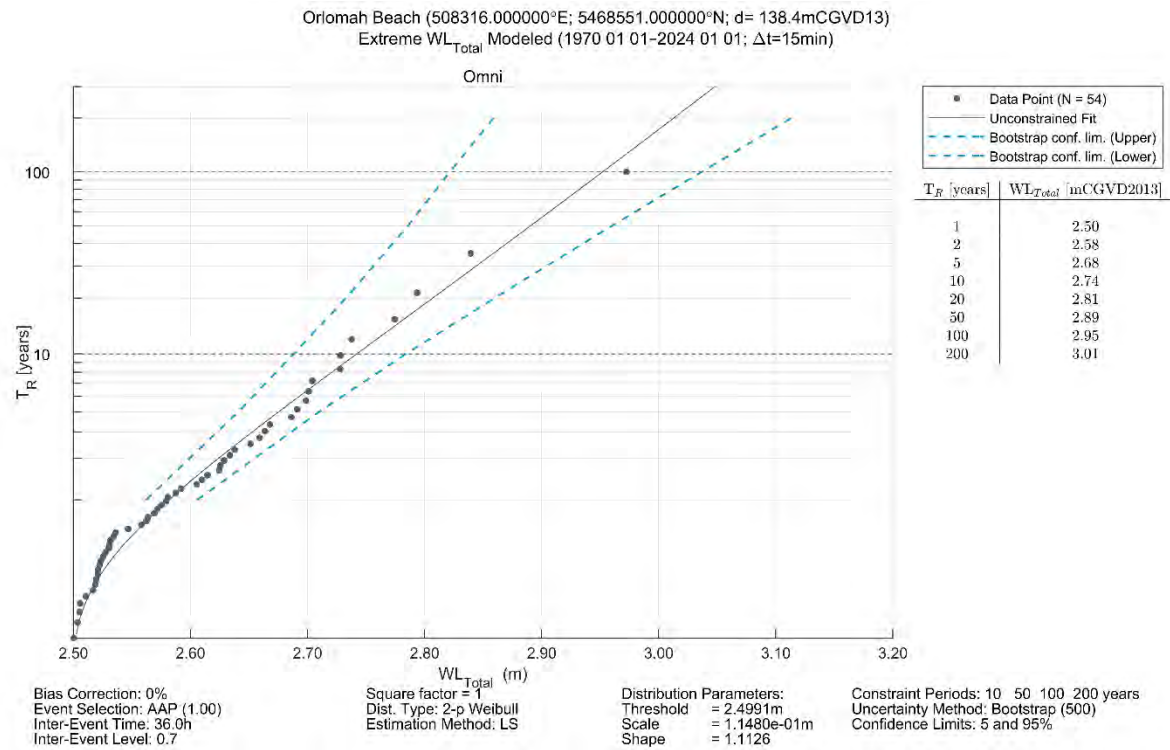


Figure C.13 Total Water Level Extreme Value Analysis at Orlomag Beach – 1970 to 2023

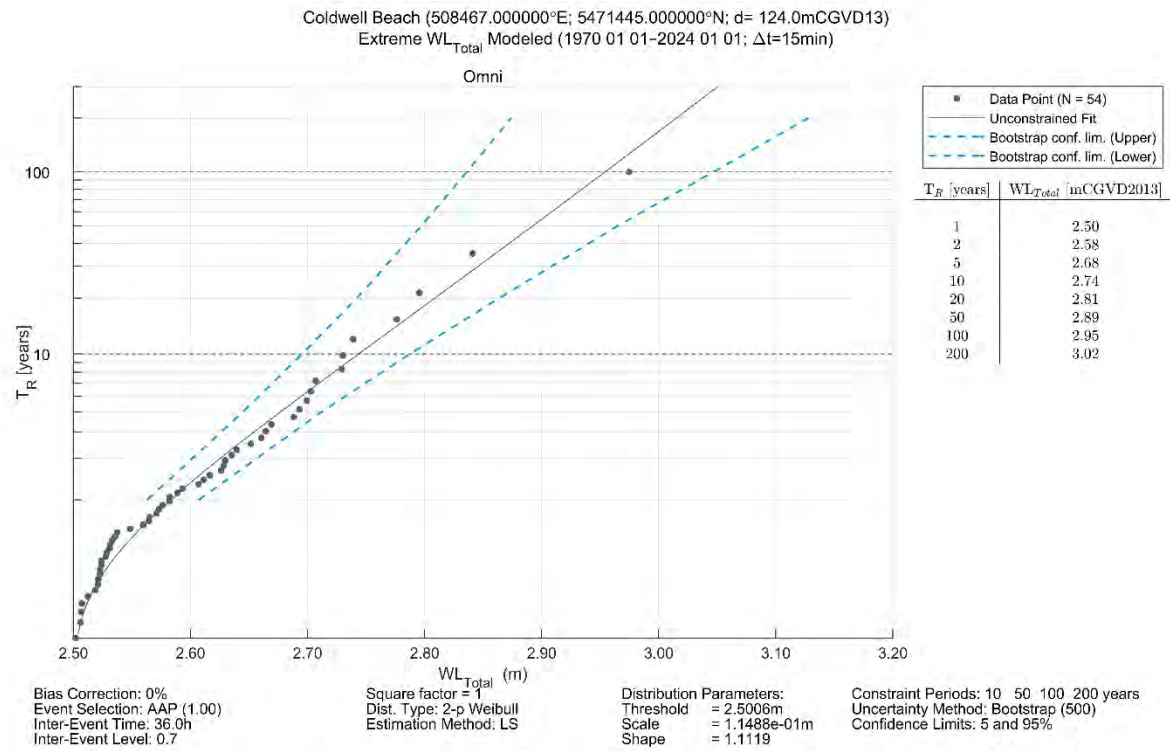


Figure C.14 Total Water Level Extreme Value Analysis at Coldwell Beach – 1970 to 2023

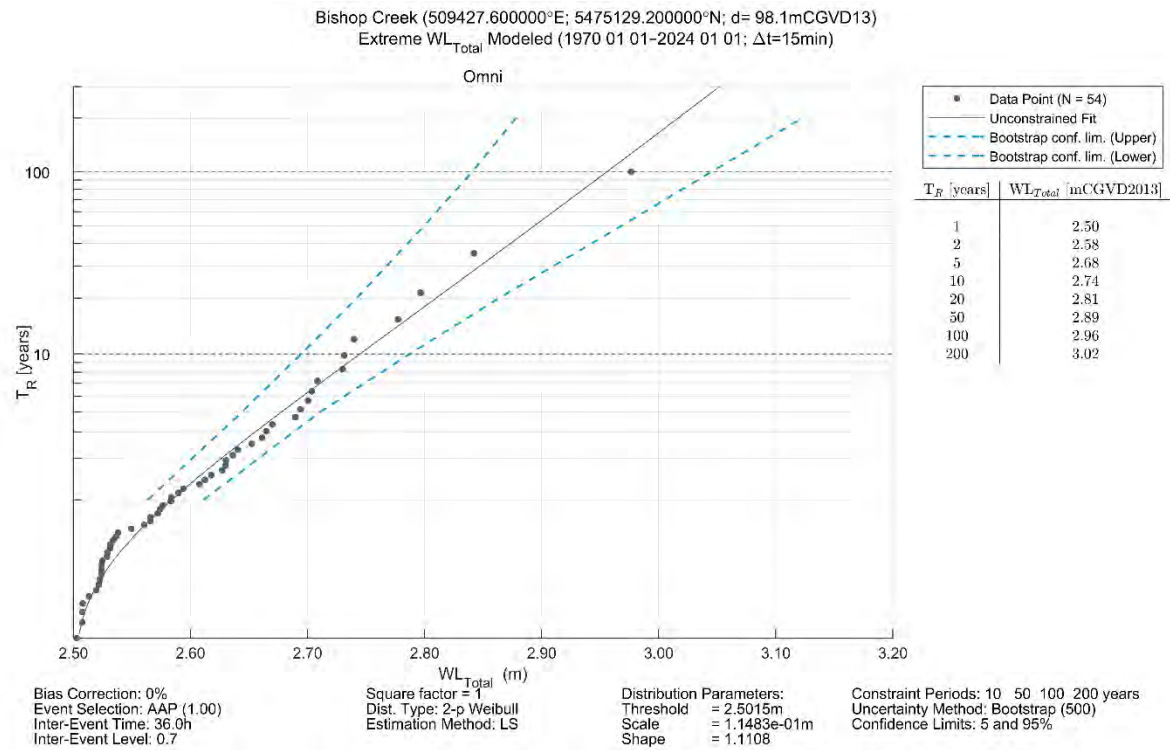


Figure C.15 Total Water Level Extreme Value Analysis at Bishop Creek – 1970 to 2023

Appendix C.4 Spectral Wave Model

Appendix C.4.1 Model Description and Configuration

MIKE 21 Spectral Waves (SW)²⁷ is a third-generation spectral wind-wave model based on the finite volume method on unstructured meshes and enables full time domain simulations. The model simulates the growth, decay and transformation of wind-generated waves and swells in offshore and coastal areas.

MIKE 21 SW includes the following physical phenomena:

- Wave growth by action of wind;
- Non-linear wave-wave interaction;
- Dissipation due to white-capping;
- Dissipation due to bottom friction;
- Dissipation due to depth-induced wave breaking;
- Refraction and shoaling due to depth variations;
- Wave-current interaction; and
- Effect of time-varying water depth and flooding and drying.

Using the mesh depicted in Figure C.16, different parameterizations were tested and evaluated until satisfactory fetch limited waves were attained. The size of the elements varies from 380 m in the outer areas to less than 80 m along the study area shoreline, resulting in a total of 10,375 elements and 5,681 calculation nodes.

Table C.6 SW Model Parametrization for Wind-Waves Assessment

Setting	SW _{DNV}
Time Formulation	Quasi stationary
Basic Equations	Fully spectral / Modified WAM cycle 4
Spectral Discretization	Log. 30 freq.; min 0.0625 (Hz) and factor of 1.12 with 36 directions
Energy Transfer	Quadruplets
Air Properties/Wind Forcing	Long-term Burrard Inlet 70% scaled
Air-Sea Interaction	Growth 1.2 / Uncoupled / drag v1 and Charnock 0.01
Water Level	Extreme Water Levels + SLR
Wave Breaking	0.8 specified gamma
Bottom Friction	Nikuradse kn 0.04 (m)

²⁷Version 2024 was used: https://manuals.mikepoweredbydhi.help/2024/Coast_and_Sea/MIKE21SW.pdf

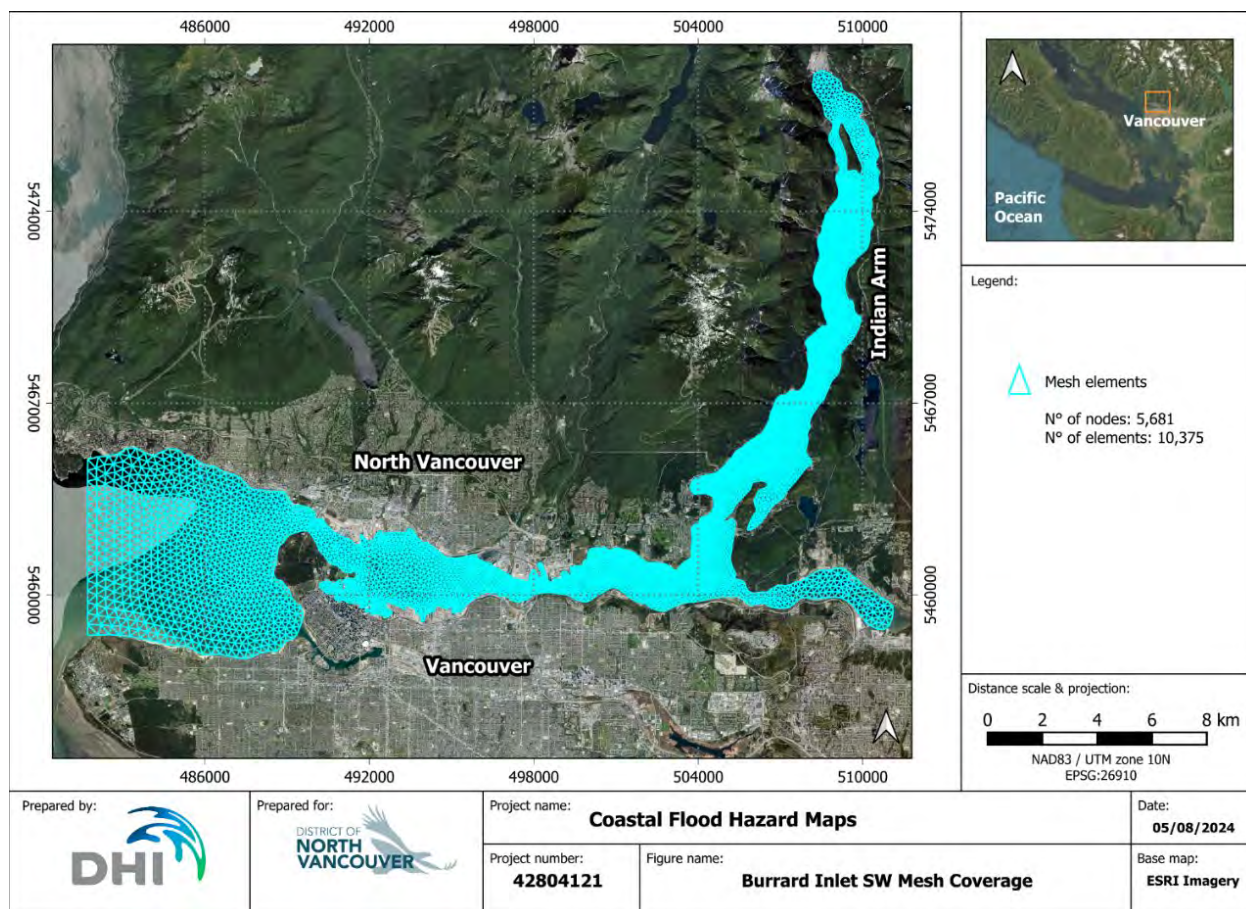


Figure C.16 MIKE SW Model Mesh Overview for Burrard Inlet

Appendix C.4.2 Additional Results

In addition to the scenarios presented in section 3.2.3 (Spectral Wave Model Results), Table C.7 contains the complete list of scenarios that were evaluated as part of the discrete wave event analysis. Furthermore, in Table C.8 and Table C.9 the results for all combinations of discrete scenarios evaluated are presented.

Upon reviewing the complete results list, it is possible to observe wave heights exceeding 0.9 m under extreme conditions, primarily along the shoreline formed by stations 6 and 11, where a greater fetch can be achieved (Table C.8 and Table C.9). It is important to mention that the directional discretization of wind, under the intensity of omnidirectional results, corresponds to a conservative approximation in assessing wave characteristics for the area, given the topographical limitations. In the Sea Level Rise scenarios, no significant variations in height (1 cm) or period (fraction of a second) are observed, which is likely attributed to fetch limitations and the short period of the waves.

Table C.7 Wave model scenarios, including winds and water levels

SW Scenario	AEP (%)	Wind Direction (deg)	Wind Speed (m/s)	Water Level (m CGVD13)
200-year RTP	0.5	0 – 345 / $\Delta 15^\circ$	19.8	3.0
+ SLR 0.5 m	0.5	0 – 345 / $\Delta 15^\circ$	19.8	3.5
+ SLR 1.0 m	0.5	0 – 345 / $\Delta 15^\circ$	19.8	4.0

Table C.8 Complete List of Significant Wave Height Output at Points of Interest for 200-Year Return Period Events

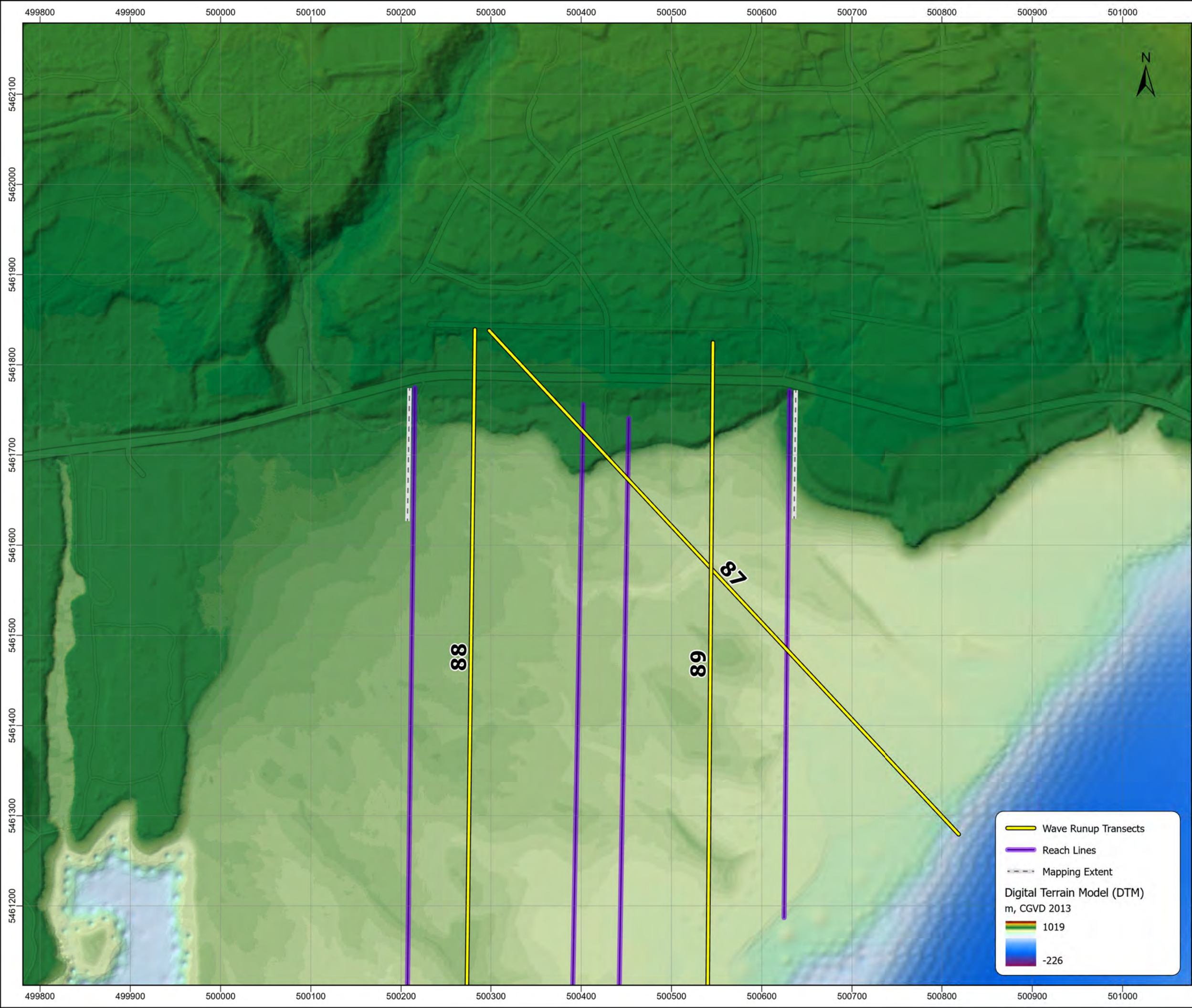
Significant Wave Height (m)		Extraction Points															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Wind Direction (°)	0	0.70	0.82	0.89	0.88	0.74	0.83	0.75	0.77	0.75	0.71	0.84	0.78	0.79	0.79	0.56	0.61
	15	0.74	0.85	0.90	0.88	0.76	0.86	0.80	0.83	0.84	0.80	0.90	0.84	0.84	0.84	0.56	0.62
	30	0.75	0.84	0.88	0.85	0.75	0.84	0.82	0.87	0.89	0.87	0.93	0.87	0.86	0.87	0.58	0.66
	45	0.76	0.82	0.82	0.80	0.72	0.80	0.80	0.87	0.90	0.89	0.92	0.86	0.85	0.87	0.63	0.71
	60	0.76	0.79	0.76	0.73	0.71	0.74	0.77	0.84	0.88	0.88	0.86	0.83	0.82	0.86	0.68	0.78
	75	0.75	0.75	0.70	0.66	0.68	0.68	0.73	0.81	0.85	0.86	0.79	0.79	0.78	0.84	0.75	0.84
	90	0.73	0.70	0.64	0.60	0.65	0.61	0.71	0.79	0.83	0.83	0.70	0.74	0.74	0.81	0.79	0.88
	105	0.71	0.68	0.63	0.60	0.62	0.55	0.70	0.75	0.78	0.78	0.61	0.70	0.71	0.77	0.81	0.88
	120	0.74	0.71	0.67	0.62	0.62	0.55	0.69	0.74	0.74	0.73	0.59	0.70	0.71	0.74	0.78	0.84
	135	0.78	0.74	0.70	0.68	0.66	0.61	0.73	0.73	0.72	0.66	0.63	0.72	0.71	0.71	0.75	0.78
	150	0.81	0.78	0.71	0.72	0.71	0.70	0.78	0.74	0.73	0.61	0.69	0.75	0.72	0.68	0.71	0.72
	165	0.86	0.81	0.73	0.77	0.75	0.80	0.83	0.79	0.76	0.59	0.75	0.77	0.74	0.66	0.66	0.65
	180	0.88	0.83	0.74	0.82	0.80	0.88	0.89	0.83	0.79	0.57	0.80	0.78	0.75	0.65	0.63	0.60
	195	0.86	0.81	0.73	0.85	0.83	0.94	0.91	0.85	0.81	0.55	0.80	0.75	0.74	0.67	0.64	0.61
	210	0.80	0.76	0.69	0.85	0.83	0.95	0.91	0.85	0.80	0.52	0.79	0.71	0.73	0.73	0.69	0.65
	225	0.71	0.68	0.63	0.80	0.80	0.94	0.88	0.83	0.78	0.51	0.75	0.67	0.71	0.76	0.75	0.70
	240	0.60	0.58	0.55	0.73	0.74	0.89	0.82	0.79	0.73	0.50	0.69	0.62	0.69	0.79	0.80	0.75
	255	0.49	0.49	0.47	0.63	0.65	0.80	0.75	0.74	0.67	0.50	0.63	0.57	0.66	0.82	0.84	0.79
	270	0.41	0.44	0.45	0.52	0.55	0.70	0.66	0.66	0.60	0.50	0.56	0.53	0.63	0.83	0.86	0.79
	285	0.39	0.44	0.48	0.51	0.48	0.61	0.57	0.59	0.54	0.49	0.50	0.49	0.60	0.80	0.84	0.78
	300	0.41	0.49	0.57	0.59	0.49	0.54	0.51	0.53	0.49	0.48	0.50	0.48	0.57	0.77	0.81	0.75
	315	0.48	0.58	0.66	0.69	0.56	0.60	0.51	0.50	0.47	0.46	0.54	0.50	0.58	0.73	0.75	0.70
	330	0.56	0.67	0.76	0.77	0.64	0.69	0.58	0.56	0.52	0.48	0.64	0.59	0.65	0.71	0.68	0.64
	345	0.64	0.76	0.84	0.84	0.70	0.77	0.68	0.67	0.63	0.59	0.75	0.70	0.72	0.73	0.61	0.61

Table C.9 Complete List of Peak Period Output at Points of Interest for 200-Year Return Period Events

Peak Period (s)		Extraction Points															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Wind Direction (°)	0	2.8	3.1	3.3	3.3	3.0	3.2	3.0	3.2	3.2	3.2	3.2	3.2	3.1	3.1	2.2	2.3
	15	2.9	3.2	3.3	3.3	3.0	3.2	3.1	3.2	3.3	3.3	3.4	3.3	3.2	3.2	2.1	2.3
	30	2.9	3.1	3.3	3.3	2.9	3.2	3.1	3.3	3.3	3.4	3.5	3.4	3.3	3.3	2.3	2.5
	45	2.9	3.0	3.2	3.2	2.9	3.1	3.0	3.2	3.3	3.3	3.4	3.4	3.2	3.2	2.6	2.7
	60	2.8	2.9	3.0	2.8	2.8	2.9	2.9	3.1	3.2	3.3	3.3	3.3	3.1	3.0	2.9	2.9
	75	2.7	2.8	2.7	2.4	2.6	2.7	2.8	2.9	3.1	3.2	3.2	3.1	2.7	2.9	2.9	3.2
	90	2.6	2.6	2.4	2.3	2.5	2.5	2.6	2.8	3.0	3.1	3.0	2.6	2.6	2.9	3.0	3.2
	105	2.6	2.5	2.4	2.3	2.3	2.2	2.5	2.7	2.9	2.9	2.4	2.5	2.6	2.9	3.0	3.2
	120	2.6	2.6	2.6	2.4	2.3	2.1	2.6	2.7	2.8	2.7	2.3	2.6	2.7	2.9	3.0	3.2
	135	2.9	2.9	2.7	2.6	2.5	2.3	2.7	2.7	2.6	2.6	2.6	2.8	2.7	2.7	2.8	3.0
	150	3.0	2.9	2.8	2.8	2.8	2.9	2.9	2.6	2.6	2.5	2.8	2.8	2.7	2.6	2.6	2.9
	165	3.2	3.0	2.9	3.1	3.0	3.2	3.0	2.8	2.9	2.5	2.9	2.9	2.6	2.4	2.5	2.6
	180	3.2	3.1	2.9	3.2	3.2	3.3	3.2	3.0	3.0	2.4	3.0	2.9	2.7	2.4	2.4	2.3
	195	3.2	3.1	3.0	3.3	3.3	3.4	3.2	3.1	3.1	2.1	3.0	2.8	2.7	2.6	2.4	2.4
	210	3.2	3.1	3.0	3.3	3.3	3.4	3.3	3.2	3.0	2.0	3.0	2.8	2.8	2.8	2.5	2.6
	225	3.0	2.8	2.9	3.3	3.3	3.4	3.2	3.1	2.9	2.1	2.9	2.7	2.8	2.9	2.8	2.8
	240	2.6	2.4	2.0	3.2	3.3	3.3	3.2	3.0	2.8	2.1	2.8	2.6	2.7	3.1	3.0	2.9
	255	2.1	2.1	1.9	3.1	3.1	3.2	3.0	2.9	2.6	2.1	2.6	2.3	2.7	3.2	3.2	3.0
	270	1.8	1.9	1.9	2.0	2.0	2.9	2.9	2.7	2.5	2.1	2.4	2.1	2.5	3.2	3.2	3.0
	285	1.7	1.8	2.1	2.2	2.0	2.6	2.1	2.5	2.3	2.1	2.0	2.0	2.2	3.2	3.1	2.9
	300	1.8	2.1	2.3	2.6	2.1	2.2	2.0	2.1	2.1	2.1	2.1	2.0	2.2	3.2	3.0	2.8
	315	2.1	2.5	2.8	2.9	2.2	2.5	2.1	2.0	1.9	2.0	2.3	2.0	2.3	2.9	2.9	2.6
	330	2.5	2.8	3.1	3.1	2.5	3.0	2.3	2.1	2.0	1.9	2.6	2.3	2.6	2.8	2.7	2.4
	345	2.7	3.0	3.2	3.2	2.8	3.2	2.7	2.9	2.8	2.0	2.9	3.0	2.9	2.9	2.5	2.4

Appendix D. Wave Runup Assessment

Appendix D.1 Reach Delineation and Wave Runup Transect Placement



Overview:
These maps have been developed by DHI Water & Environment Inc. (DHI) for the District of North Vancouver to provide Flood Construction Reference Plane (CFRP) and Flood Construction Level (FCL) guidance. Notably, these mapping products incorporate wave effects to establish the flood hazard.

Notes:
1. The maps have been developed using the methodologies outlined in the report entitled: District of North Vancouver Coastal Flood Hazard Mapping Study, issued by DHI, June 2024. The report should be consulted for a detailed outline of the methods, assumptions and limitations of the study to develop the flood hazard maps presented herein.
2. Still Water Level (SWL) is the 0.5% AEP joint-probability estimate of tide and storm surge plus wave effects (variable across the study domain) and freeboard (600 mm).
3. Flood Construction Level is the 0.5% AEP joint-probability estimate of total water level (including tide and storm surge) plus wave effects and freeboard (600 mm).
4. Adopted Sea Level Rise is guided by Ausenco-Sandwell (2011) Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use: Guidelines for Management of Coastal Flood Hazard Land Use. Prepared by Ausenco-Sandwell for BC Ministry of Environment, and the Technical Advisory Group.
5. 2022 LIDAR data provided by the District of North Vancouver was combined with CHS NONNA bathymetric survey data, and corrected to common datum (CGVD2013), to create a Digital Elevation Model (DEM) for the study area. The flood levels are based on this DEM.

Use and Limitations:
1. Inundation limits are based on consideration of coastal processes only and do not incorporate flooding from pluvial and fluvial sources.
2. Users must note the dates of base mapping, aerial photography, ground or bathymetric surveys and issue of mapping relevant to dates of development in the map area. Subsequent developments or changes within the floodplain or channel will affect flood levels and render site-specific map information obsolete.
3. Under the provisions of the Flood Hazard Statutes Amendment Act, 2003 (Bill 56), local governments have the role and responsibility for making decisions about local floodplain development practices, including decisions about floodplain bylaws within their communities. Information on floodplain management guidelines can be found in the BC Flood Hazard Area Land Use Management Guidelines.
4. The accuracy of the location of a floodplain boundary as shown on this map is limited by the base topography.
5. The floodplain limits are not established on the ground by legal survey. A site survey is required to reconcile property location, ground elevations and designated flood level information.
6. Erosion, riverine hazards and overland flood effects are not included.
7. Results and mapping are appropriate and applicable on a reach-scale, for planning purposes only. Detailed site specific (i.e. lot level) FCL studies are highly recommended, as required, on a case-by-case basis to refine FCL limits for infrastructure specific purposes.

Data Sources:
- 2018 Canadian Hydrographic Service (CHS) NON-Navigational (NONNA) data.
- 2022 District of North Vancouver LIDAR data.
- Background imagery supplied by Esri and orthophotos by the District of North Vancouver (2016)
- Infrastructure Footprints, natural and administrative boundaries provided by the District of North Vancouver GIS Department.

Scale Disclaimer: The map scale of 1:4,000 is only valid on a 11"x17" print.
Disclaimer: This document has been prepared by DHI Water & Environment Inc. (DHI) in accordance with generally accepted engineering and geoscience practices and is intended for the exclusive use and benefit of the District of North Vancouver and their authorized representatives for specific application to Coastal Flood Hazard Mapping. Variations in actual flood depths and extents may occur, and DHI does not assume liability for such variations. The contents of this document are not to be relied upon or used, in whole or in part, by or for the benefit of others without specific written authorization from DHI. No other warranty, expressed or implied, is made. DHI and its officers, directors, employees, and agents assume no responsibility for the reliance upon this document or any of its contents by any parties other than the District of North Vancouver.

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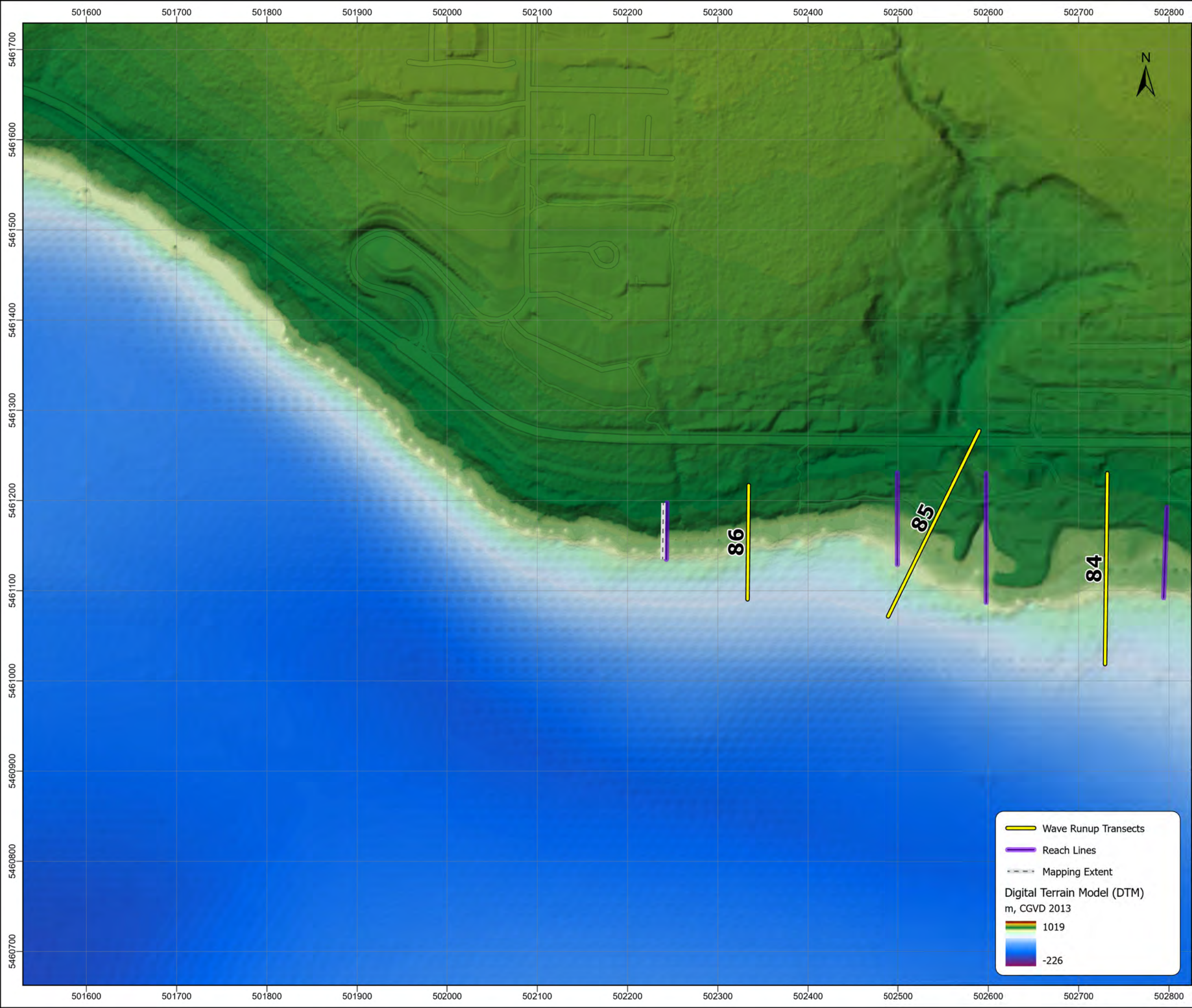
PCS: Projected Coordinate System
CGVD2013: Canadian Geodetic Vertical Datum of 2013
EPSG: European Petroleum Survey Group
CSRS: Canadian Spatial Reference System
TWL: Total Water Level
SLR: Sea Level Rise

TITLE
District of North Vancouver - Mapping References
Map 1 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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CSRS: Canadian Spatial Reference System
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SLR: Sea Level Rise

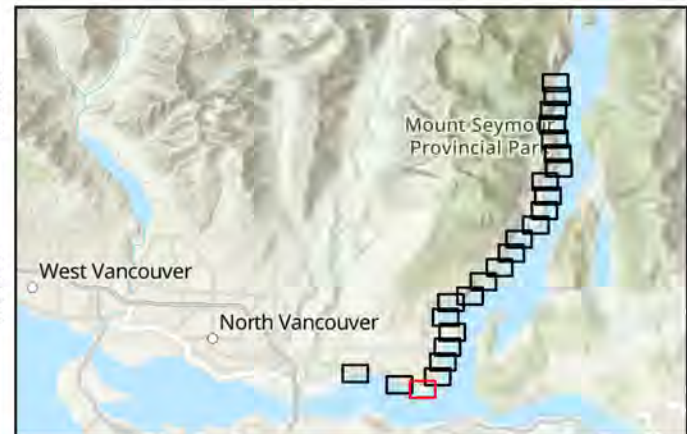
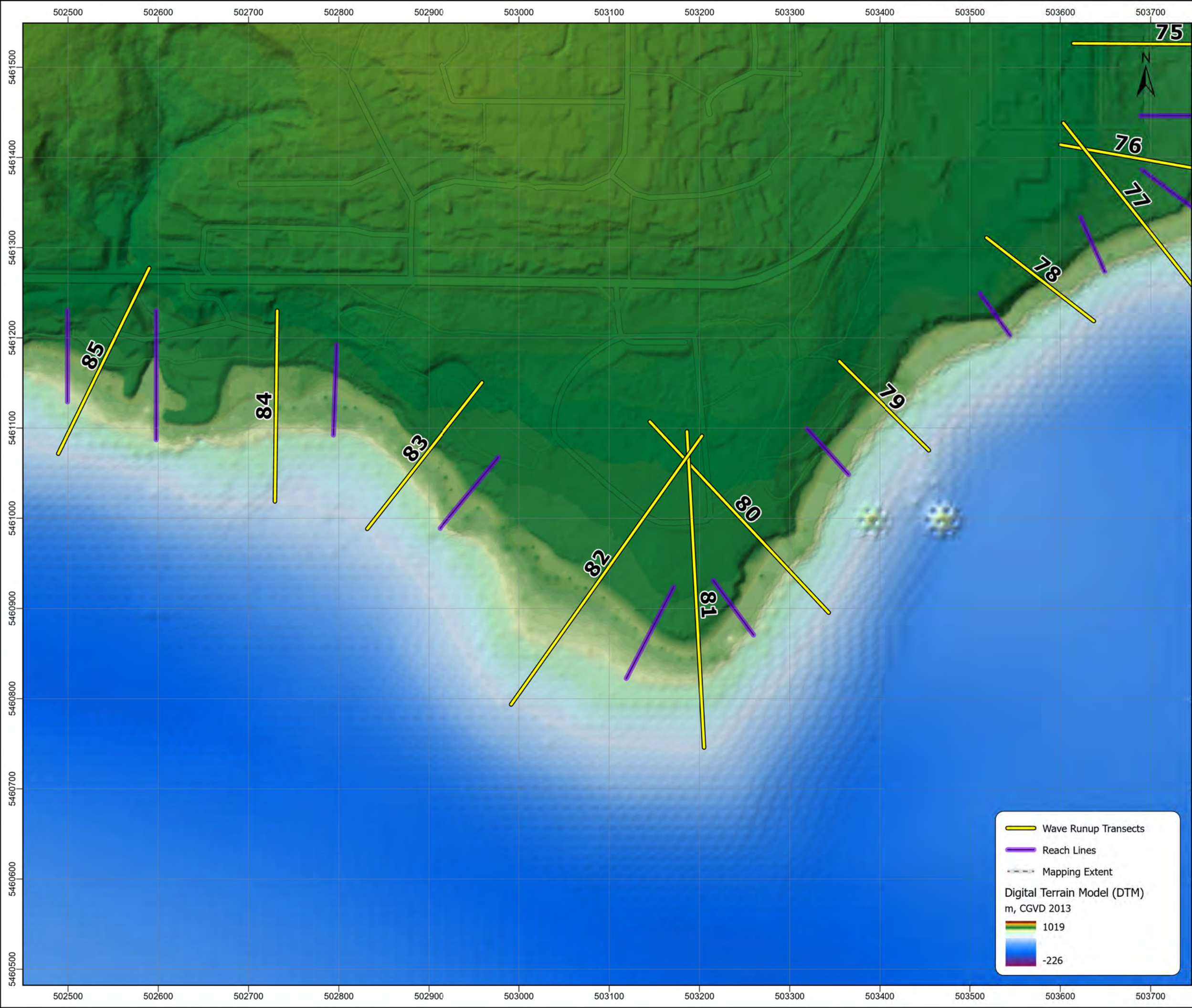
TITLE
District of North Vancouver - Mapping References
Map 2 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





Overview:
These maps have been developed by DHI Water & Environment Inc. (DHI) for the District of North Vancouver to provide Flood Construction Reference Plane (CFRP) and Flood Construction Level (FCL) guidance. Notably, these mapping products incorporate wave effects to establish the flood hazard.

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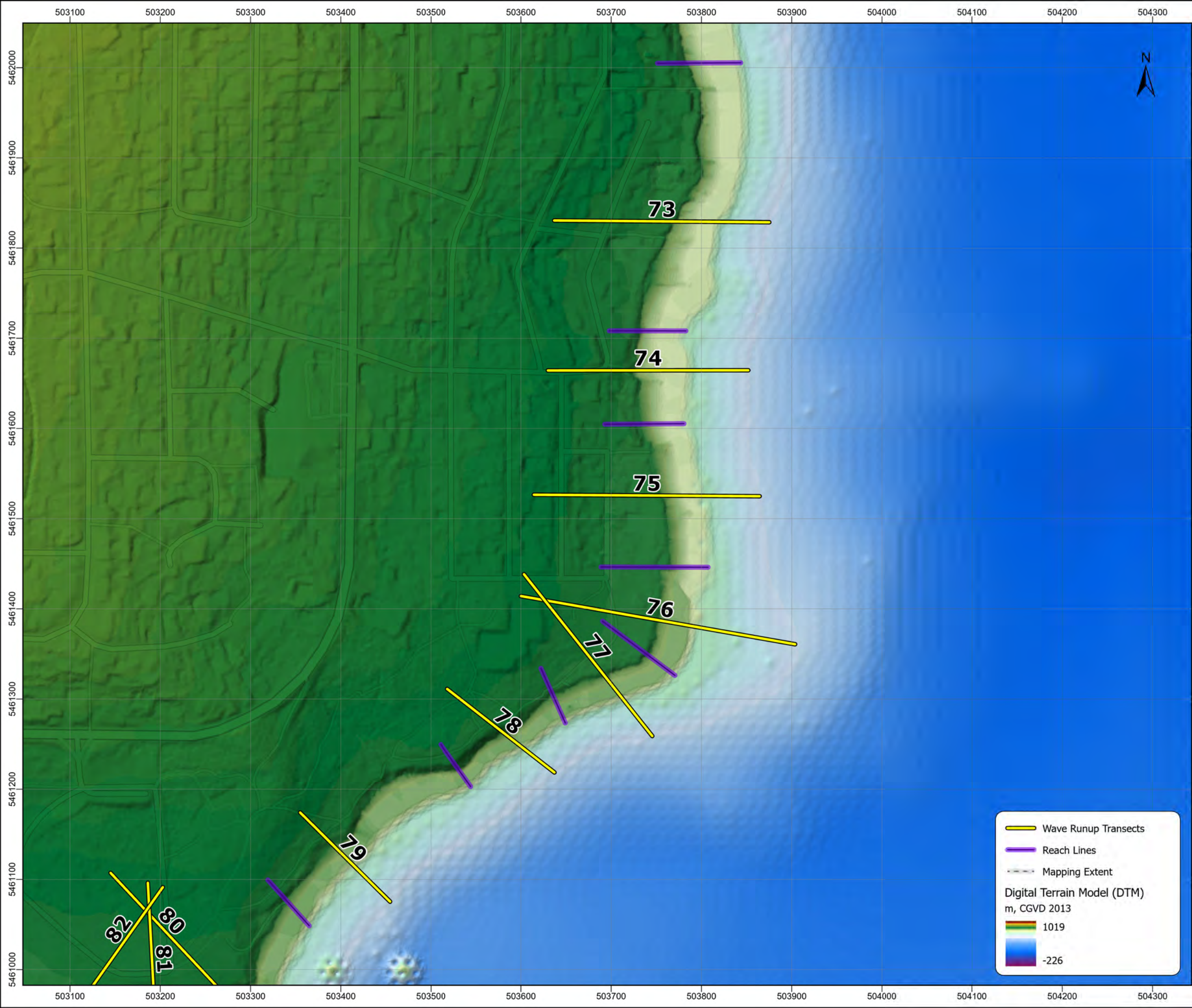
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TWL: Total Water Level
SLR: Sea Level Rise

TITLE					
District of North Vancouver - Mapping References					
Map 3 of 25					
PCS: NAD 1983 UTM Zone 10N		Scale: 1:4,000			
EPSG: 26910		0 25 50 100			
Datum: CGVD2013					
Map Units: Meter		Meters			
DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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TITLE

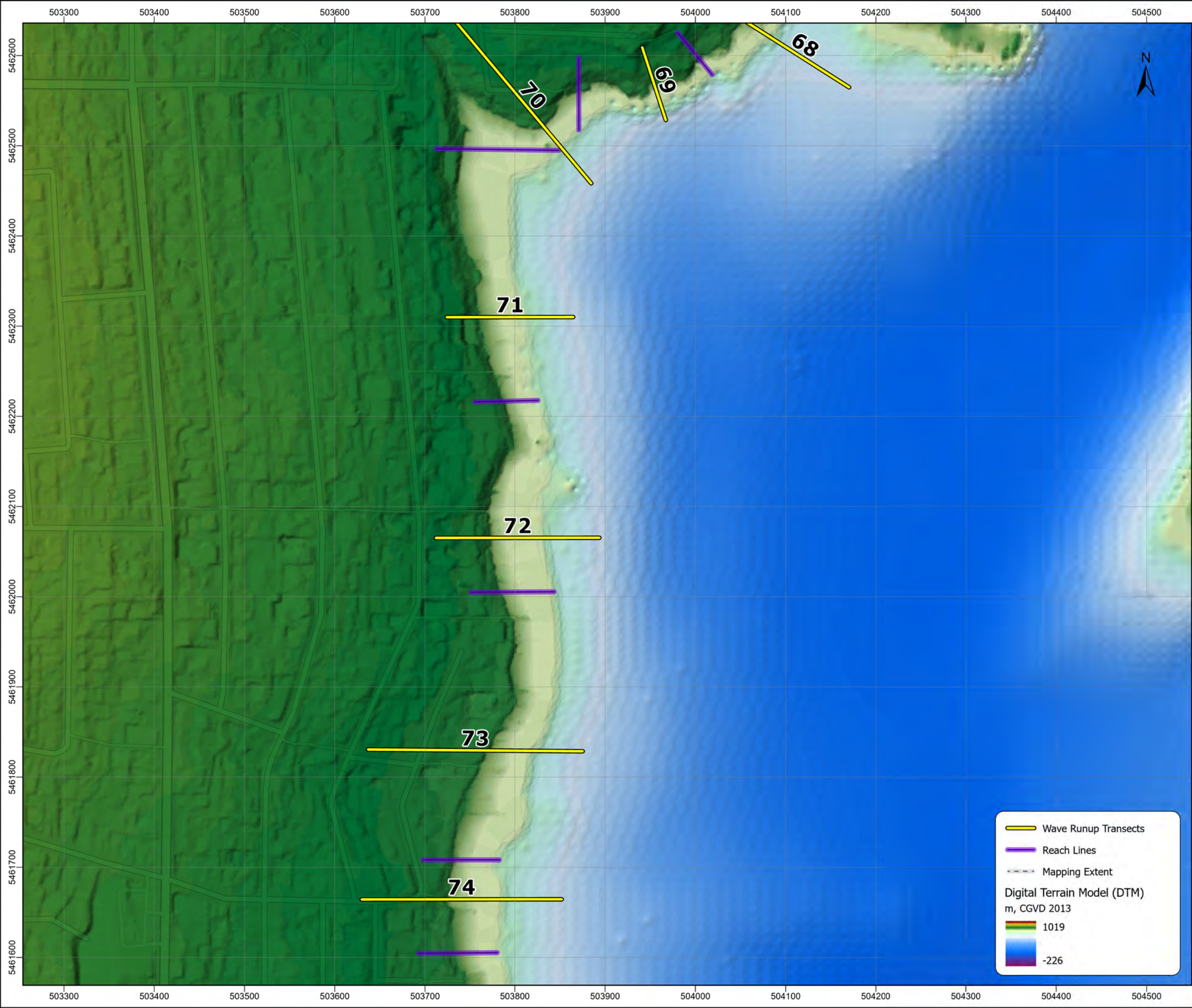
District of North Vancouver - Mapping References

Map 4 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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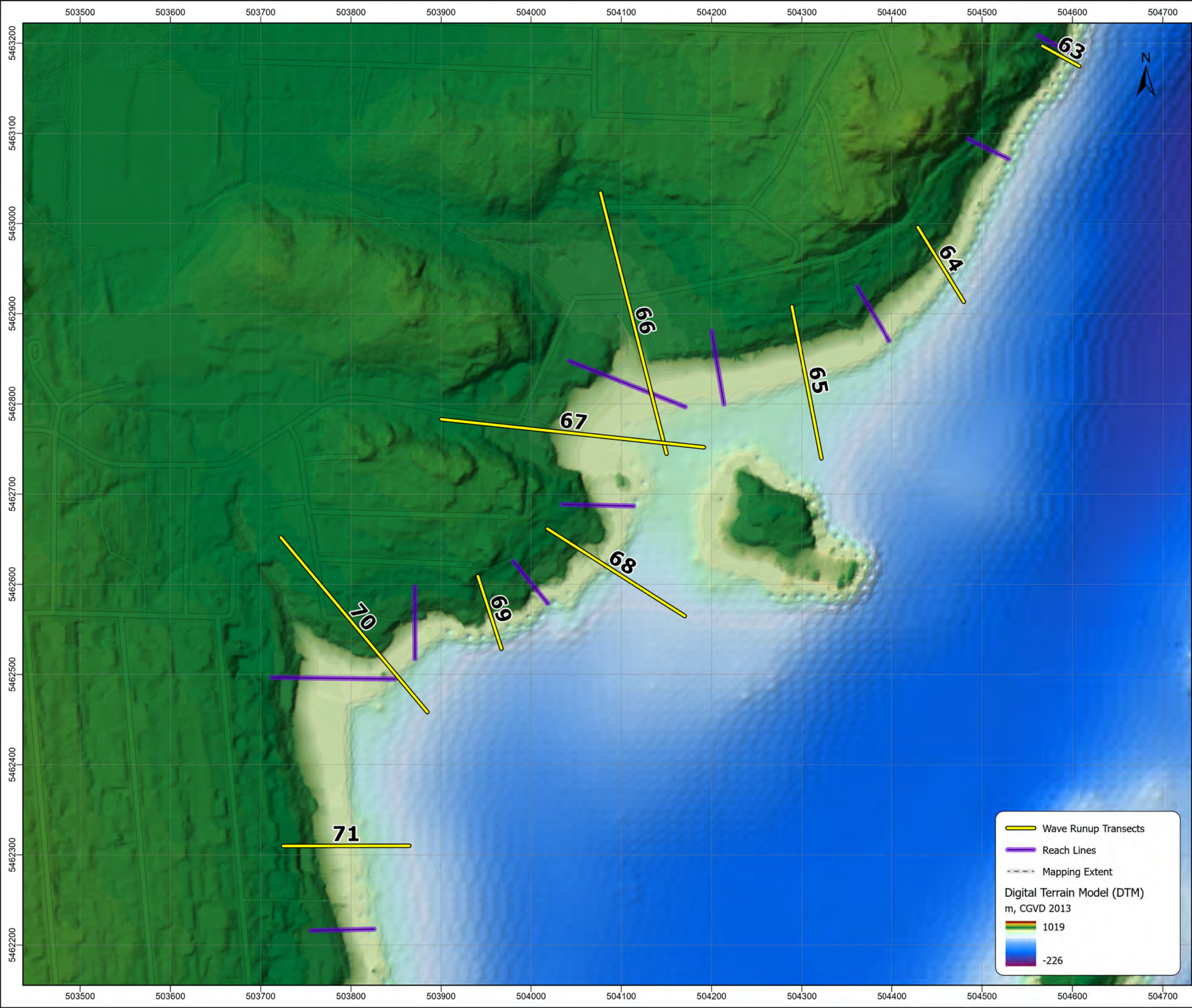
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TITLE
District of North Vancouver - Mapping References
Map 5 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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TITLE

District of North Vancouver - Mapping References

Map 6 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
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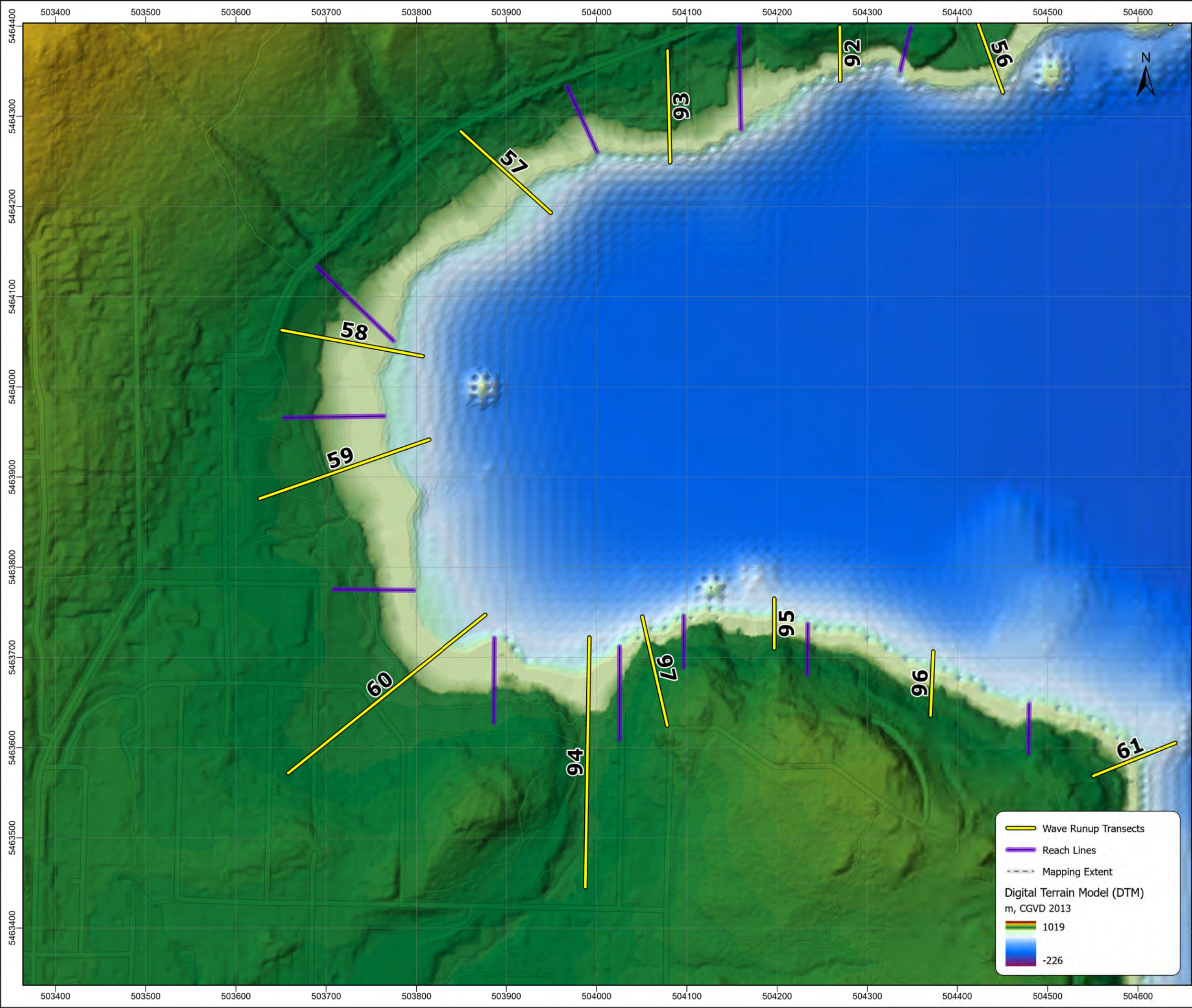
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TITLE
District of North Vancouver - Mapping References
Map 7 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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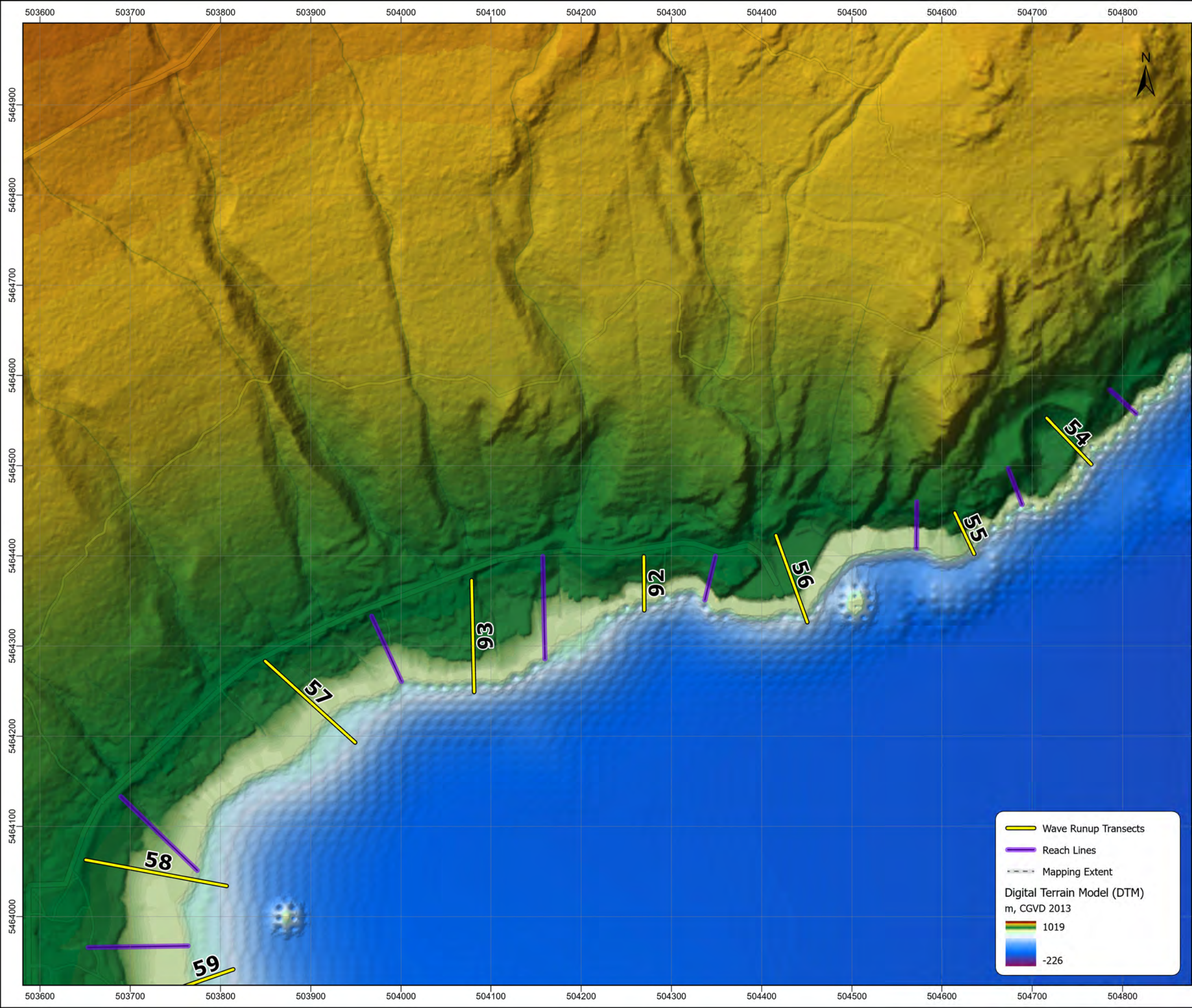
District of North Vancouver - Mapping References

Map 8 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
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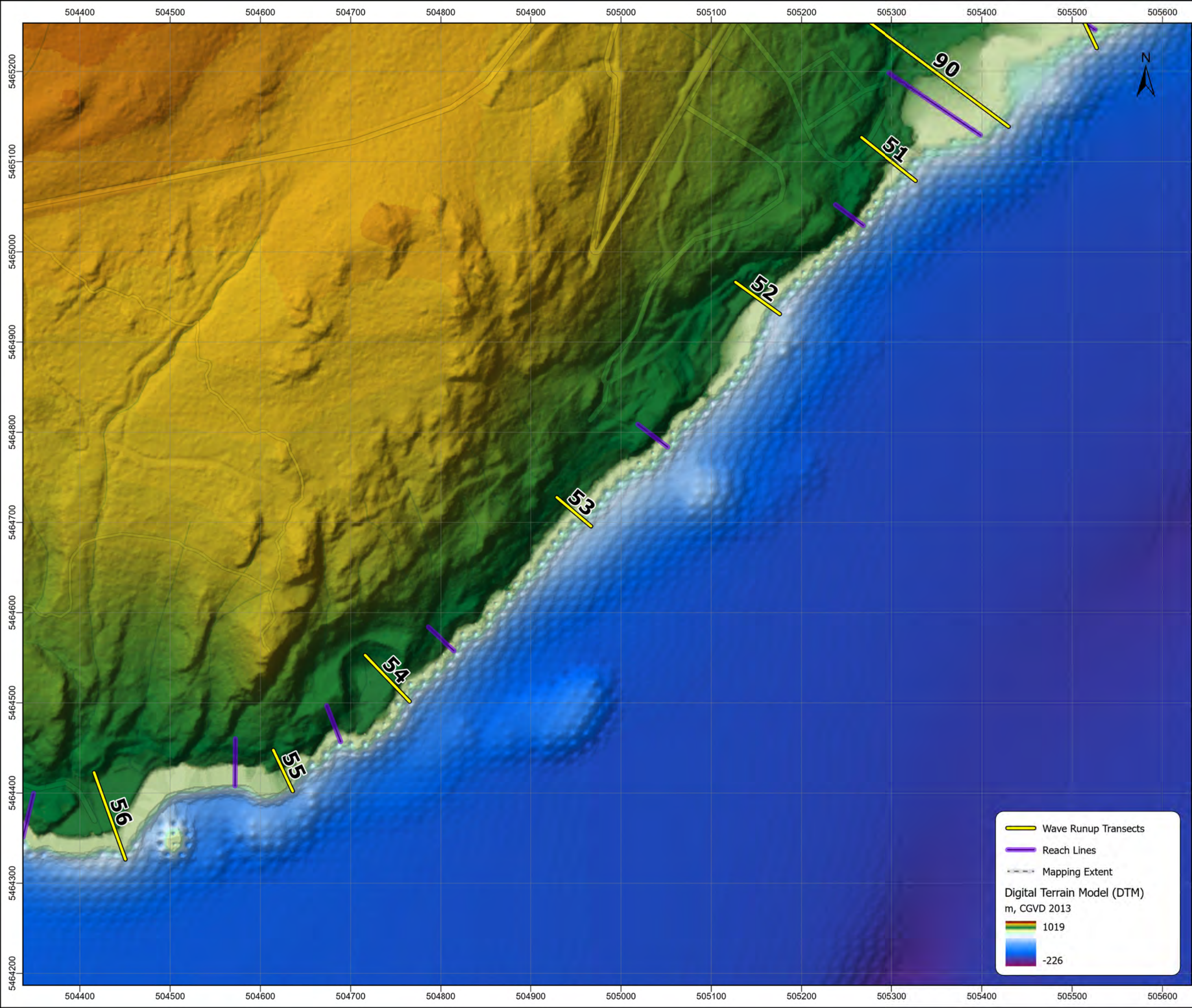
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CSRS: Canadian Spatial Reference System
TWL: Total Water Level
SLR: Sea Level Rise

TITLE
District of North Vancouver - Mapping References
Map 9 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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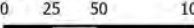
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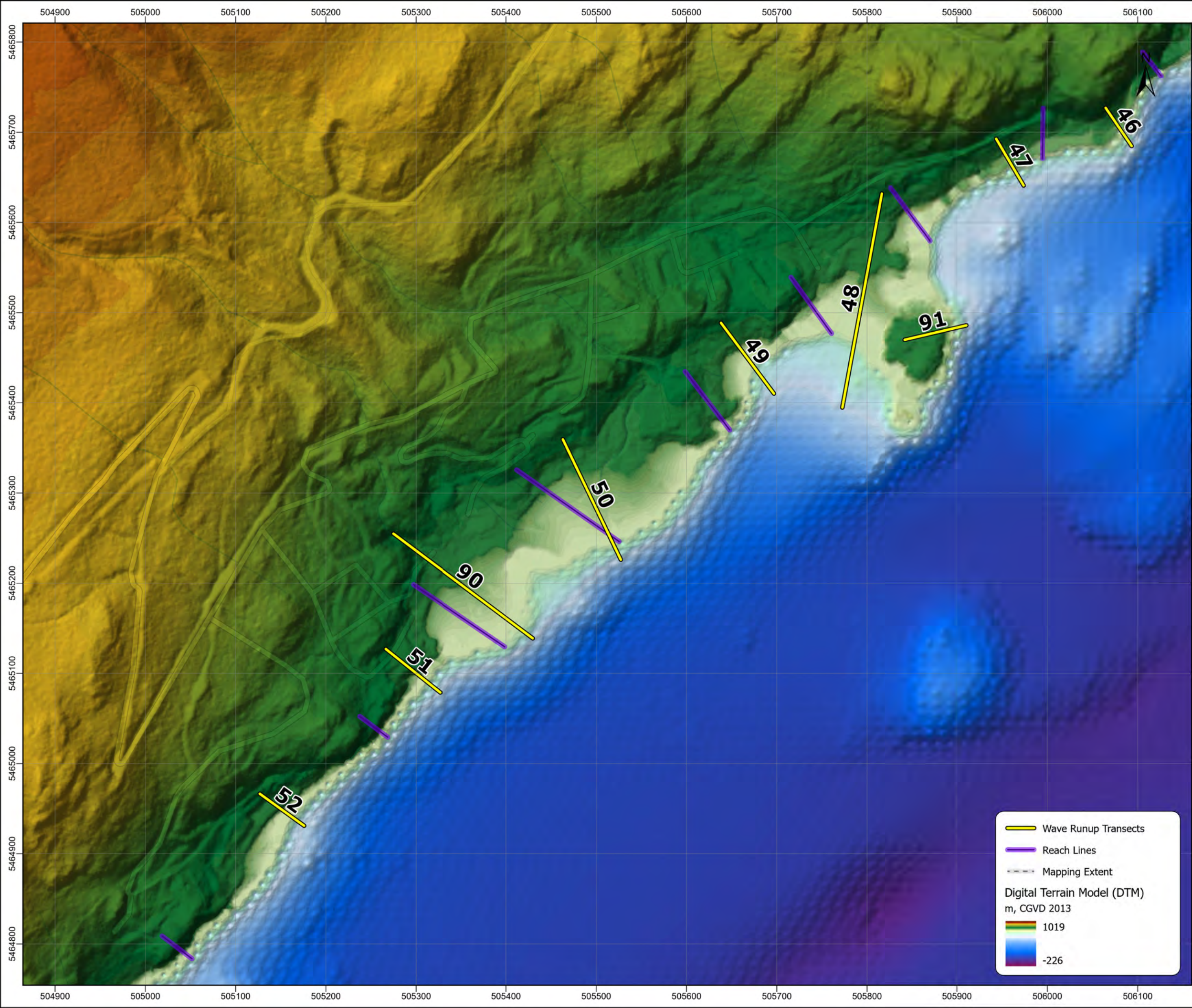
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TITLE					
District of North Vancouver - Mapping References					
Map 10 of 25					
PCS: NAD 1983 UTM Zone 10N		Scale: 1:4,000			
EPSG: 26910		0 25 50 100			
Datum: CGVD2013					
Map Units: Meter		 Meters			
DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121
					



Wave Runup Transects

Reach Lines

Mapping Extent

Digital Terrain Model (DTM)
m, CGVD 2013

1019

-226



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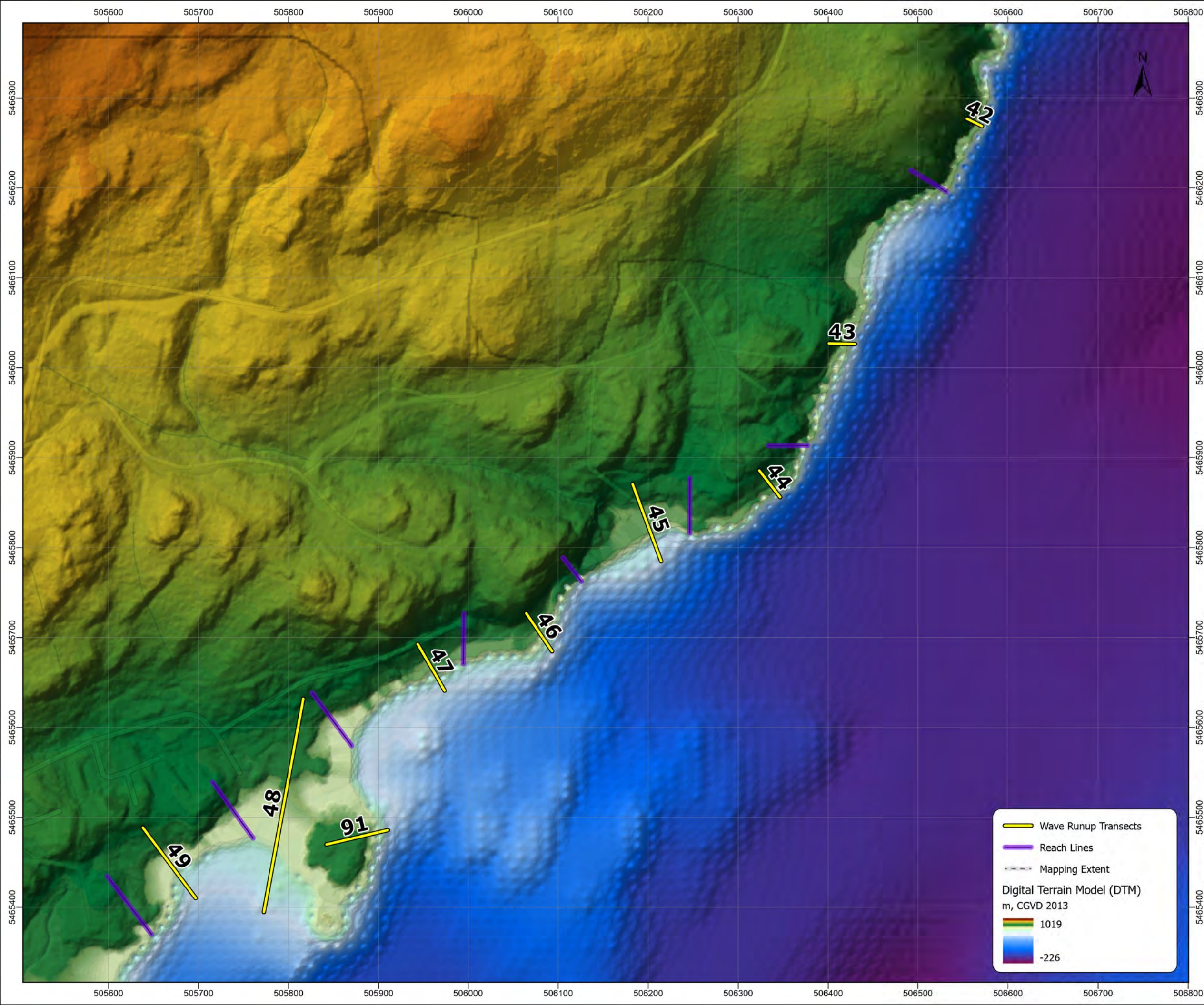
District of North Vancouver - Mapping References

Map 11 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

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REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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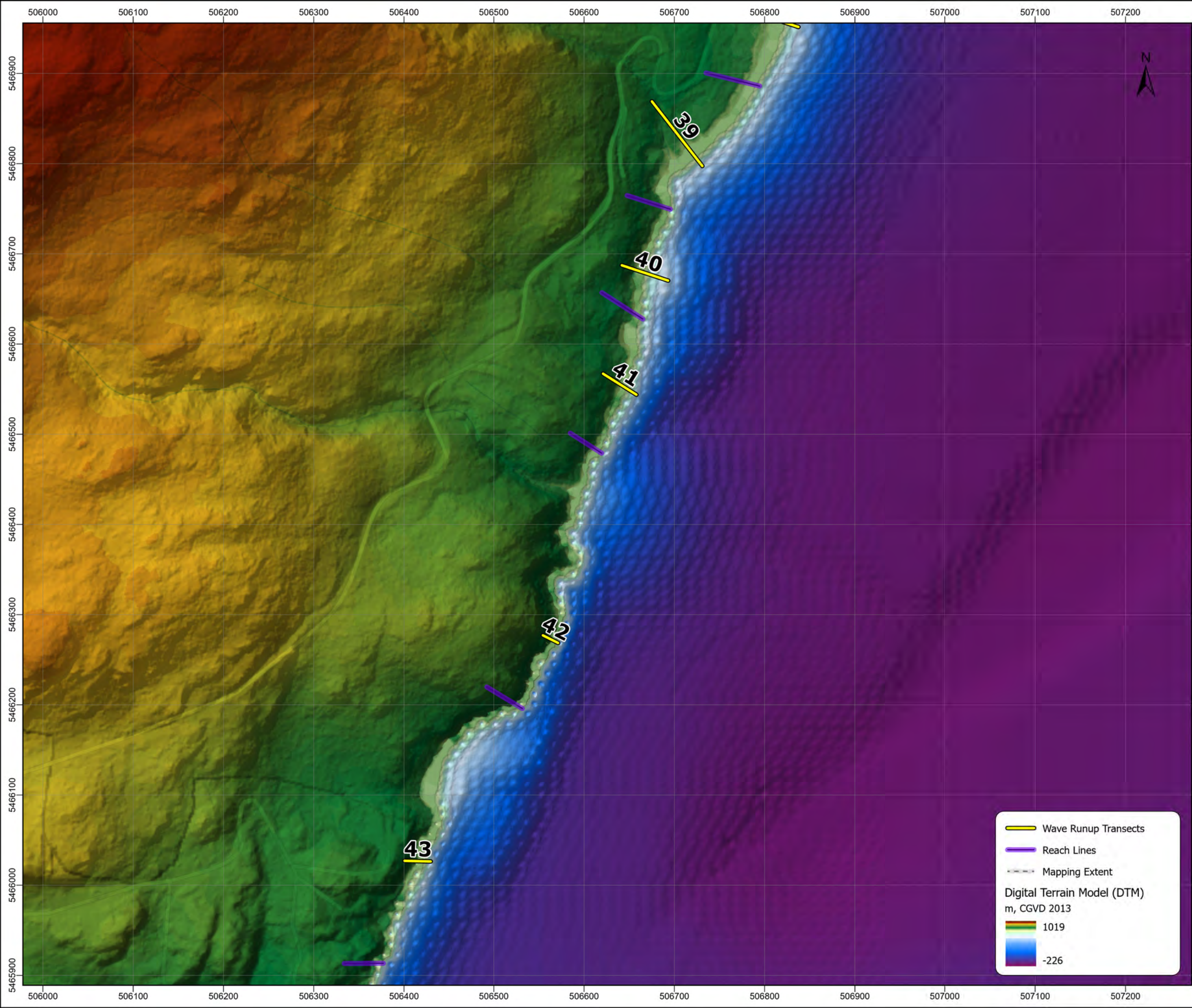
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TITLE District of North Vancouver - Mapping References Map 12 of 25			
PCS: NAD 1983 UTM Zone 10N EPSG: 26910 Datum: CGVD2013 Map Units: Meter		Scale: 1:4,000 0 25 50 100 Meters	
DATE	2024-05-24	AUTHOR	SSIN
REVISION	1	REVIEWER	DANK
APPROVER		DANK	
DHI PROJECT NUMBER		42804121	





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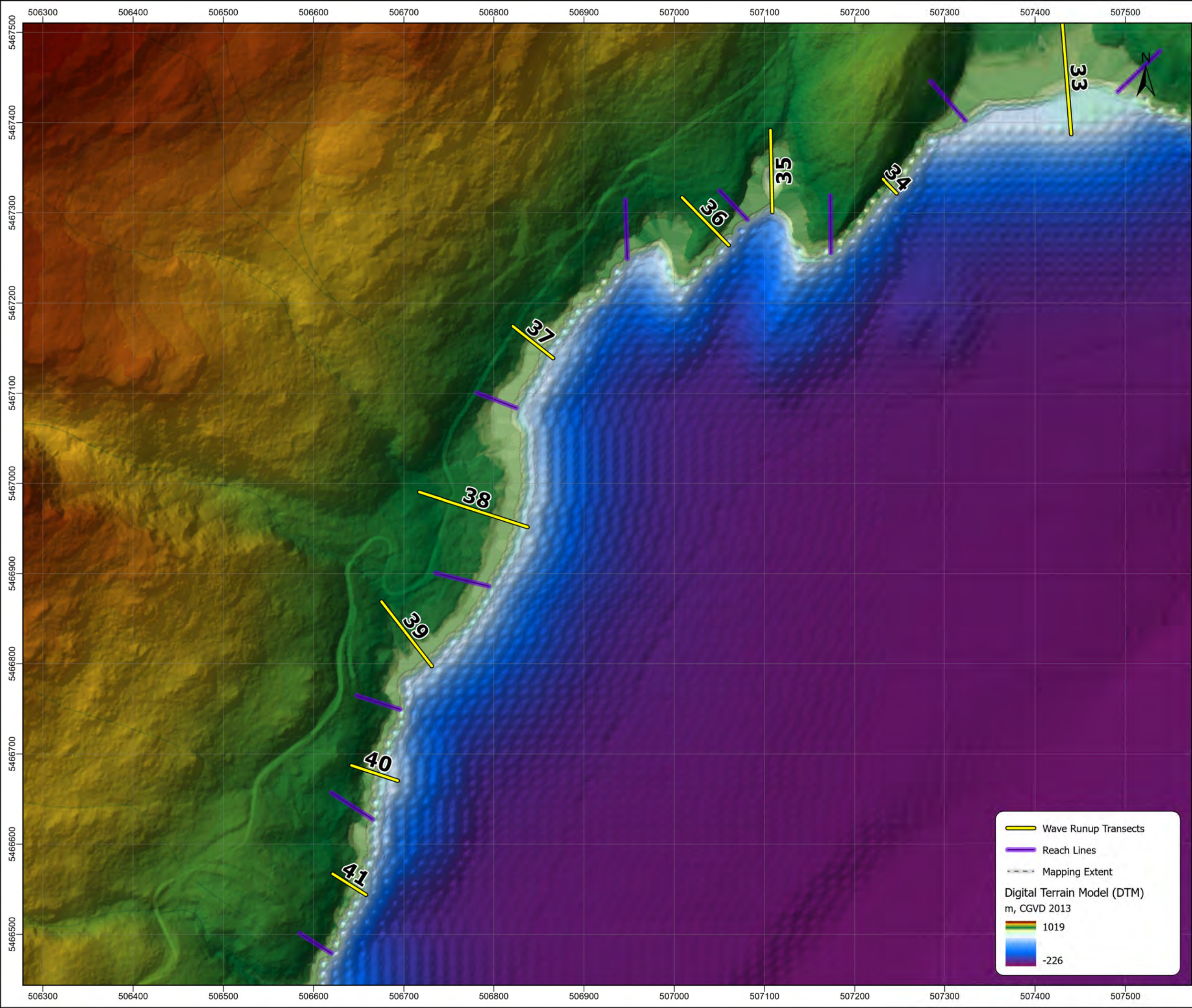
District of North Vancouver - Mapping References

Map 13 of 25

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Scale: 1:4,000
0 25 50 100
Meters

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District of North Vancouver - Mapping References

Map 14 of 25

PCS: NAD 1983 UTM Zone 10N

EPSG: 26910

Datum: CGVD2013

Map Units: Meter

Scale: 1:4,000

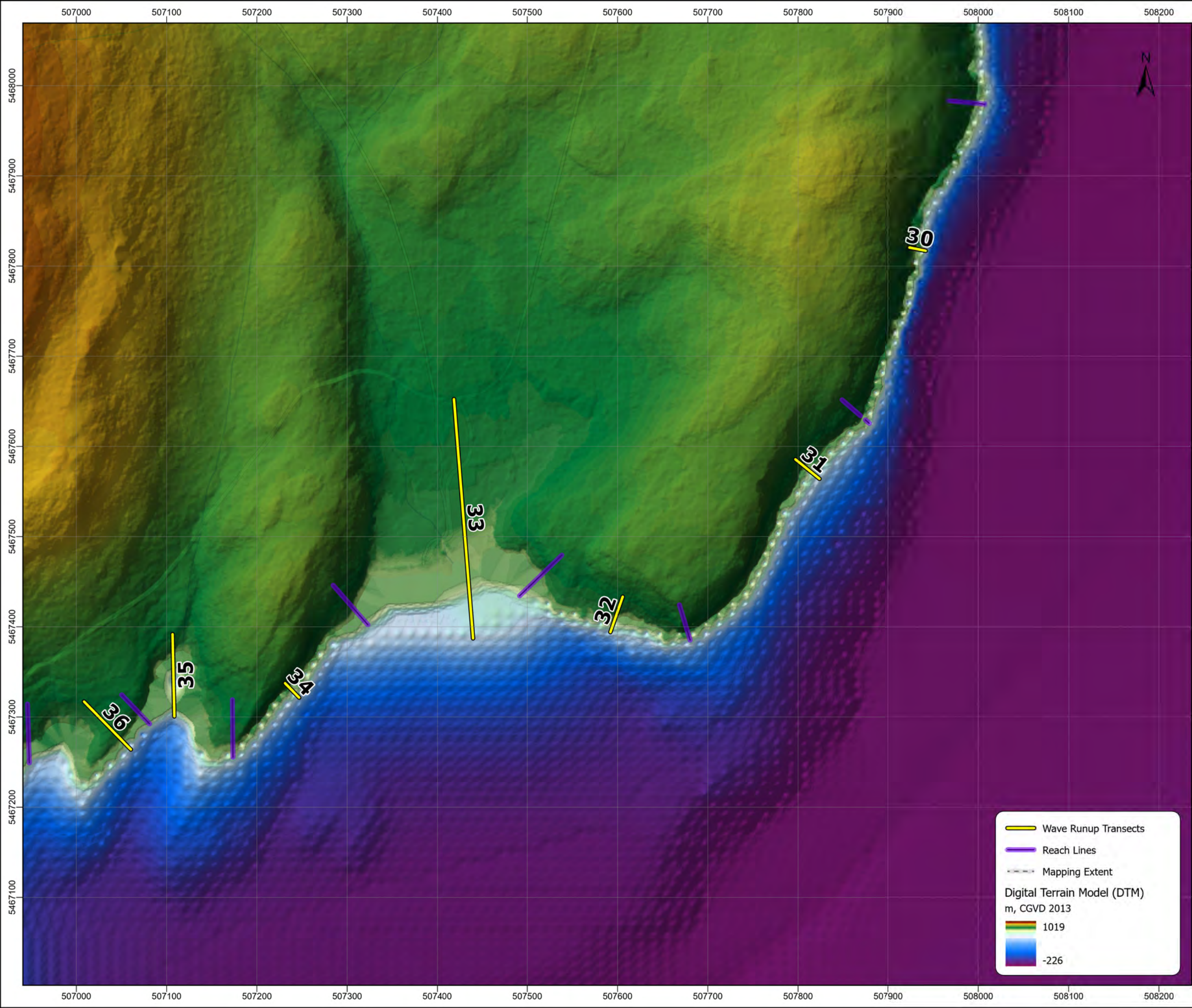
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DISTRICT OF NORTH VANCOUVER

DHI



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TWL: Total Water Level
SLR: Sea Level Rise

TITLE

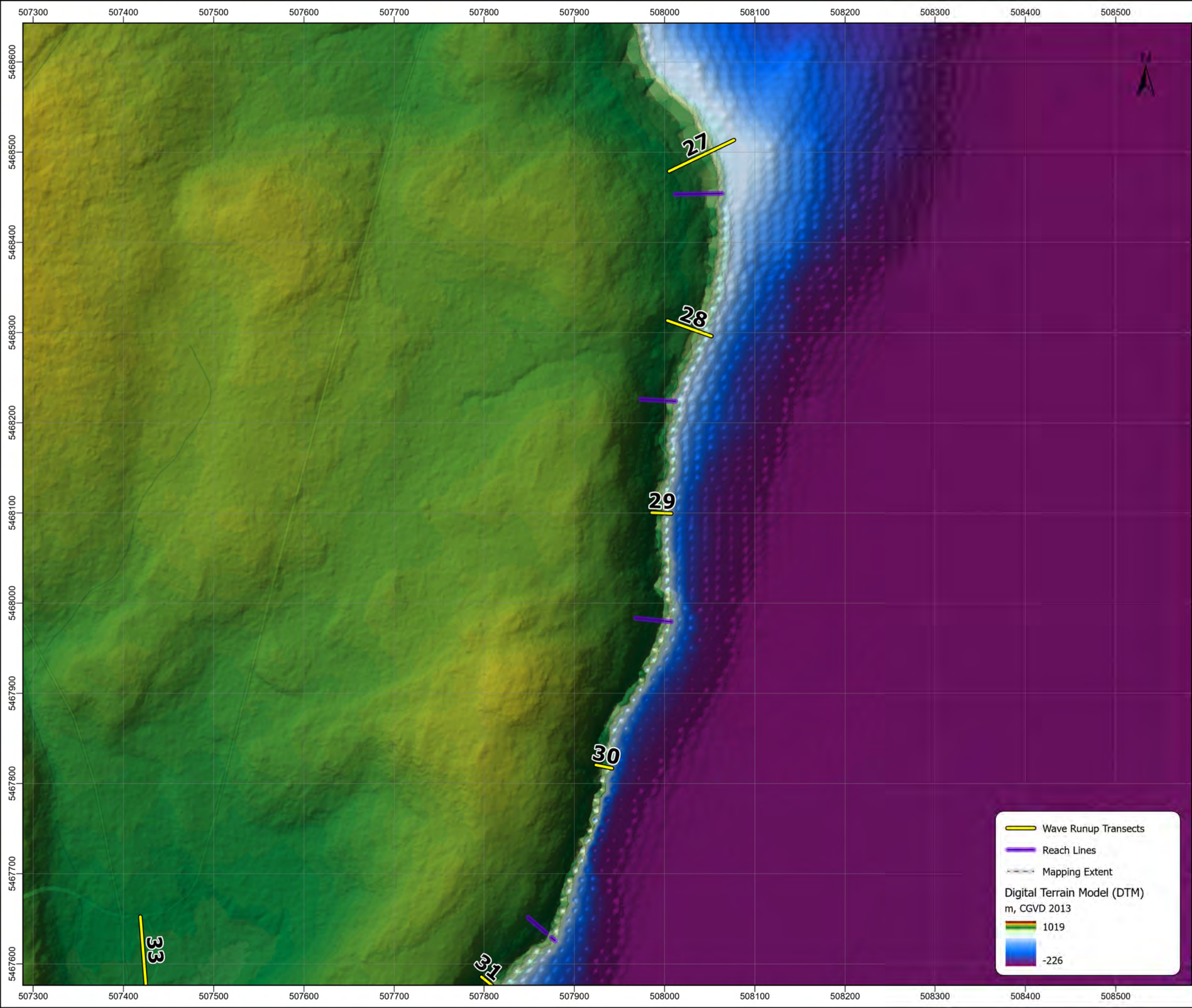
District of North Vancouver - Mapping References

Map 15 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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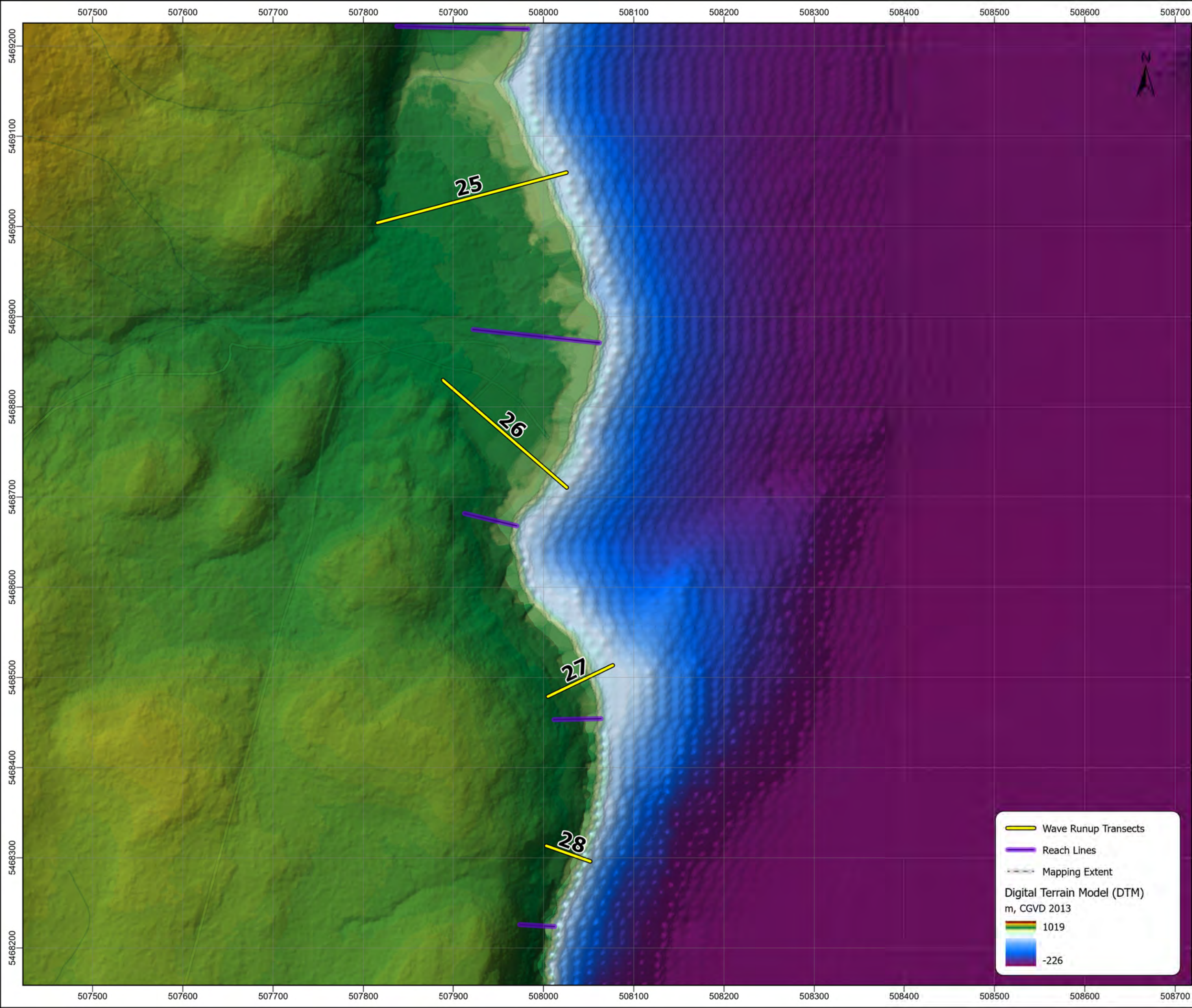
District of North Vancouver - Mapping References

Map 16 of 25

PCS: NAD 1983 UTM Zone 10N
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Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

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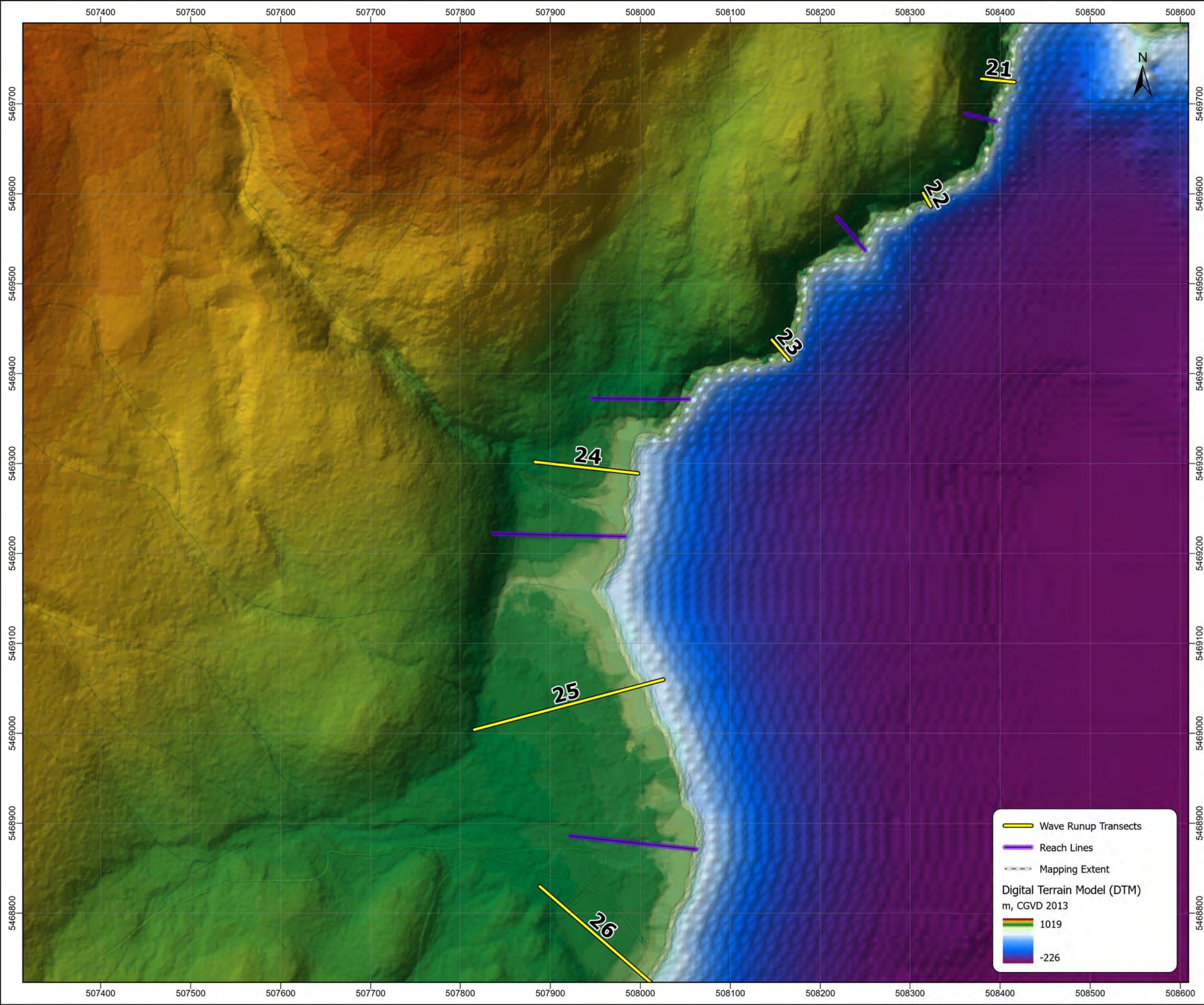
District of North Vancouver - Mapping References

Map 17 of 25

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0 25 50 100
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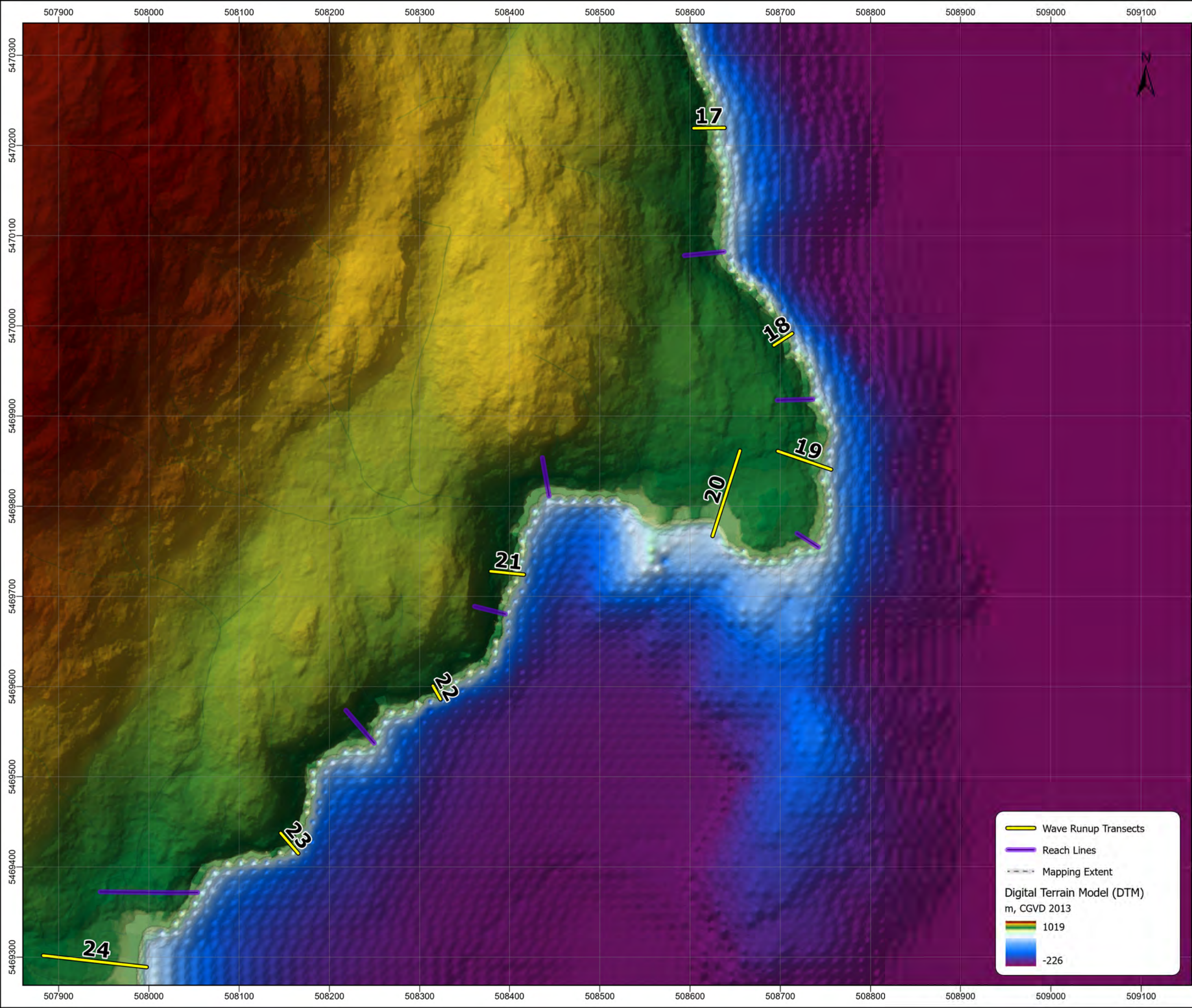
District of North Vancouver - Mapping References

Map 18 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

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0 25 50 100
Meters

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District of North Vancouver - Mapping References

Map 19 of 25

PCS: NAD 1983 UTM Zone 10N

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Datum: CGVD2013

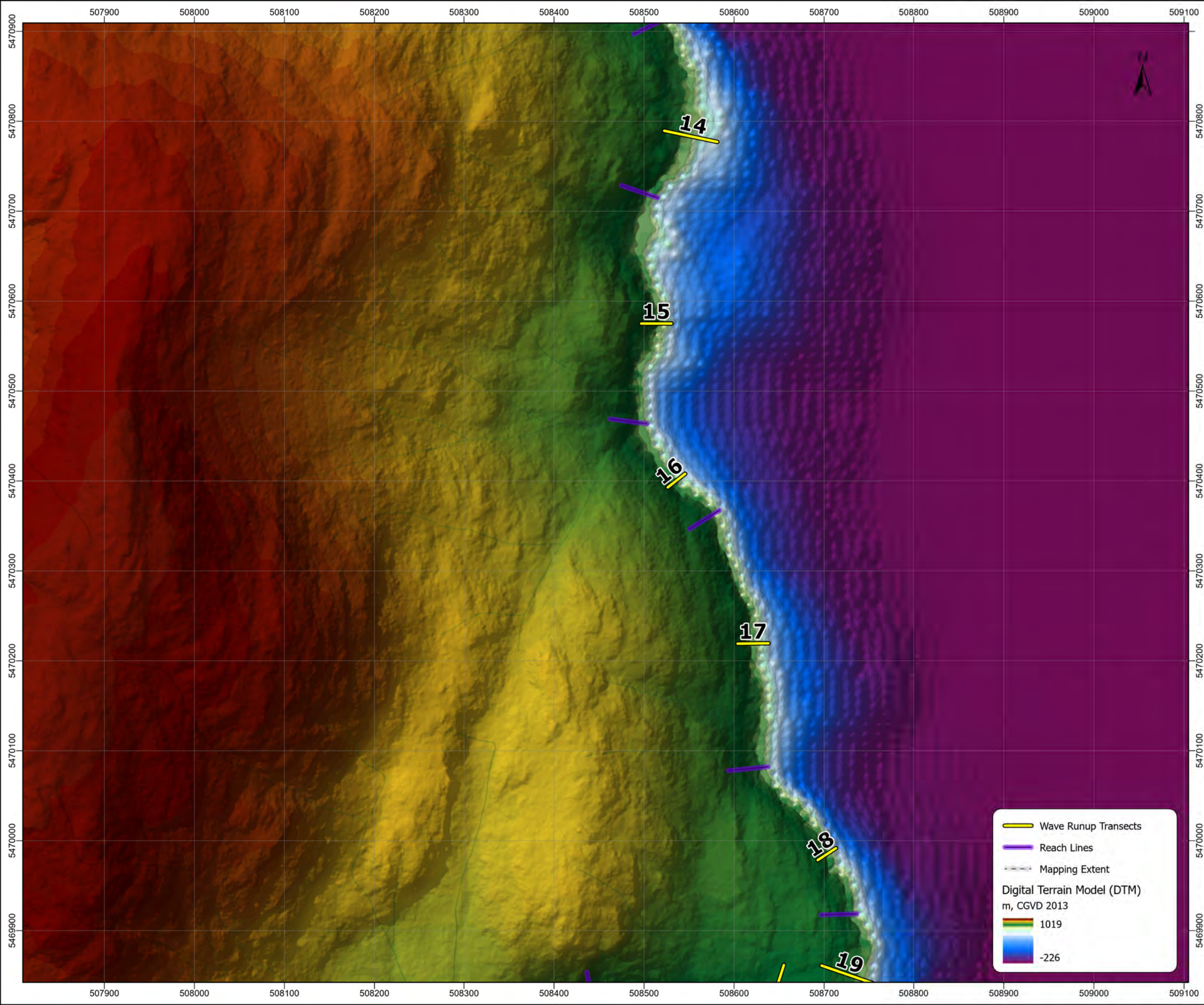
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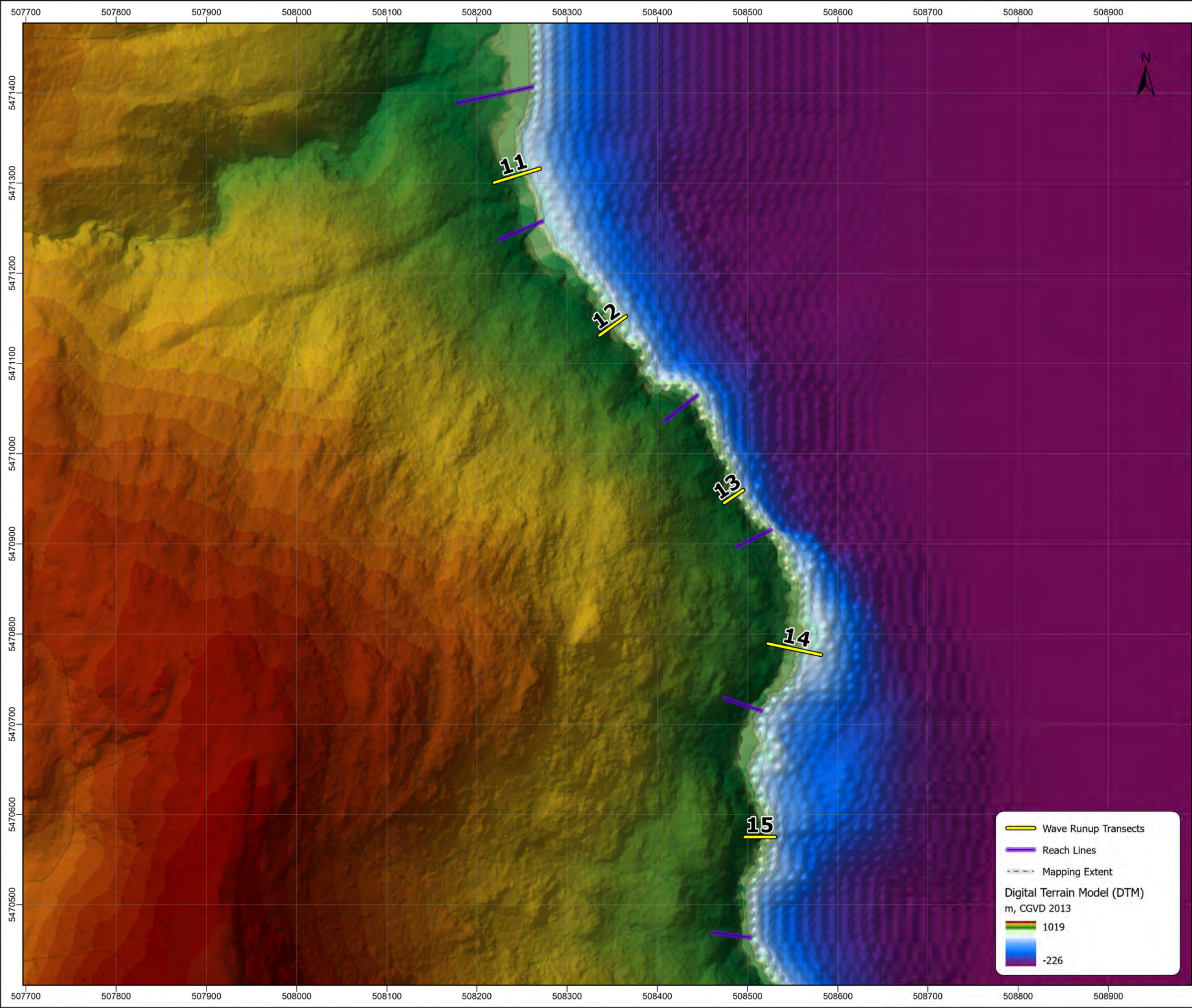
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TITLE
District of North Vancouver - Mapping References
Map 20 of 25

PCS: NAD 1983 UTM Zone 10N
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SLR: Sea Level Rise

TITLE

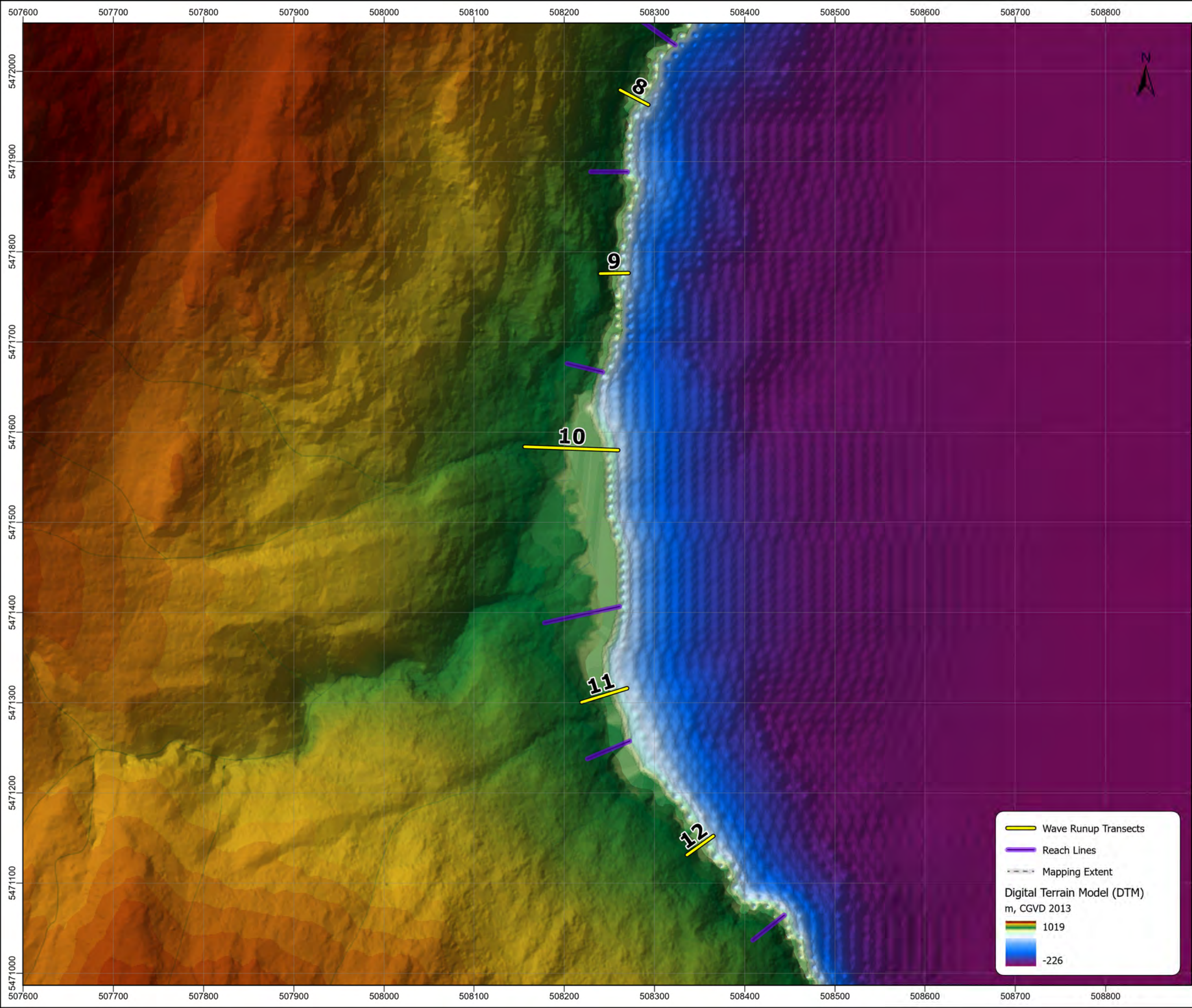
District of North Vancouver - Mapping References

Map 21 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



Wave Runup Transects

Reach Lines

Mapping Extent

Digital Terrain Model (DTM)
m, CGVD 2013

1019

-226



Overview:
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 - Erosion, riverine hazards and overland flood effects are not included.
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- Data Sources:**
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 - 2022 District of North Vancouver LIDAR data.
 - Background imagery supplied by Esri and orthophotos by the District of North Vancouver (2016)
 - Infrastructure Footprints, natural and administrative boundaries provided by the District of North Vancouver GIS Department.

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CSRS: Canadian Spatial Reference System
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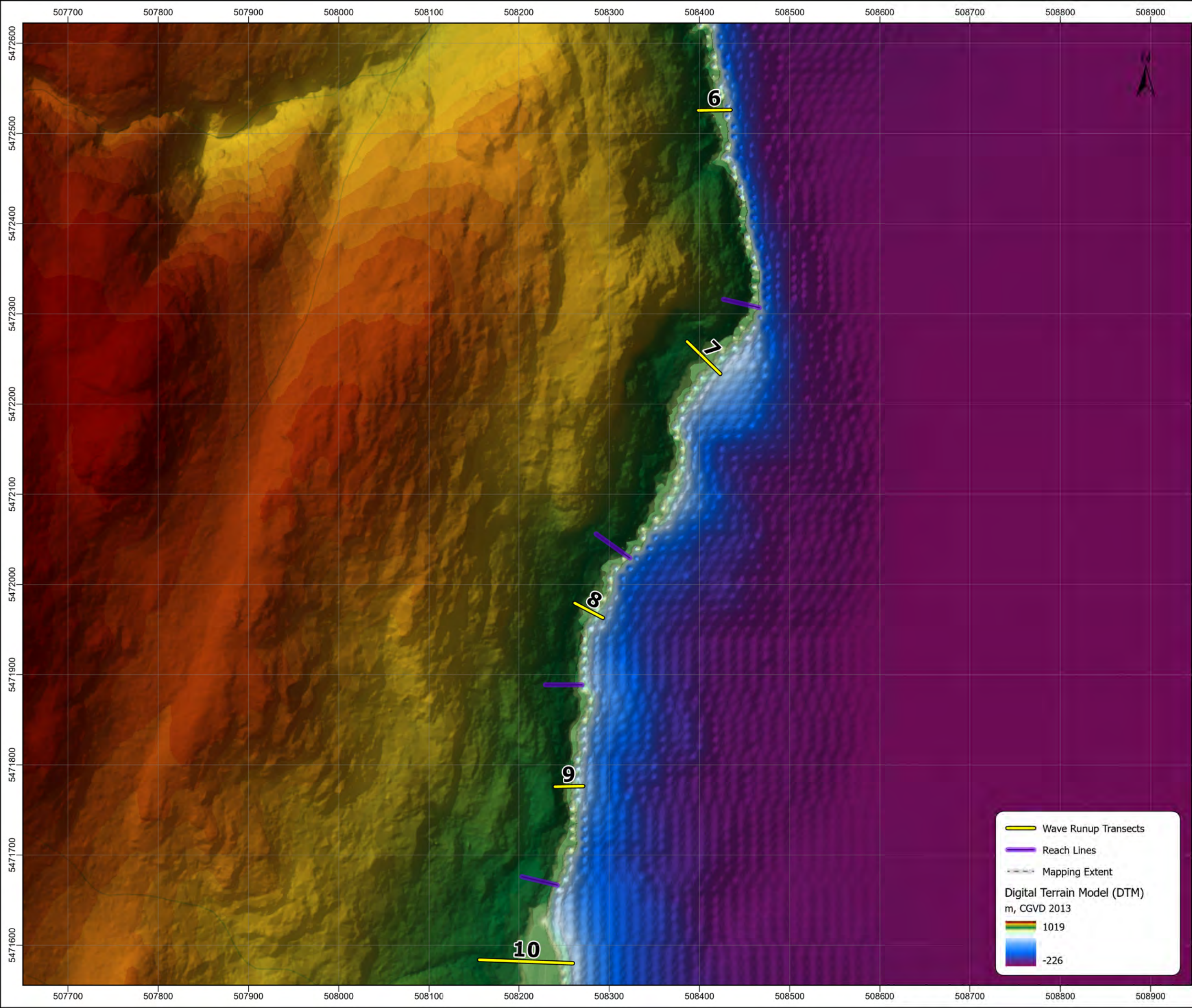
TITLE
District of North Vancouver - Mapping References
Map 22 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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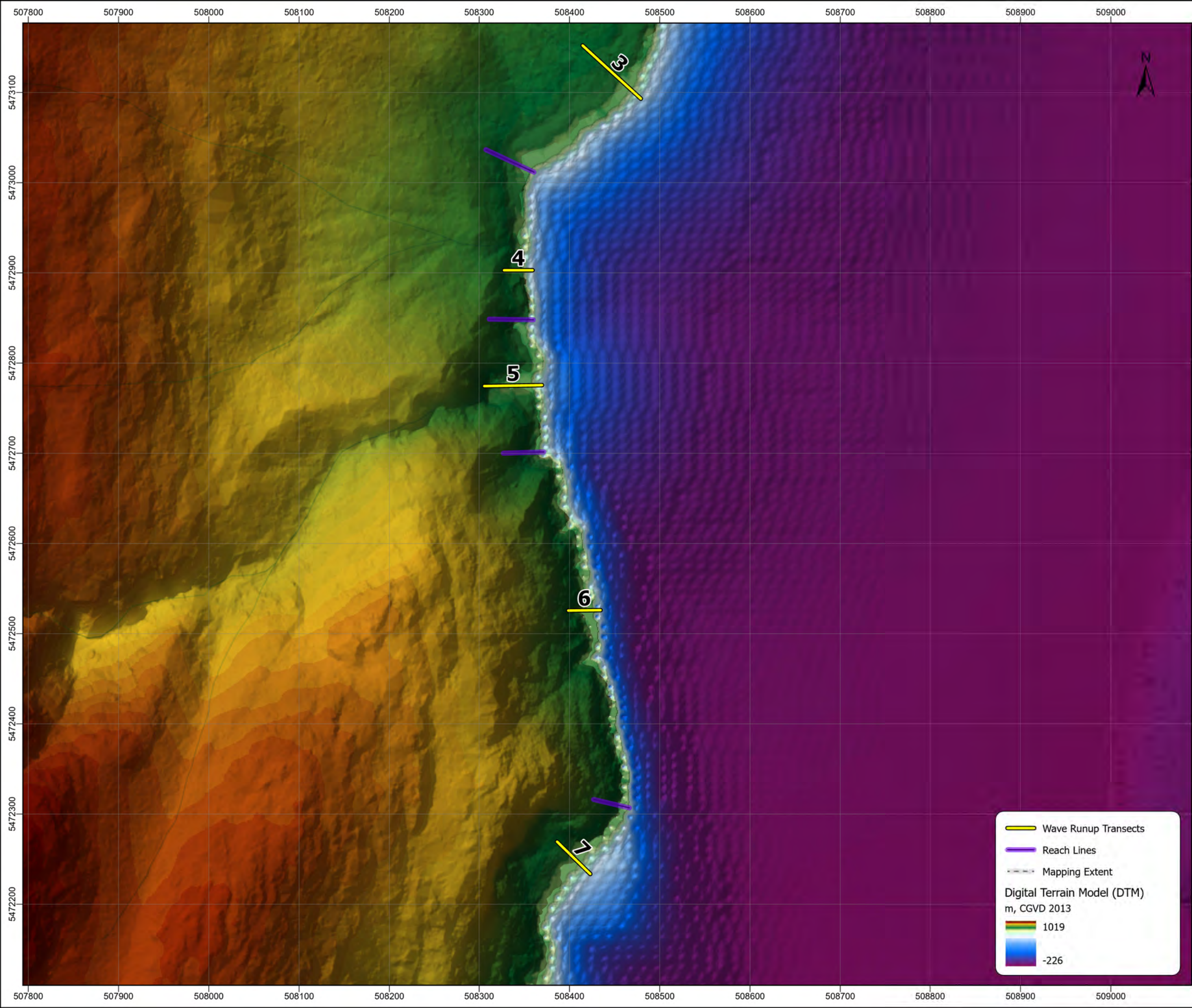
TITLE
District of North Vancouver - Mapping References
Map 23 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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TITLE

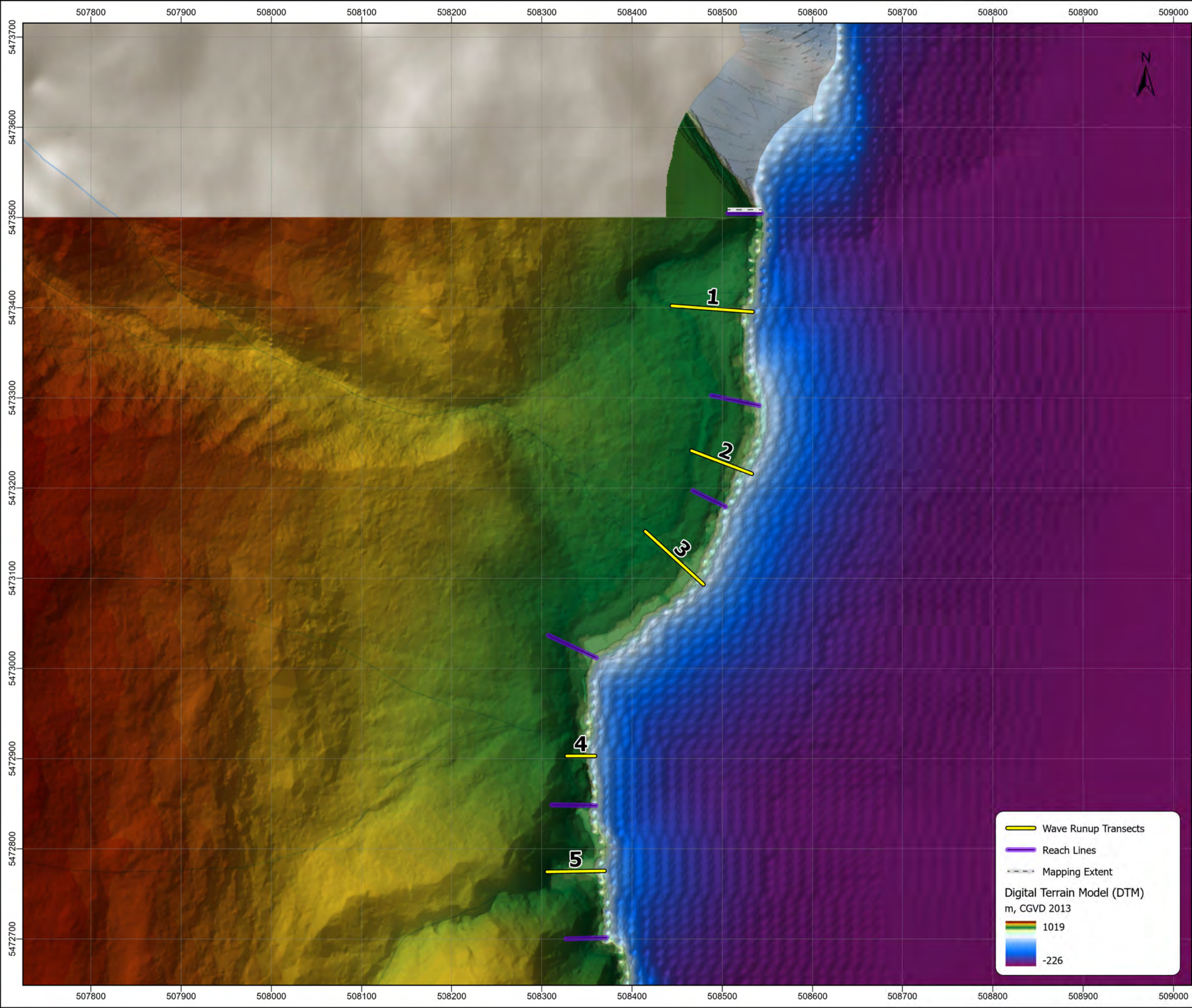
District of North Vancouver - Mapping References

Map 24 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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TITLE

District of North Vancouver - Mapping References

Map 25 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121

Appendix D.2 Transect Profiles

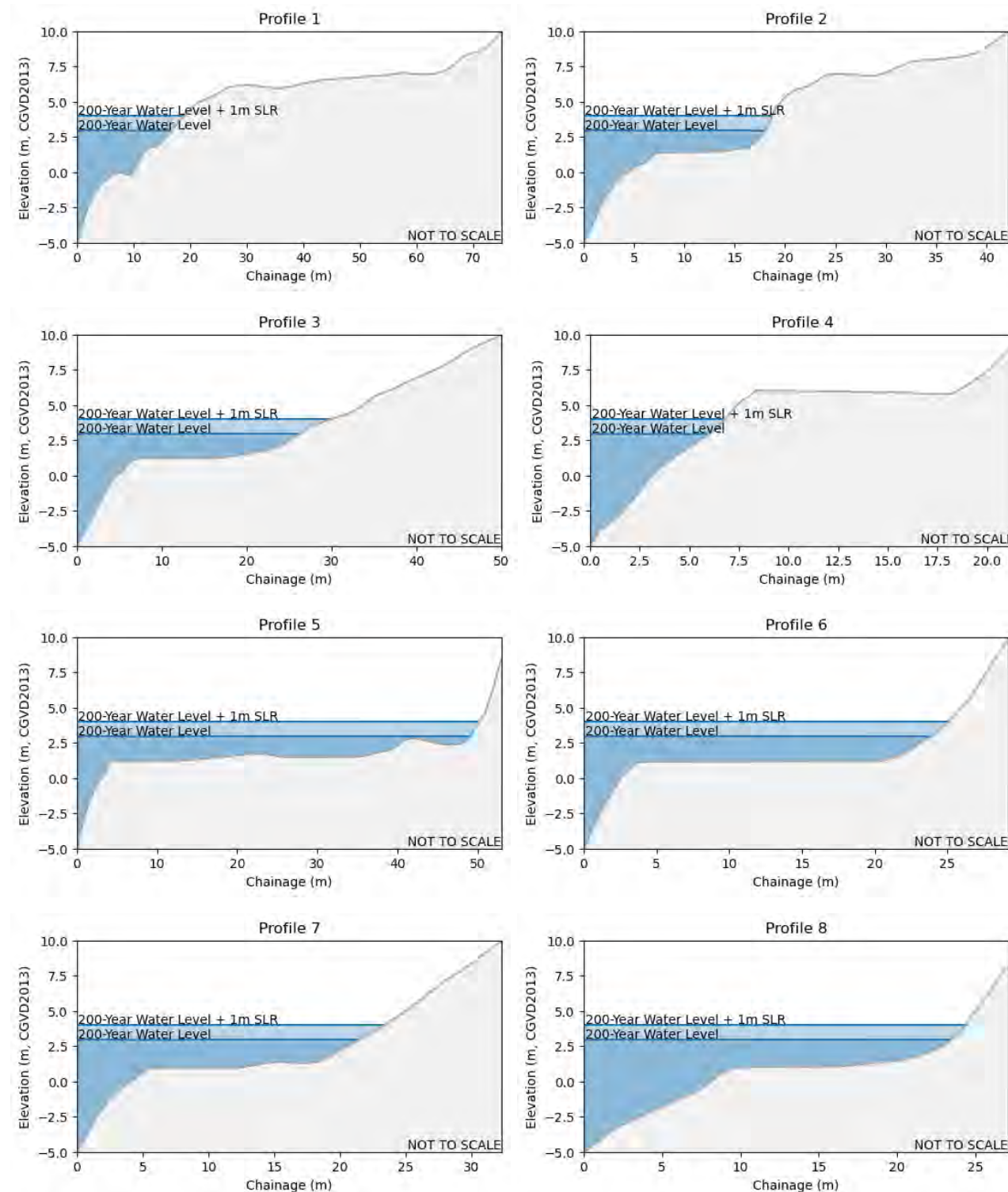


Figure D.1 Wave Runup Profiles 1 to 8

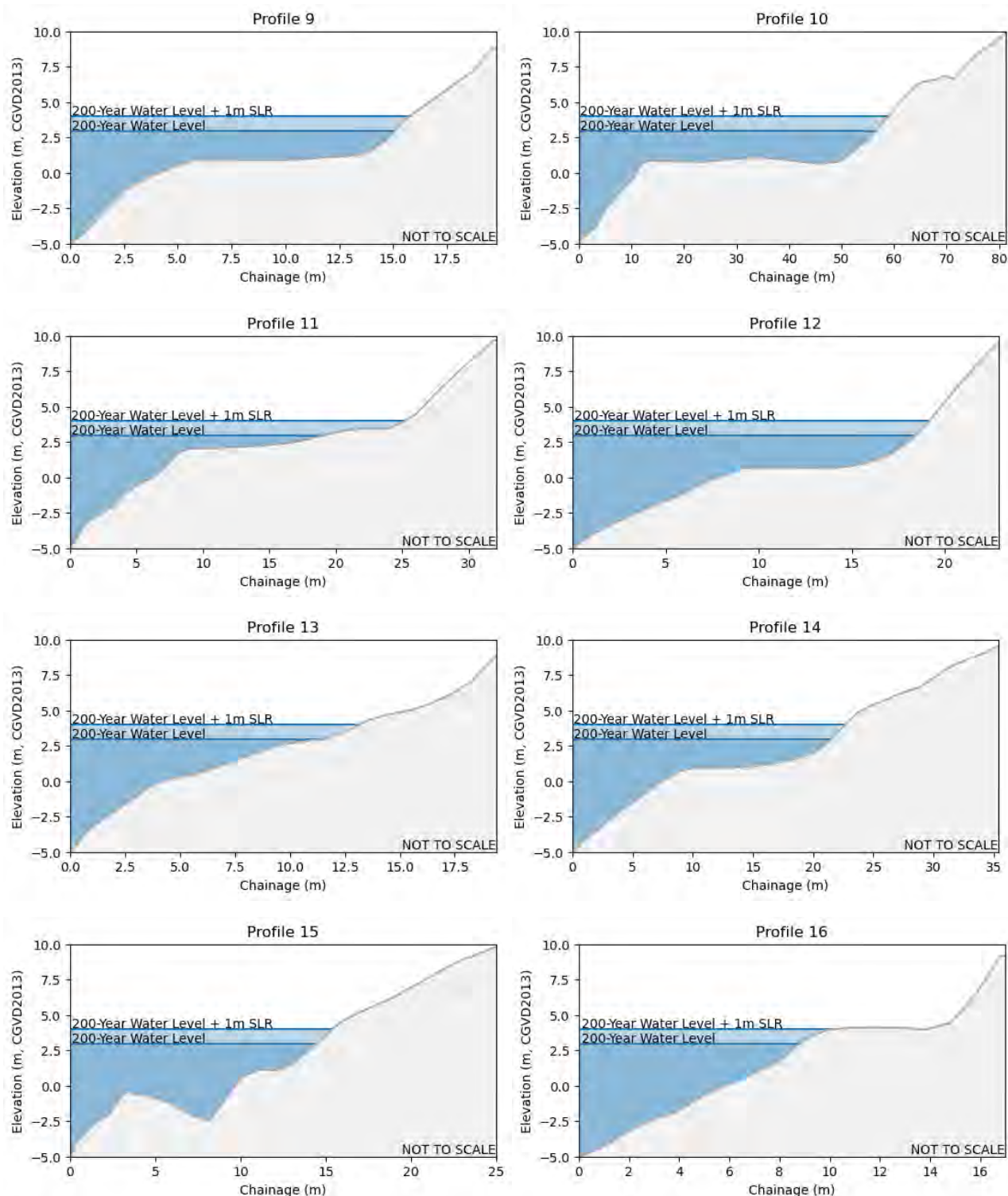


Figure D.2 Wave Runup Profiles 9 to 16

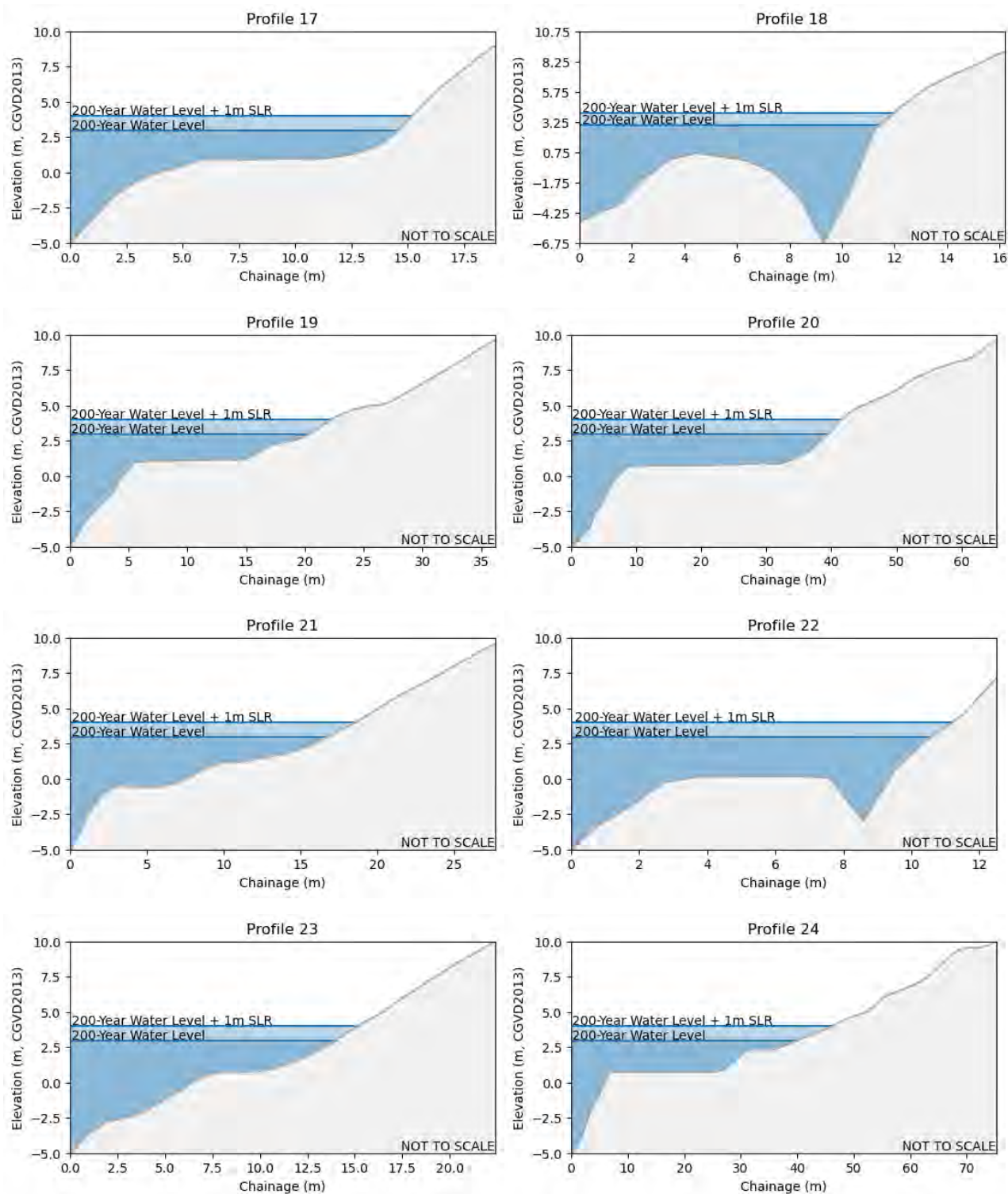


Figure D.3 Wave Runup Profiles 17 to 24

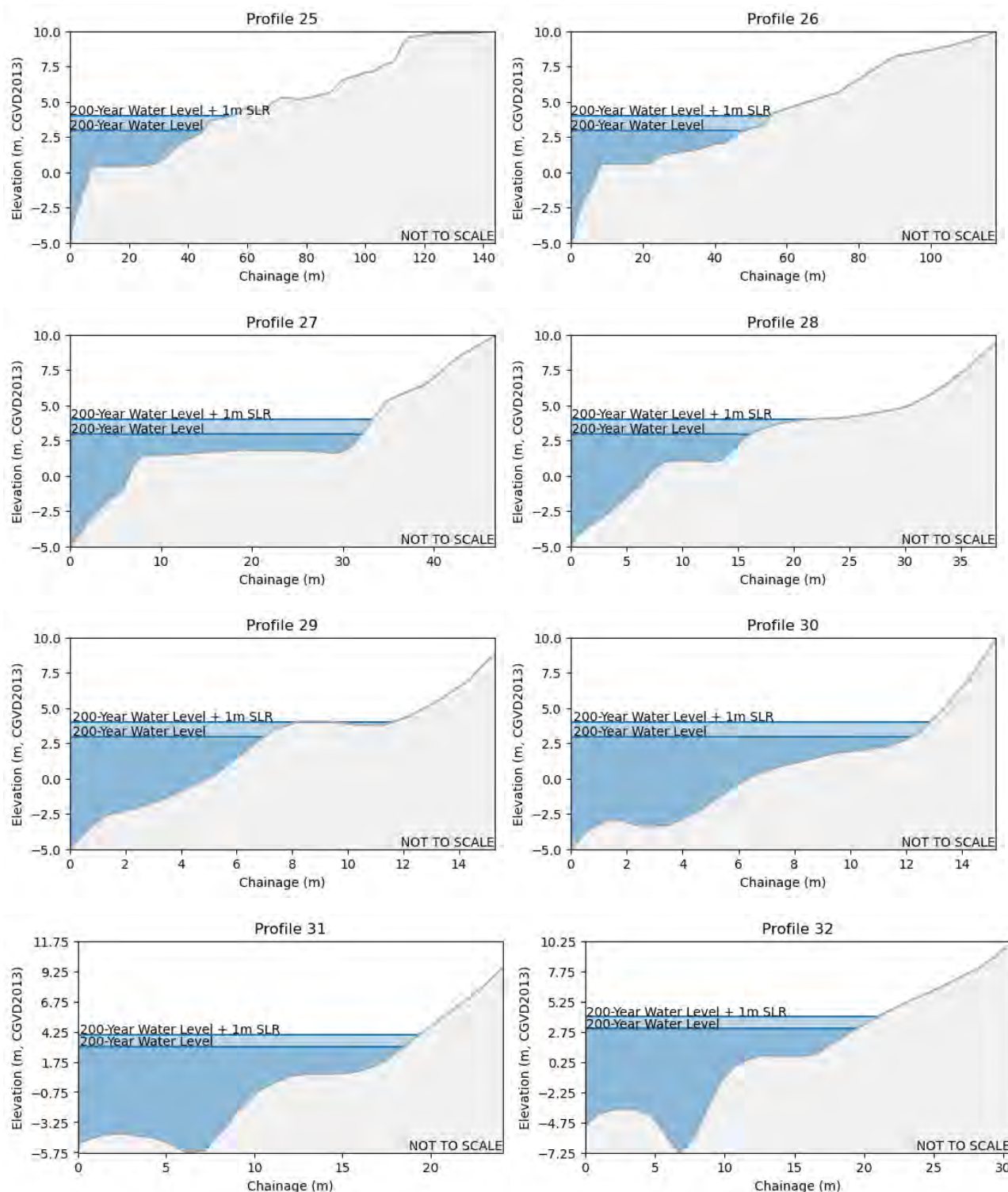


Figure D.4 Wave Runup Profiles 25 to 32

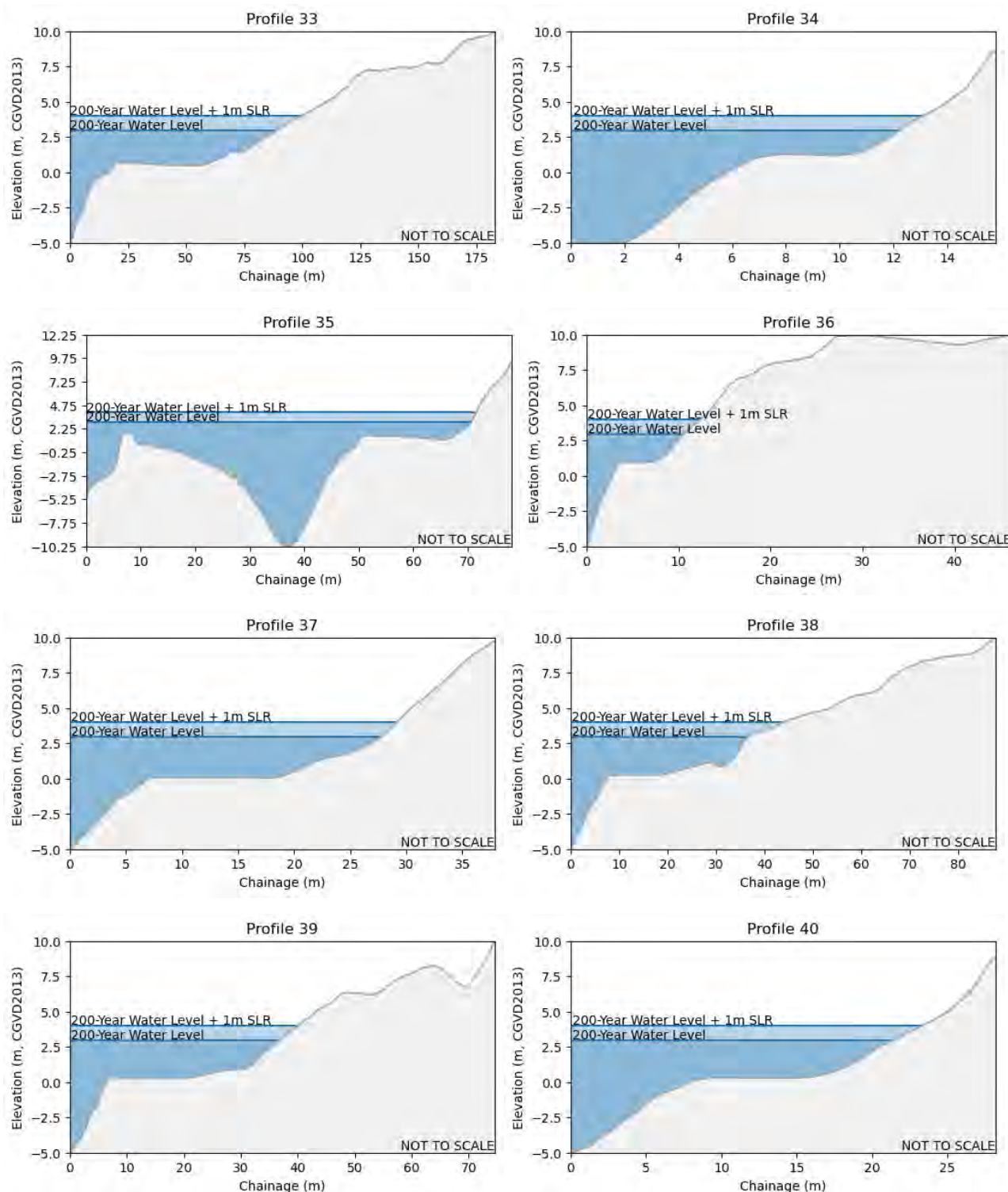


Figure D.5 Wave Runup Profiles 33 to 40

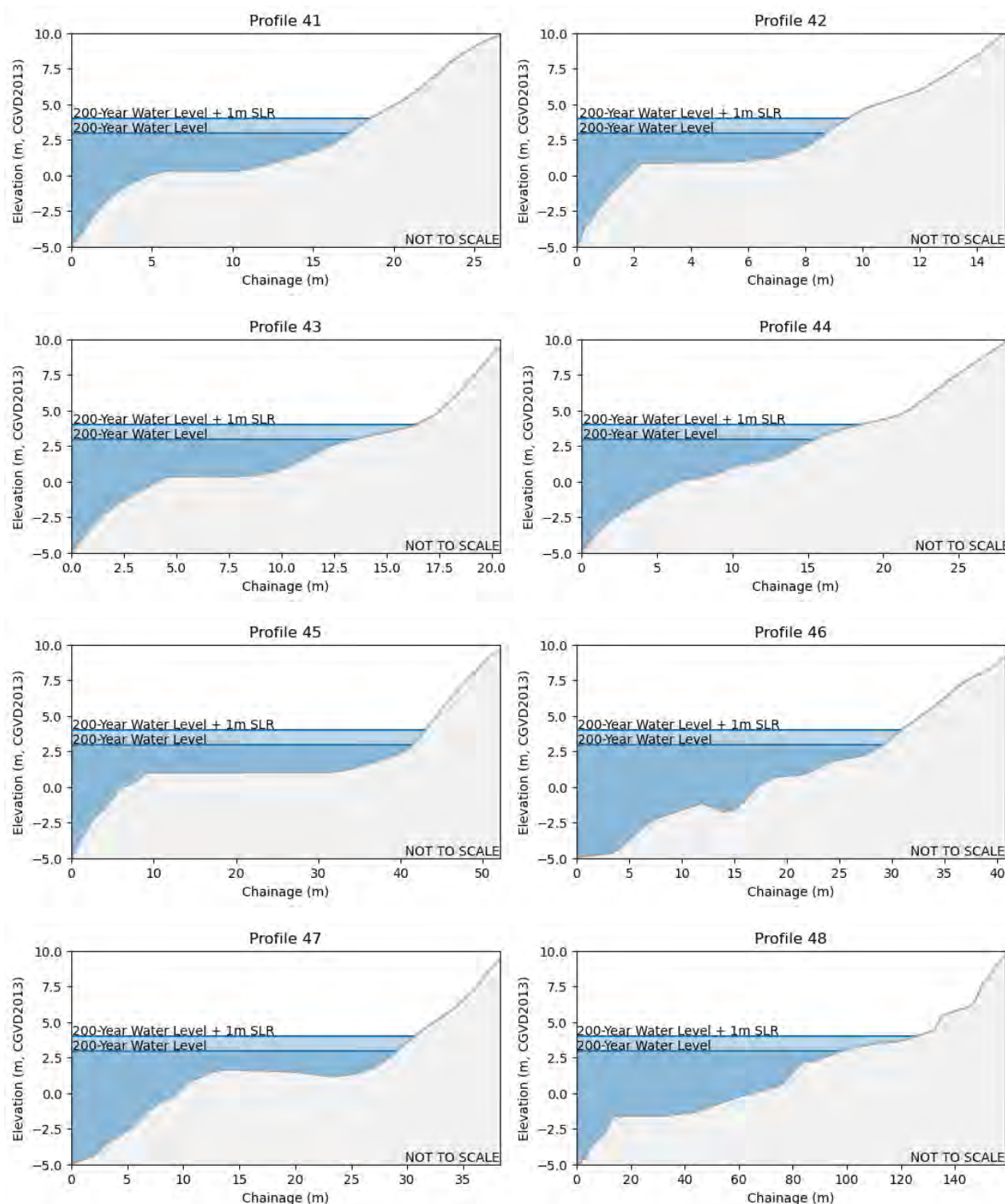


Figure D.6 Wave Runup Profiles 41 to 48

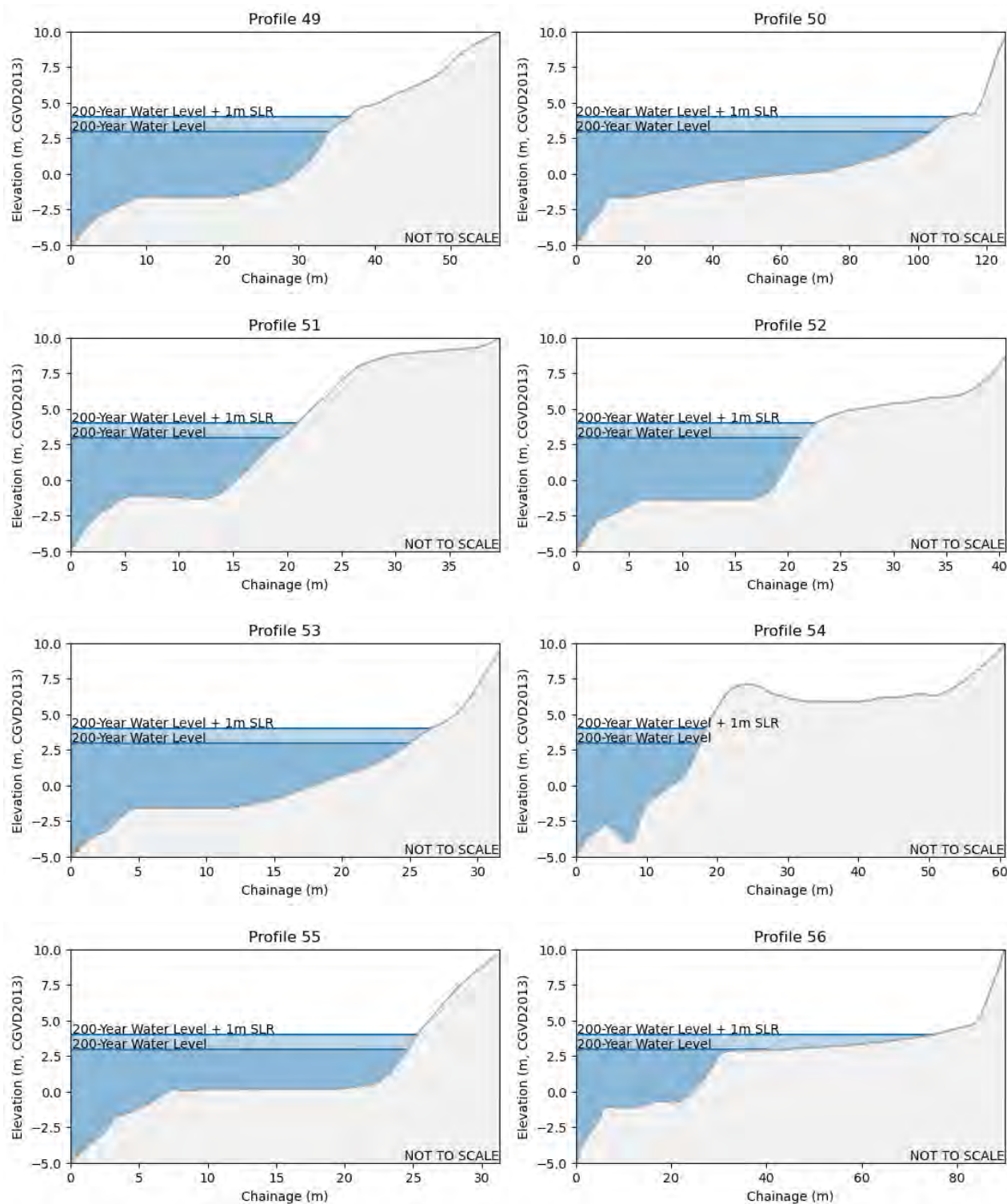


Figure D.7 Wave Runup Profiles 49 to 56

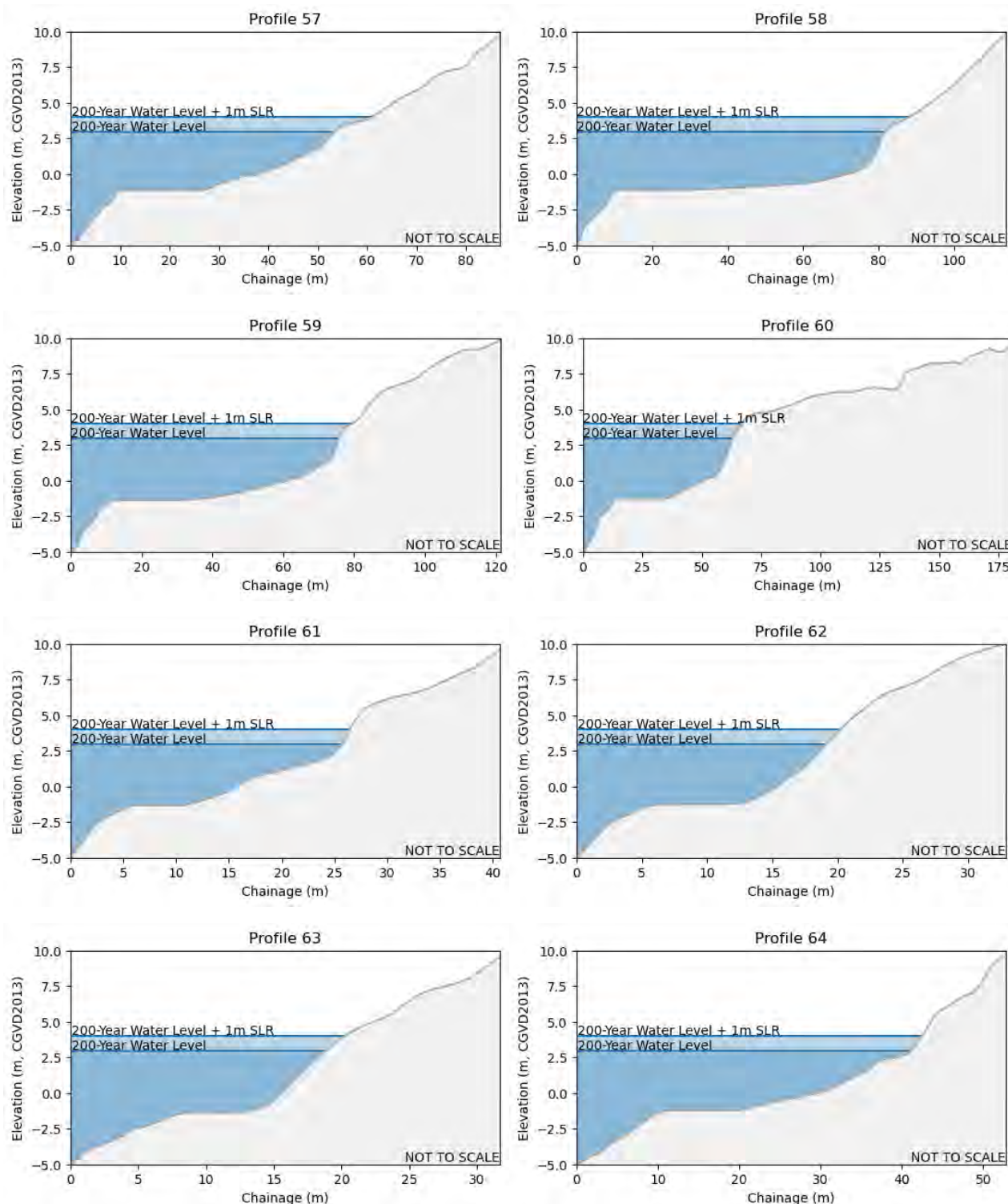


Figure D.8 Wave Runup Profiles 57 to 64

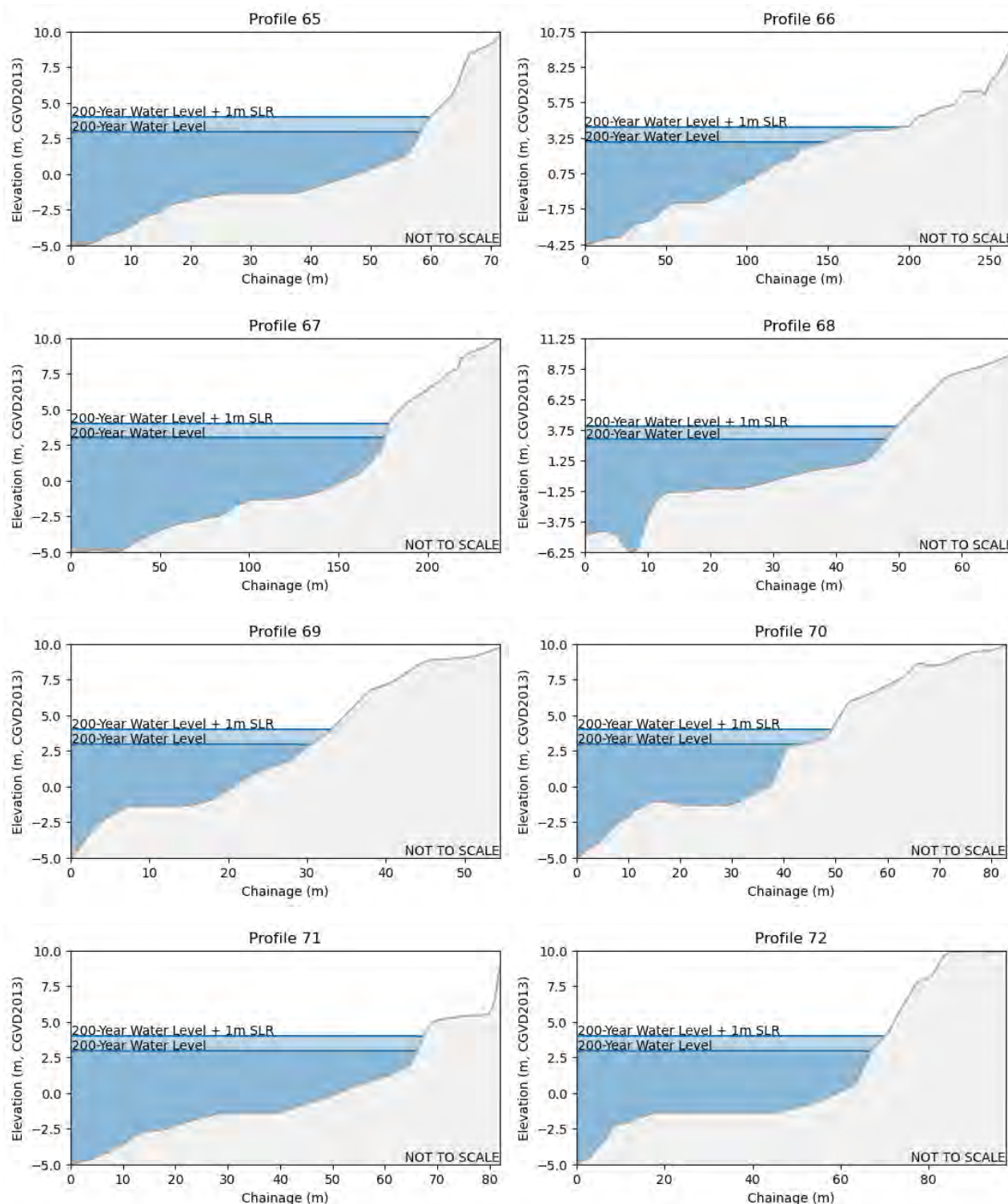


Figure D.9 Wave Runup Profiles 65 to 72

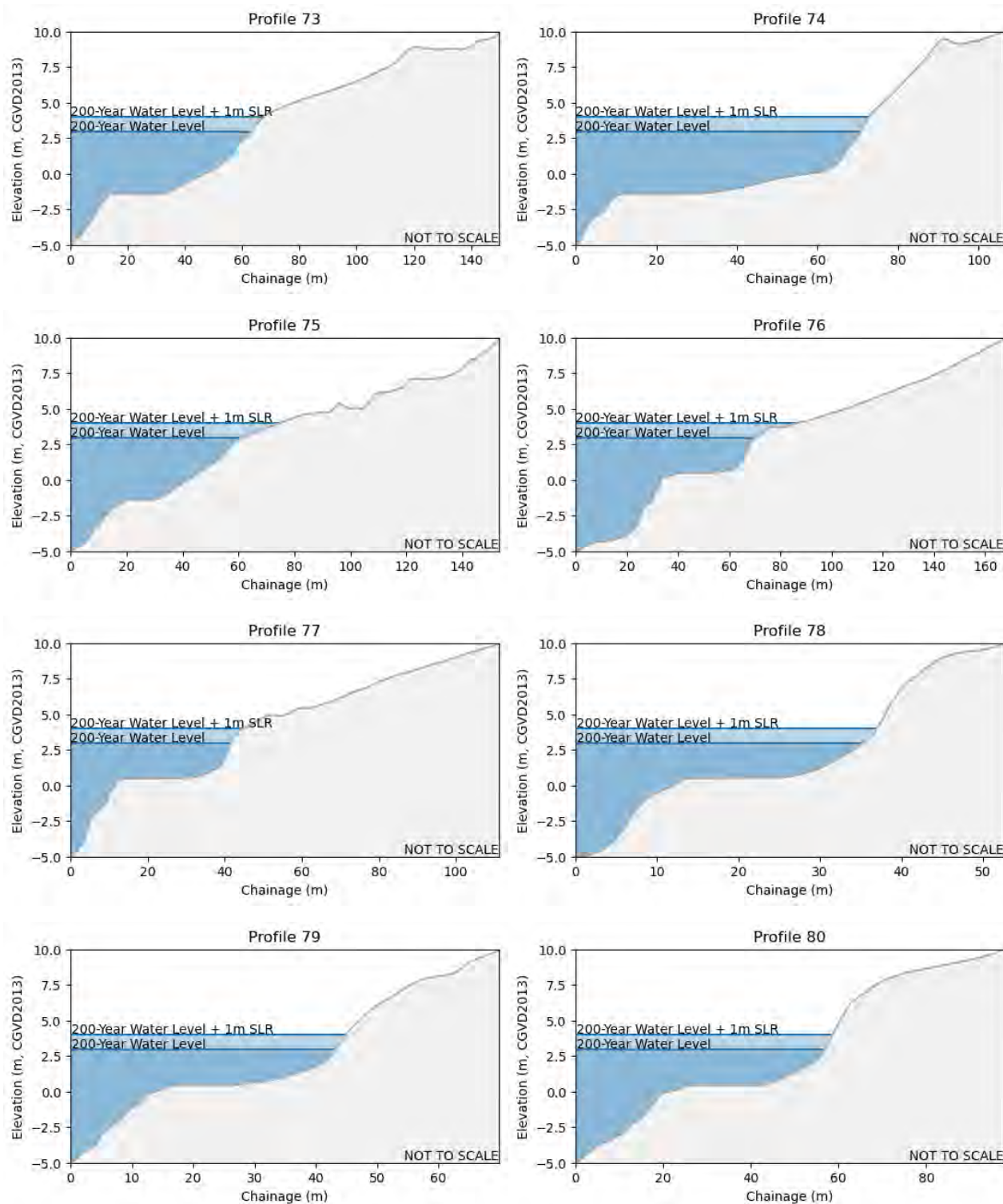


Figure D.10 Wave Runup Profiles 73 to 80

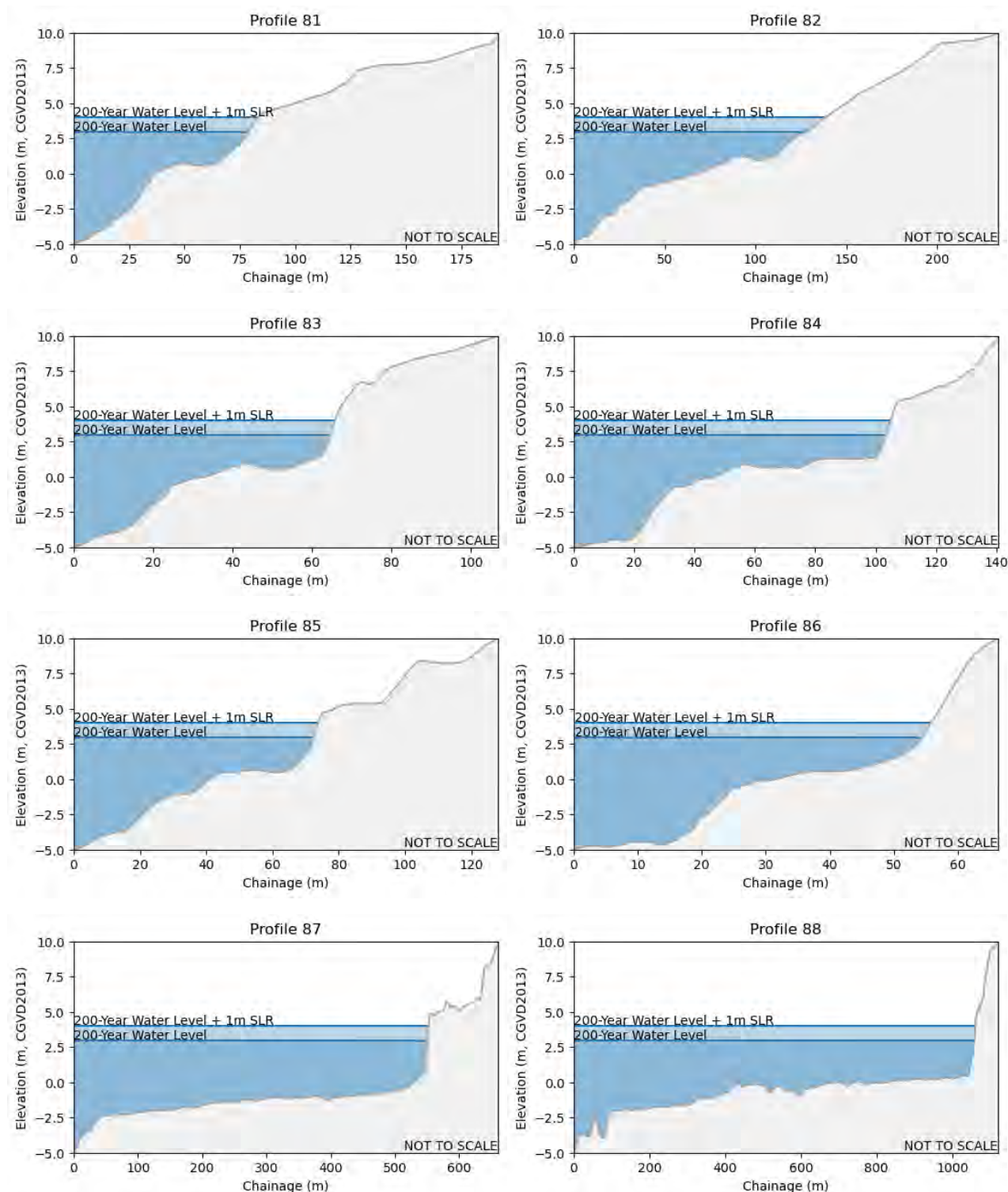


Figure D.11 Wave Runup Profiles 81 to 88

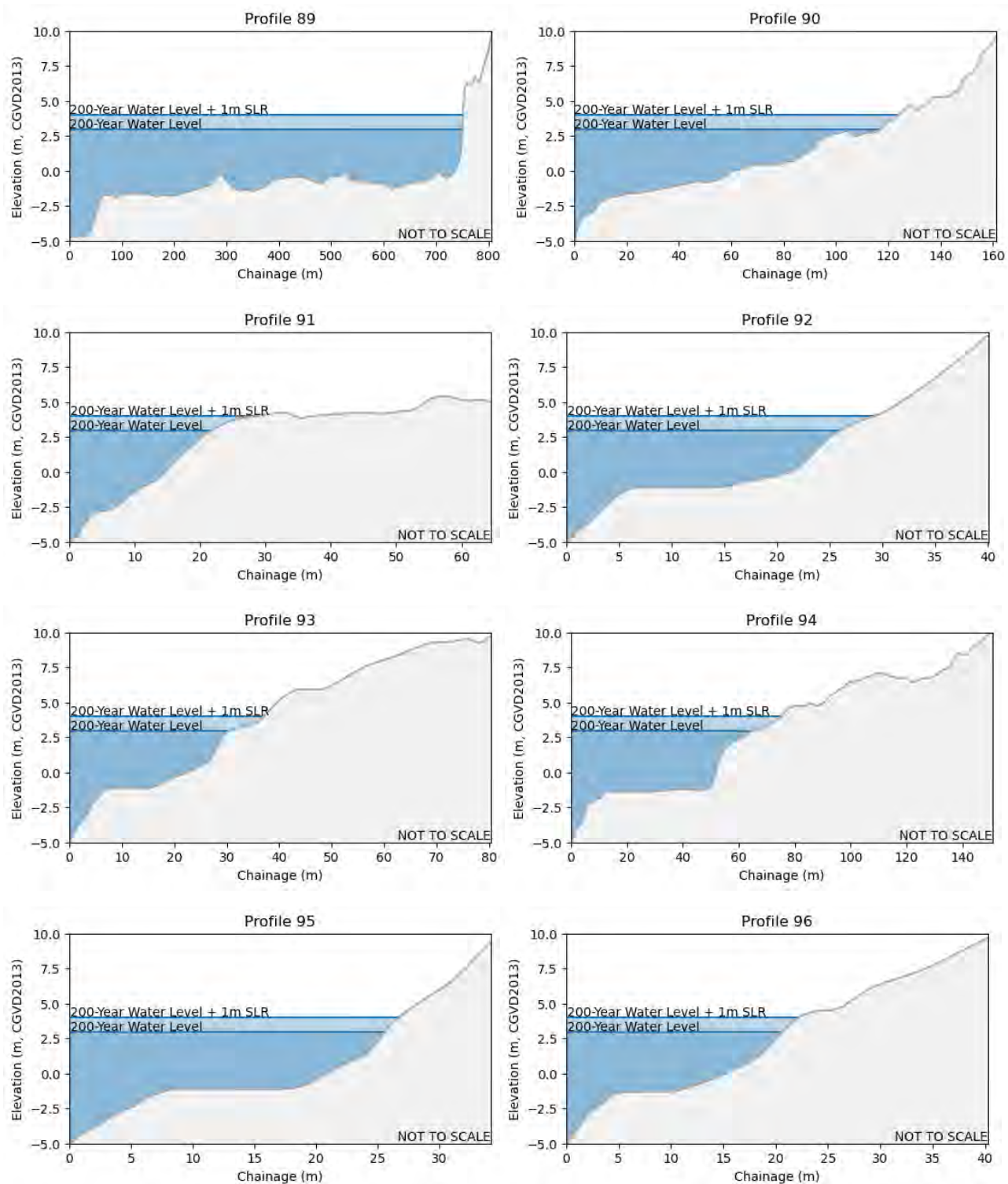


Figure D.12 Wave Runup Profiles 89 to 96

Appendix D.3 Flood Construction Levels

Table D.1 Wave Runup Results

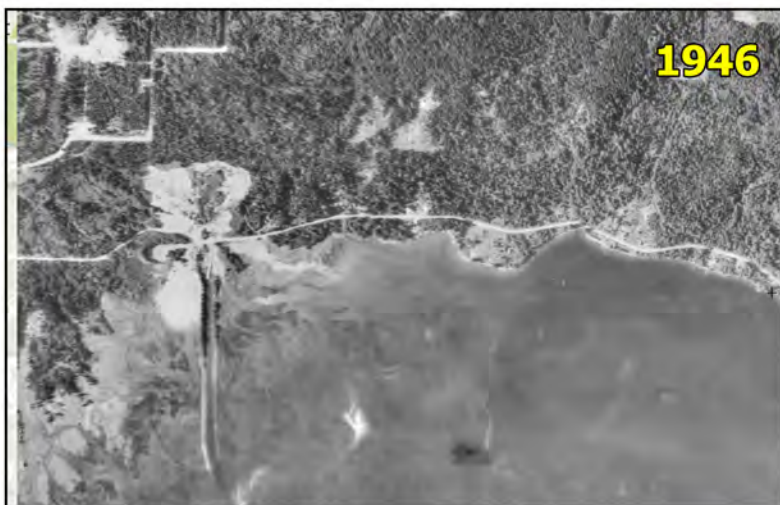
Profile	FCL for +0.5 m SLR (m, CGVD2013)	FCL for +1.0 m SLR (m, CGVD2013)
Profile 1	6.52	7.20
Profile 2	6.00	6.54
Profile 3	5.98	6.36
Profile 4	6.51	6.82
Profile 5	5.39	6.47
Profile 6	6.16	6.63
Profile 7	6.25	7.16
Profile 8	6.25	6.54
Profile 9	6.23	6.58
Profile 10	6.55	7.01
Profile 11	4.78	6.86
Profile 12	6.80	6.97
Profile 13	7.60	8.22
Profile 14	5.89	6.46
Profile 15	6.57	7.21
Profile 16	5.22	5.59
Profile 17	6.03	6.47
Profile 18	6.50	6.17
Profile 19	5.73	6.23
Profile 20	5.41	5.82
Profile 21	5.92	6.62
Profile 22	5.46	6.01
Profile 23	6.14	6.48
Profile 24	4.70	5.25
Profile 25	4.76	5.08
Profile 26	4.53	5.21
Profile 27	5.88	6.50
Profile 28	5.72	5.15
Profile 29	6.50	7.03
Profile 30	7.02	6.22
Profile 31	6.58	7.02
Profile 32	6.87	6.92
Profile 33	4.84	5.29

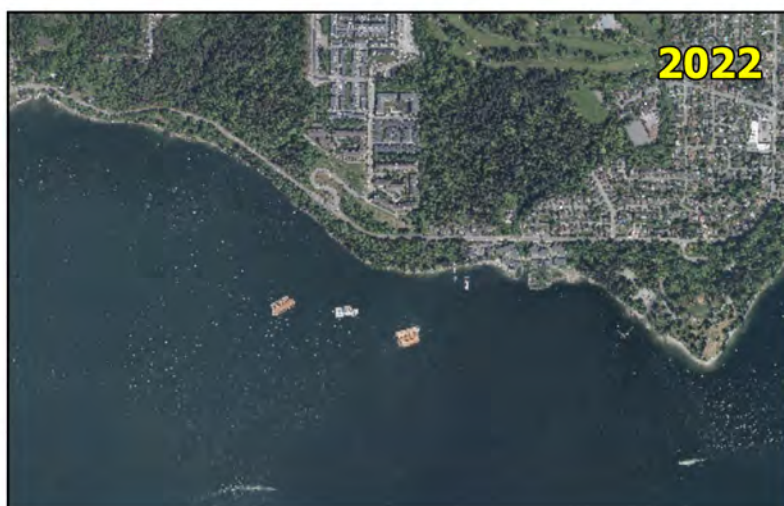
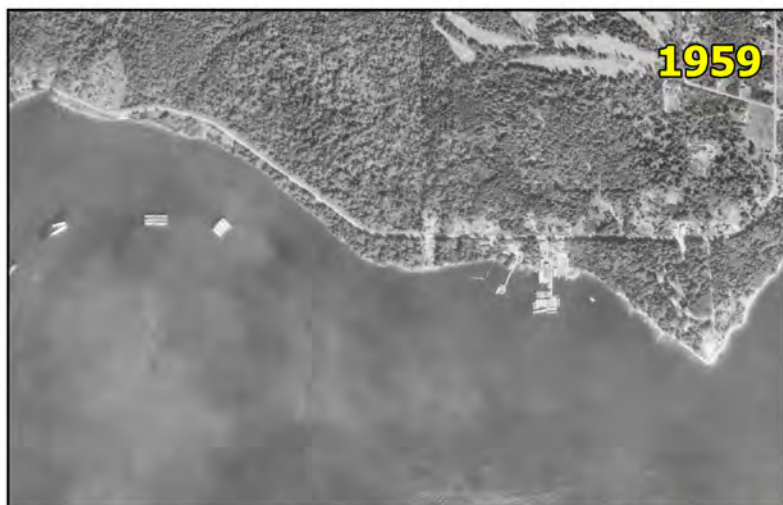
Profile	FCL for +0.5 m SLR (m, CGVD2013)	FCL for +1.0 m SLR (m, CGVD2013)
Profile 34	6.94	7.23
Profile 35	6.06	6.97
Profile 36	6.45	6.81
Profile 37	6.70	7.10
Profile 38	4.97	5.22
Profile 39	5.09	5.56
Profile 40	5.16	5.61
Profile 41	6.35	6.82
Profile 42	6.17	6.59
Profile 43	5.96	6.81
Profile 44	5.11	5.57
Profile 45	5.43	5.86
Profile 46	5.31	5.93
Profile 47	5.18	5.93
Profile 48	4.56	5.02
Profile 49	5.39	5.65
Profile 50	4.90	5.14
Profile 51	5.15	5.56
Profile 52	6.10	6.60
Profile 53	6.49	6.92
Profile 54	5.07	5.61
Profile 55	6.08	6.38
Profile 56	4.48	4.98
Profile 57	4.81	5.29
Profile 58	5.16	5.41
Profile 59	5.34	5.52
Profile 60	5.27	5.41
Profile 61	7.18	7.83
Profile 62	7.41	7.66
Profile 63	5.17	5.71
Profile 64	5.07	5.66
Profile 65	5.24	5.74
Profile 66	4.46	4.82
Profile 67	4.94	5.46
Profile 68	5.14	5.63

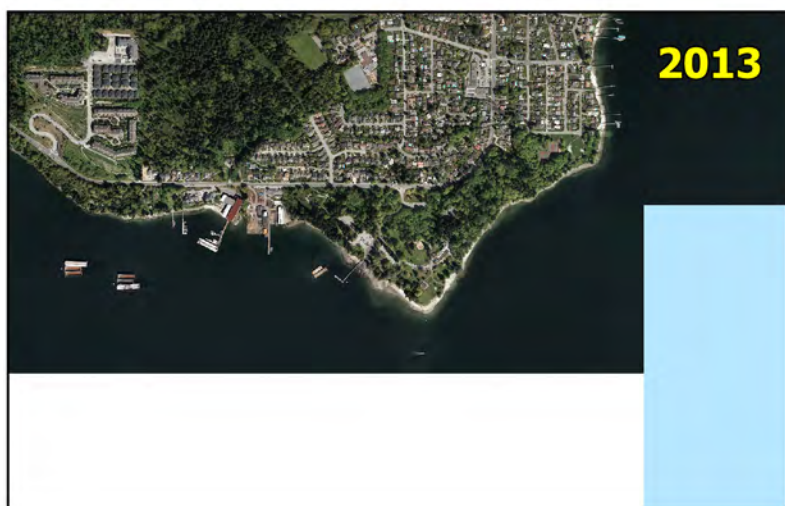
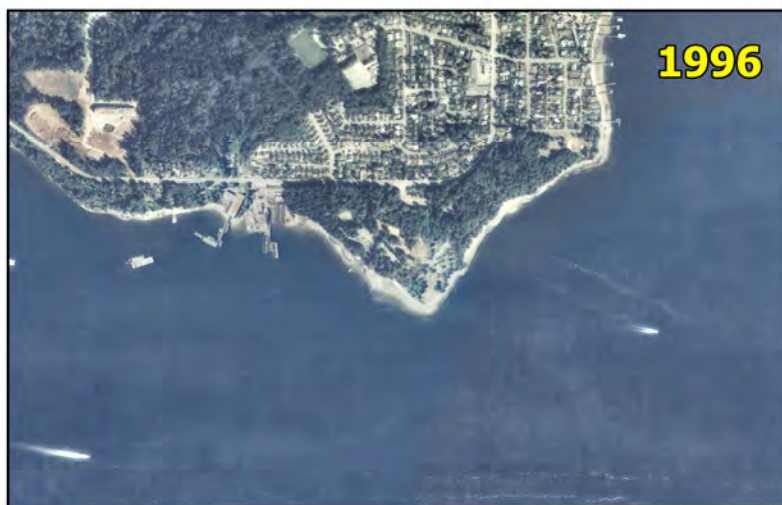
Profile	FCL for +0.5 m SLR (m, CGVD2013)	FCL for +1.0 m SLR (m, CGVD2013)
Profile 69	5.11	5.75
Profile 70	4.85	5.48
Profile 71	5.25	5.71
Profile 72	5.31	5.72
Profile 73	5.06	5.51
Profile 74	5.38	5.75
Profile 75	4.85	5.13
Profile 76	4.86	4.95
Profile 77	5.04	5.34
Profile 78	5.24	5.61
Profile 79	5.21	5.76
Profile 80	5.20	5.84
Profile 81	5.15	5.61
Profile 82	4.65	5.16
Profile 83	5.32	6.03
Profile 84	4.88	5.44
Profile 85	5.44	5.56
Profile 86	5.01	5.50
Profile 87	5.47	5.53
Profile 88	4.68	5.34
Profile 89	5.01	5.30
Profile 90	4.53	5.27
Profile 91	5.04	5.04
Profile 92	4.87	5.30
Profile 93	4.64	5.22
Profile 94	4.85	5.33
Profile 95	7.23	7.76
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Profile 97	6.10	6.50
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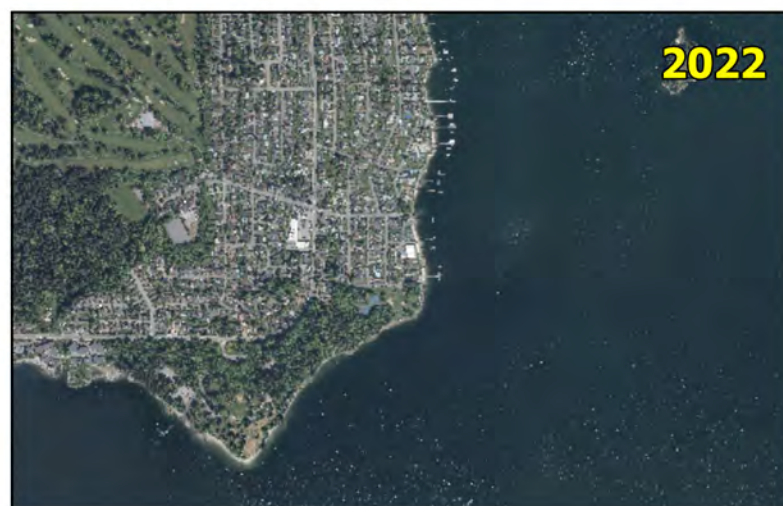
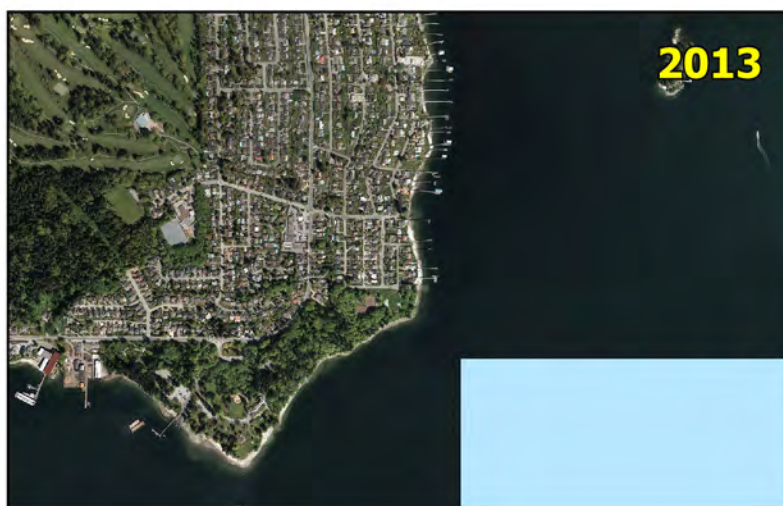
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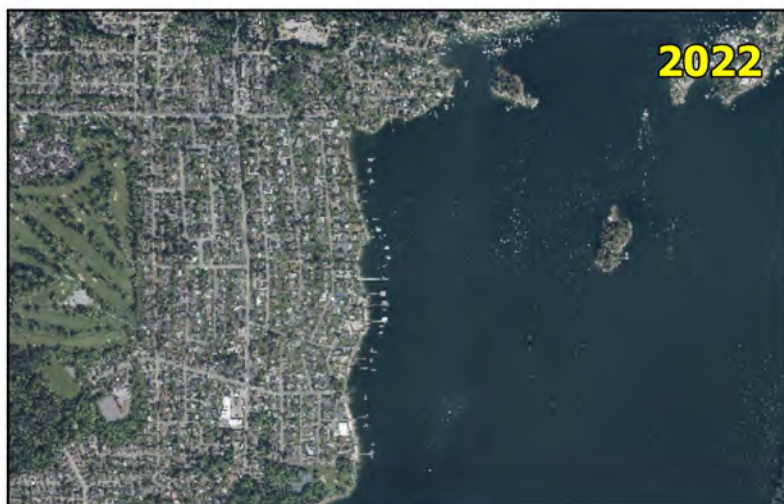
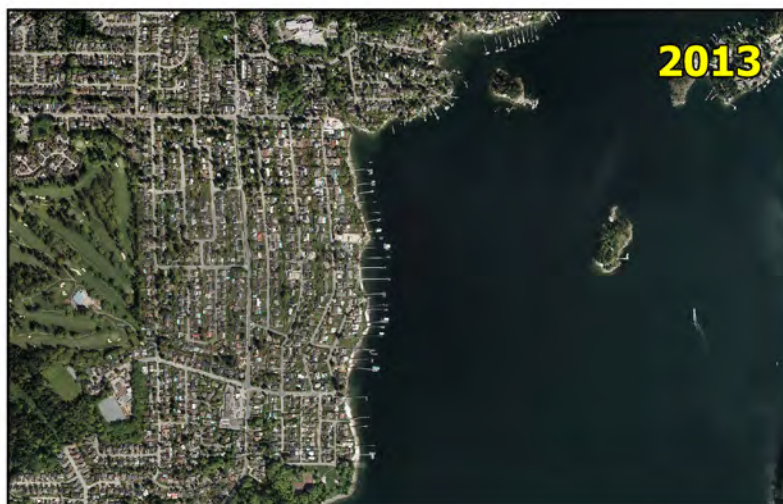
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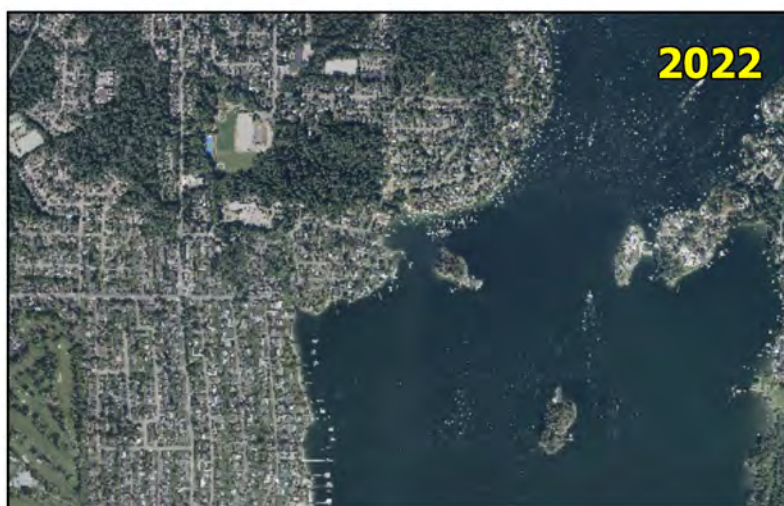
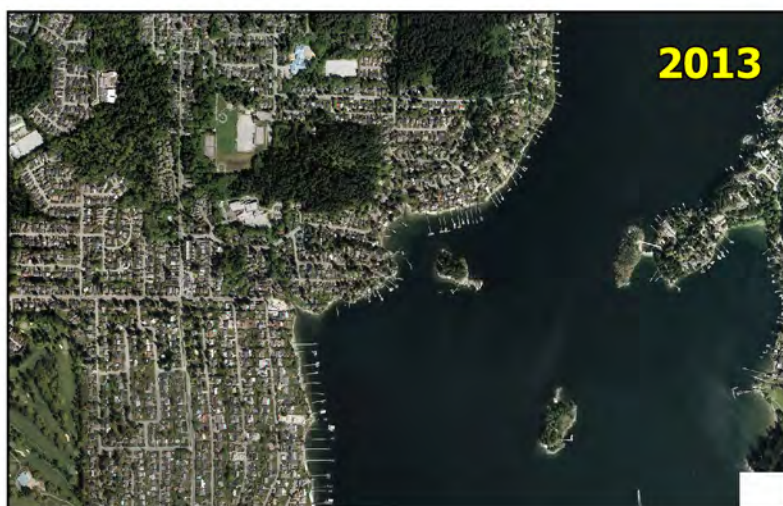


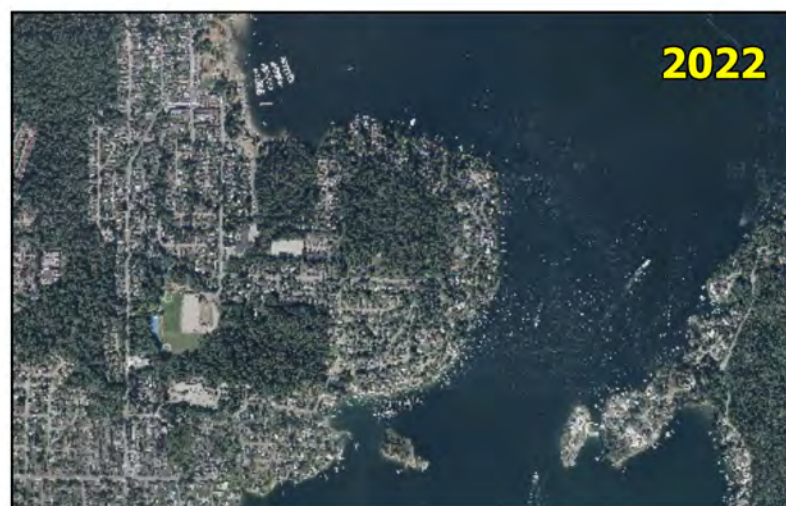
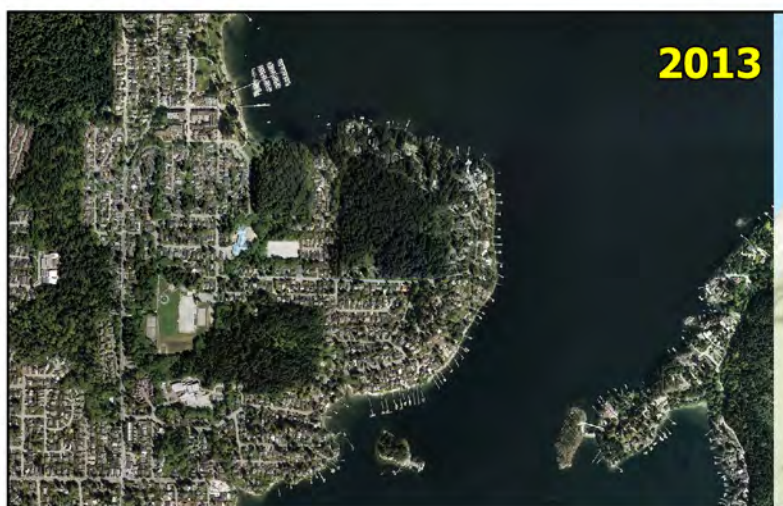


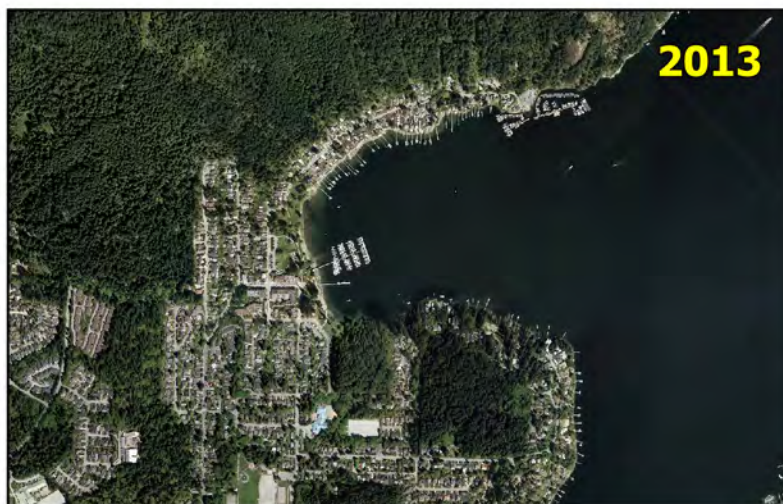


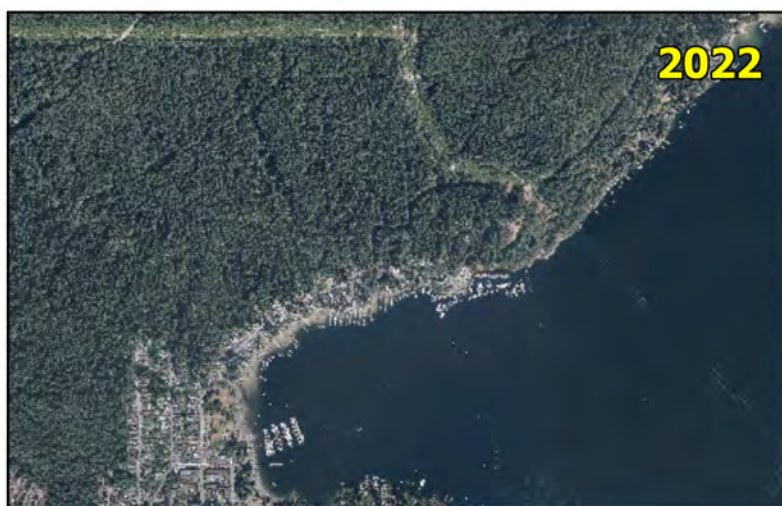
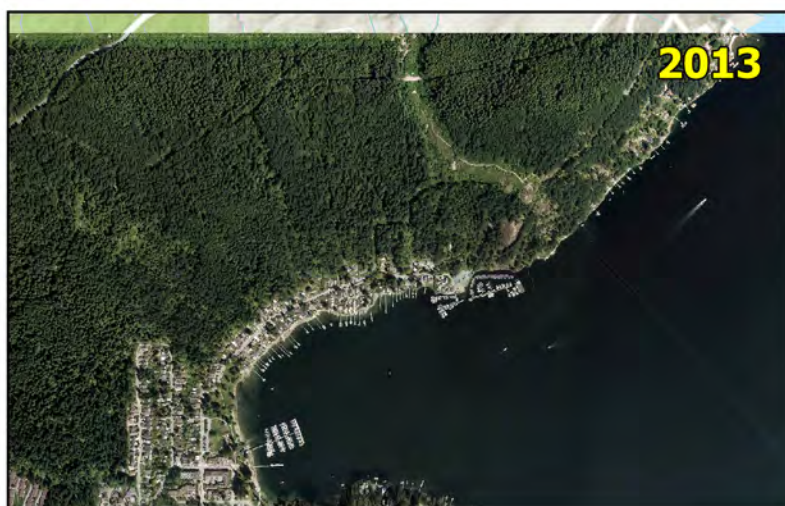




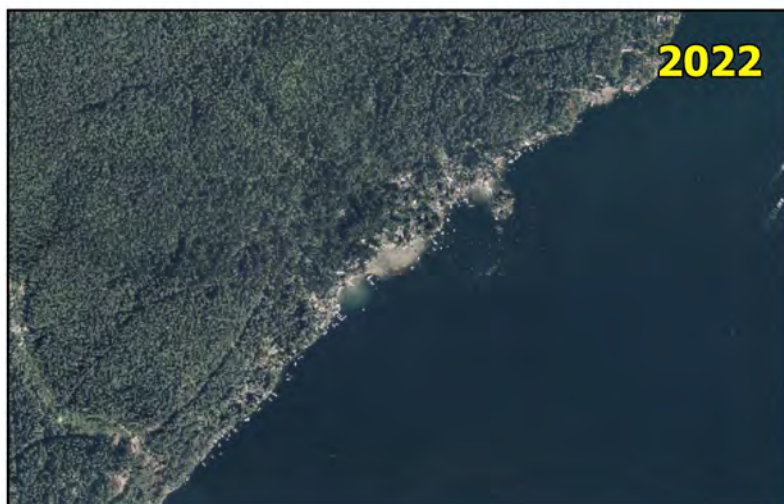
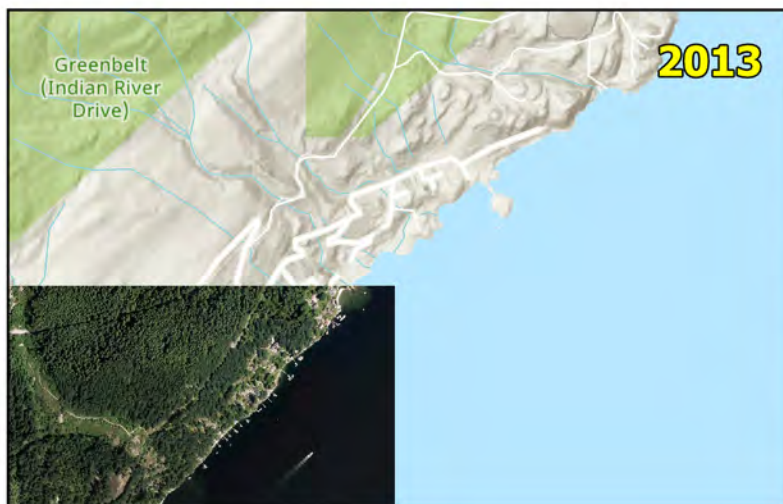
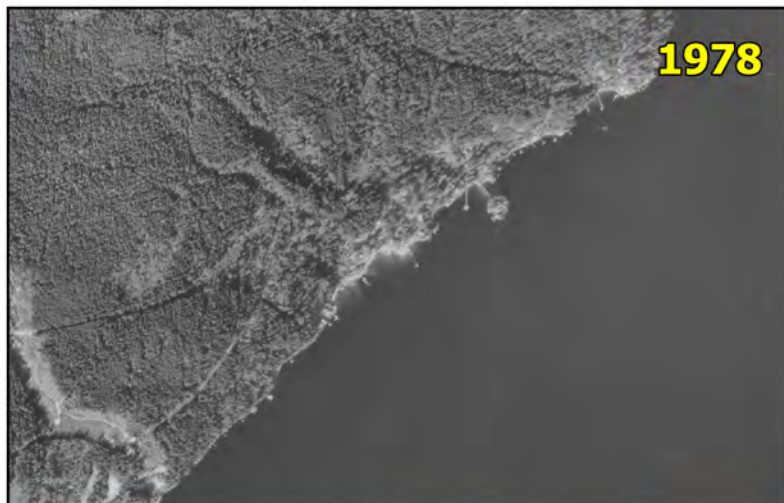
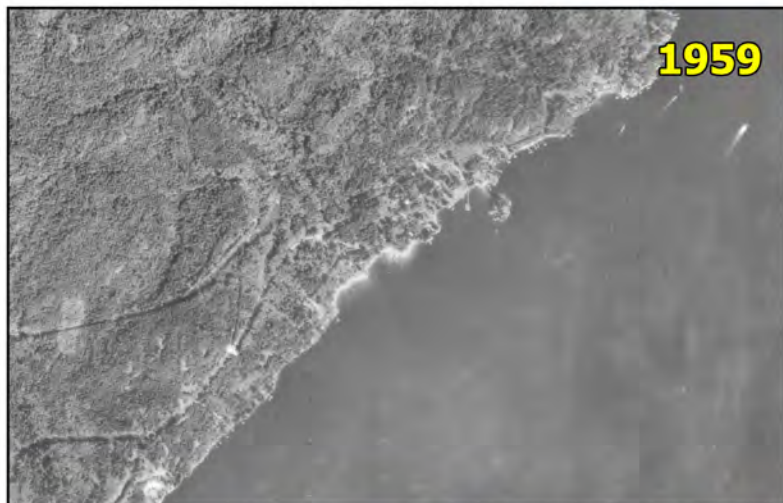
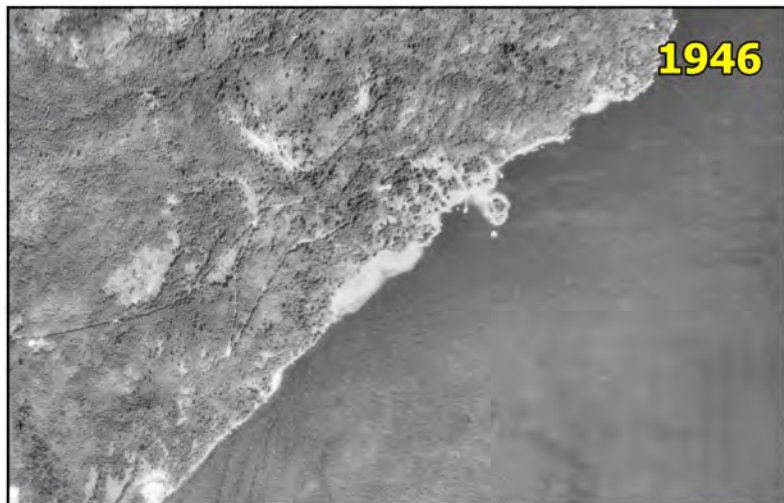


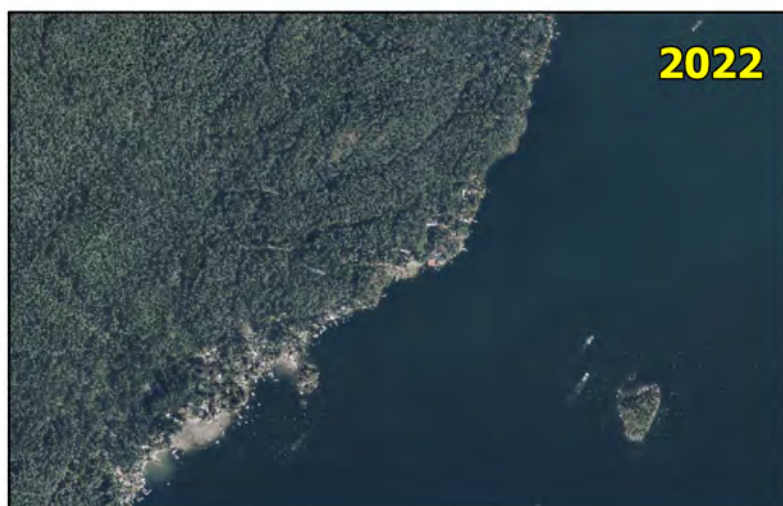
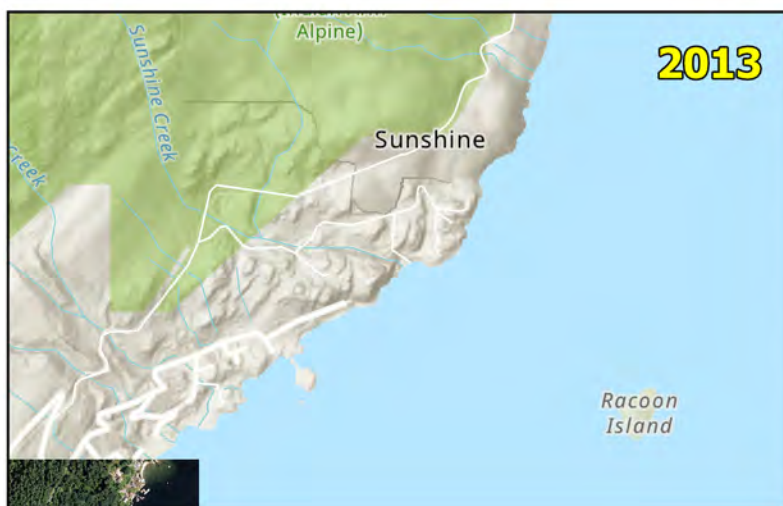
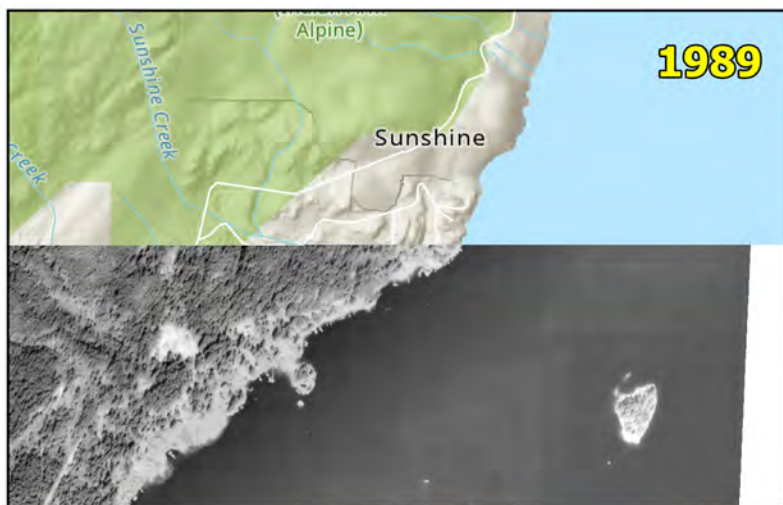
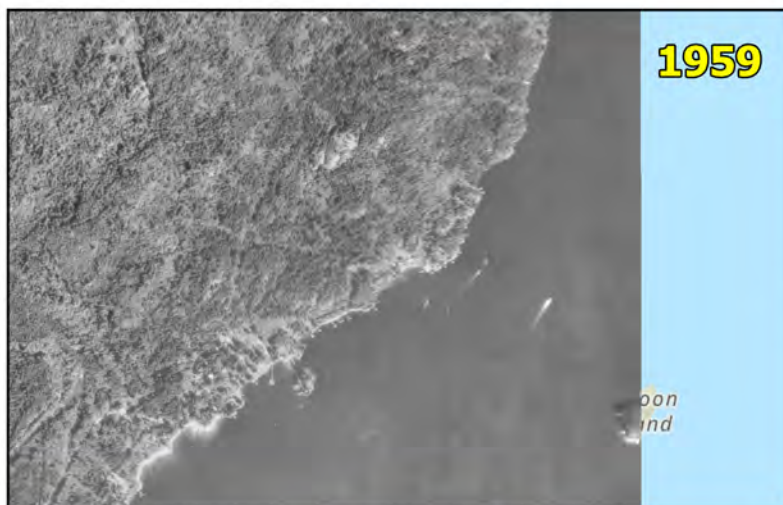
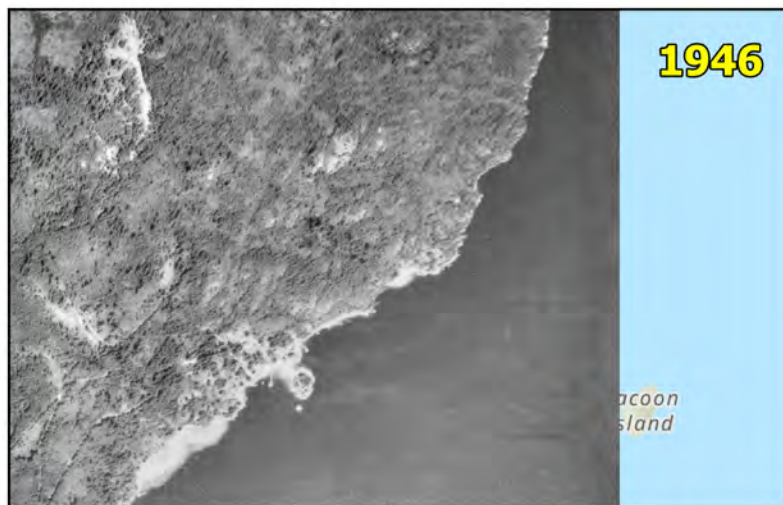


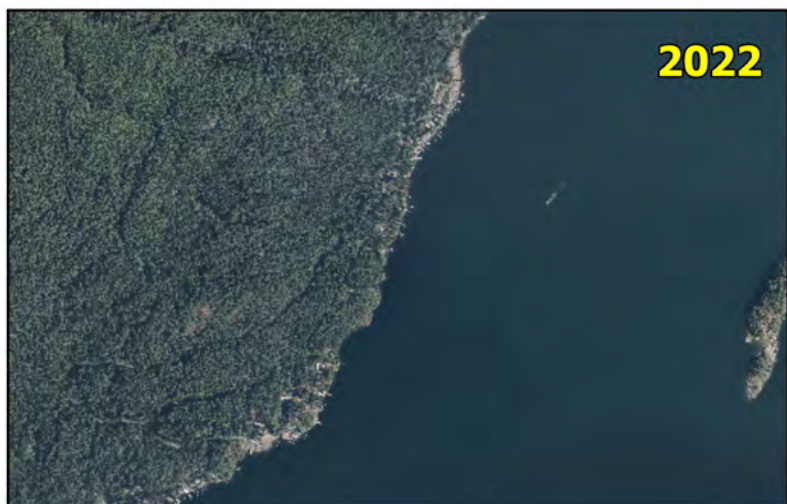
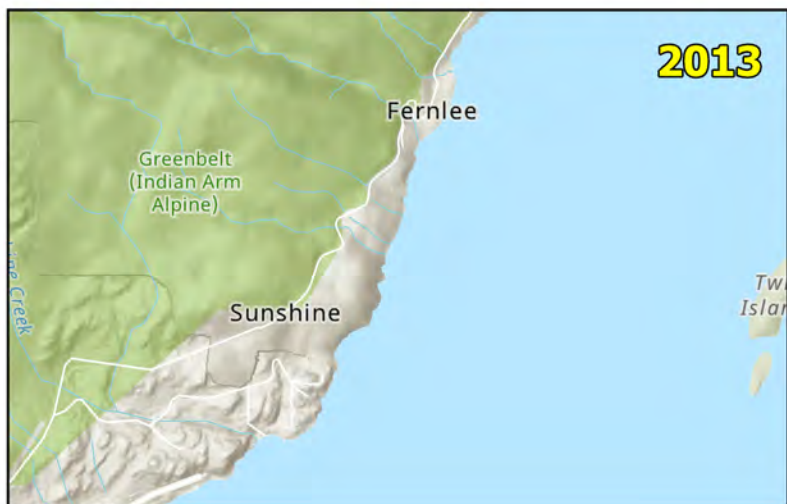


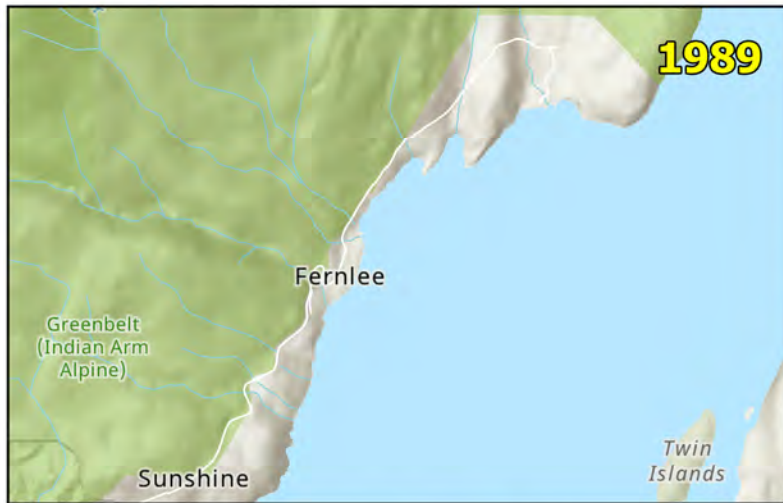
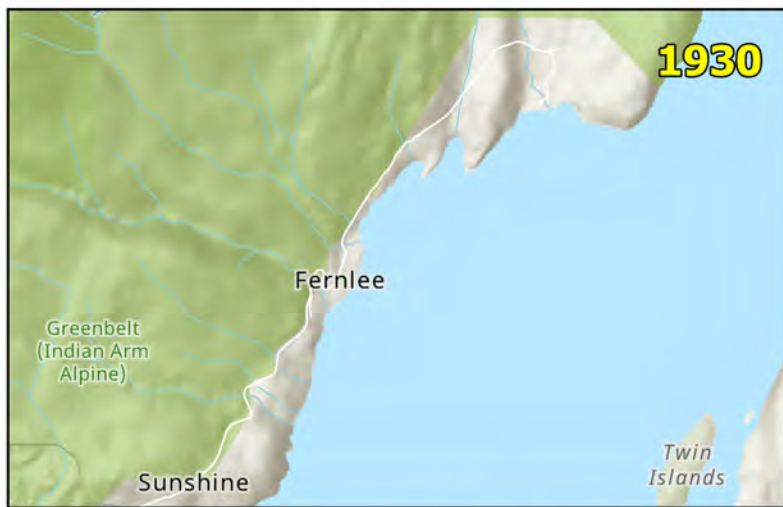


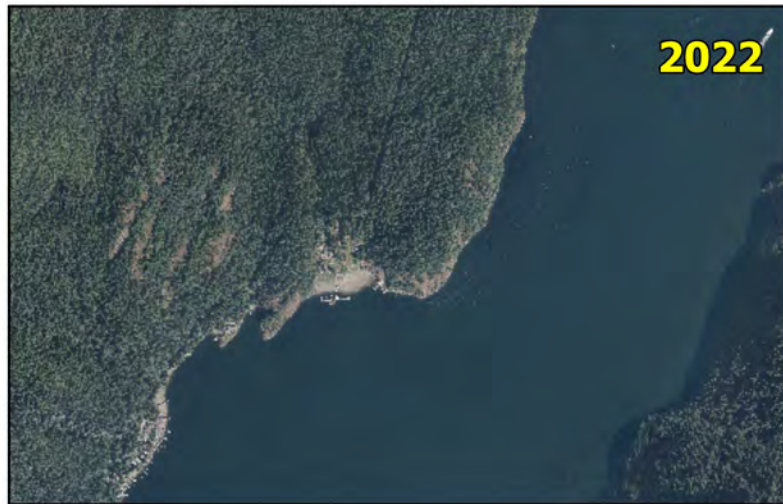
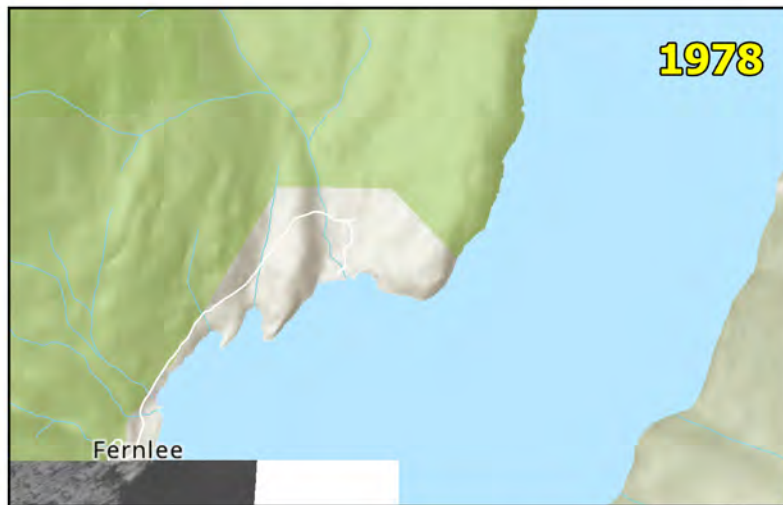
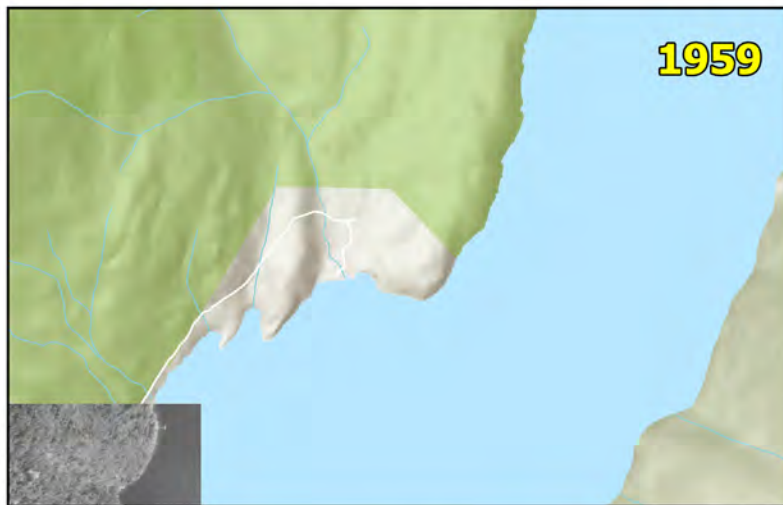


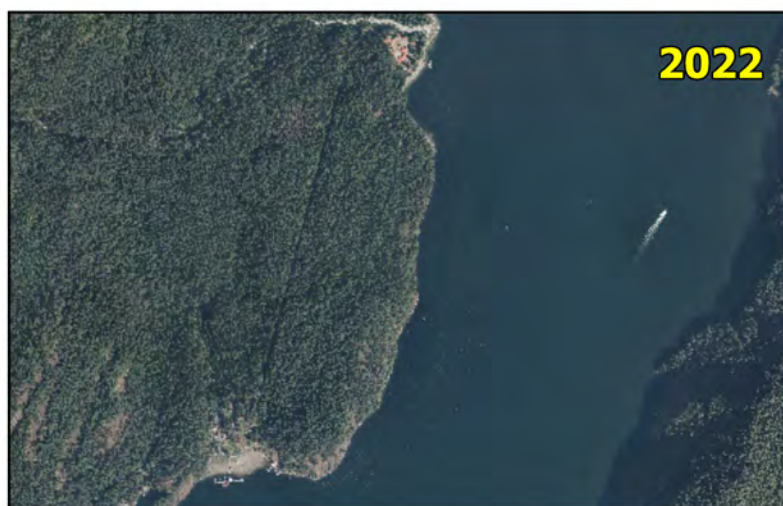
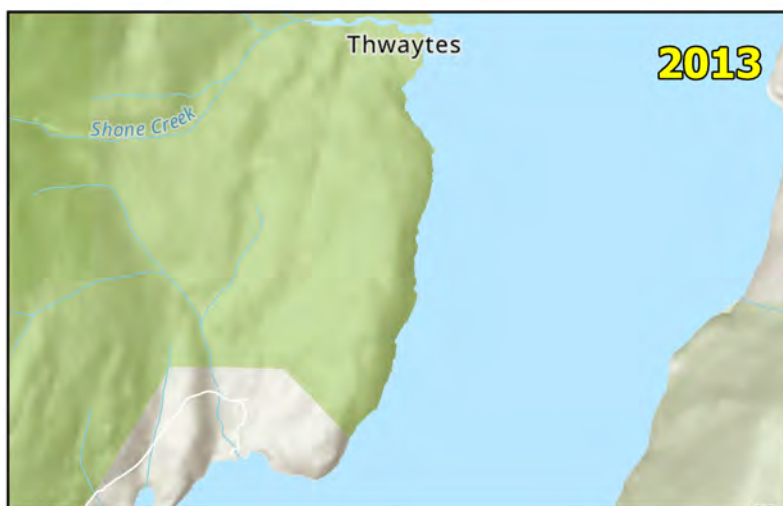
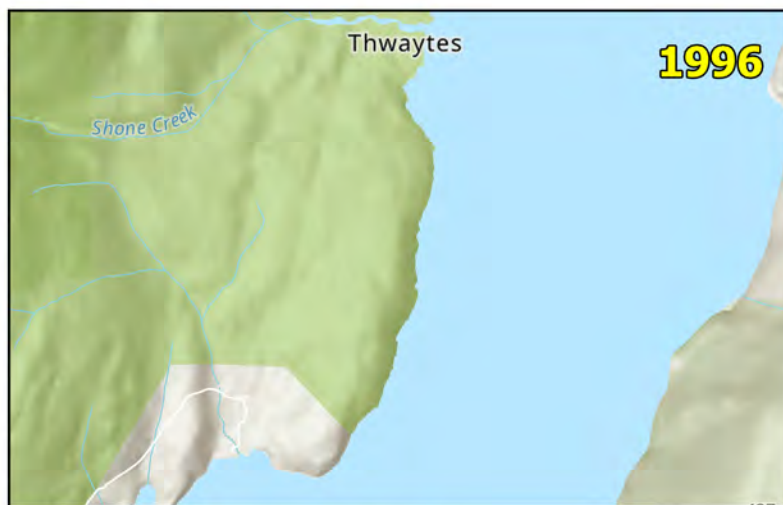
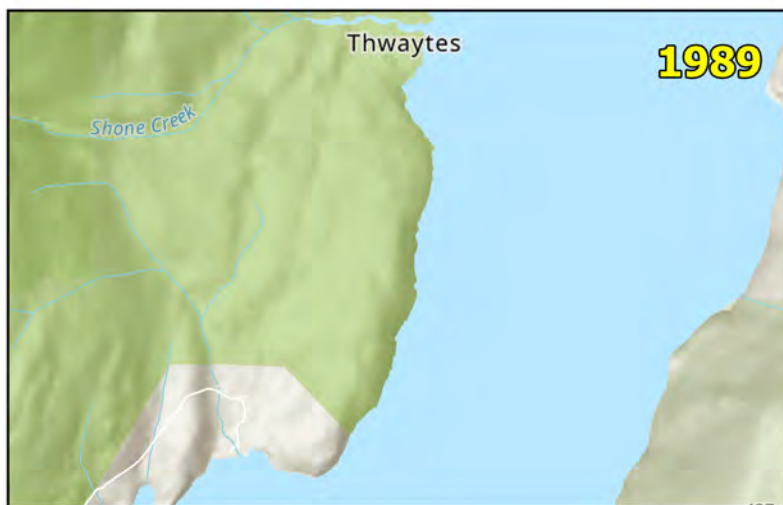
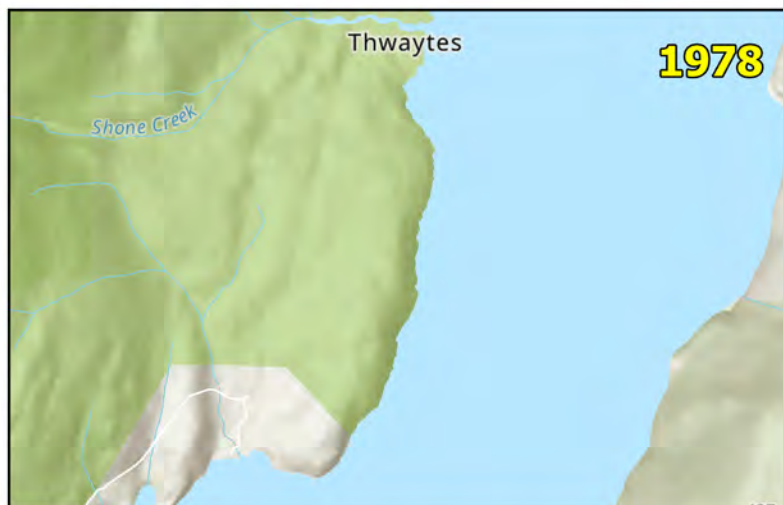
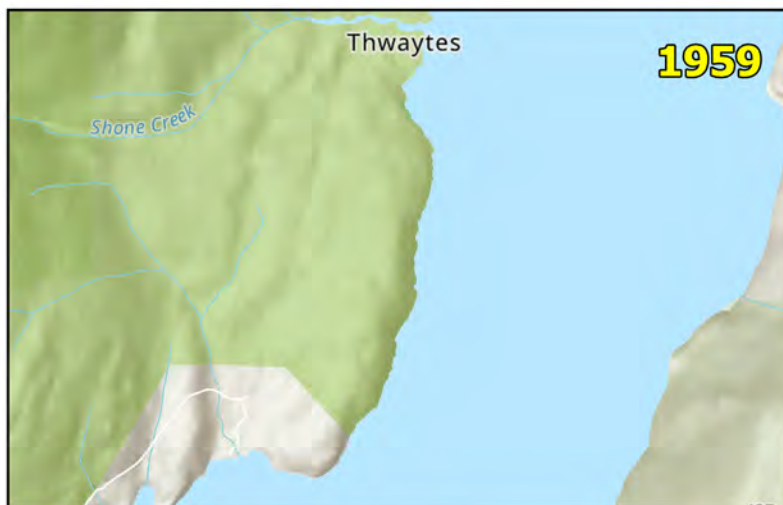
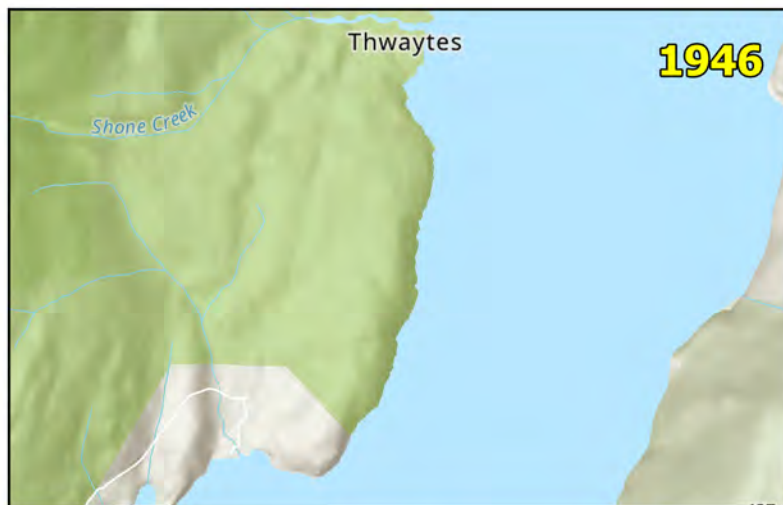
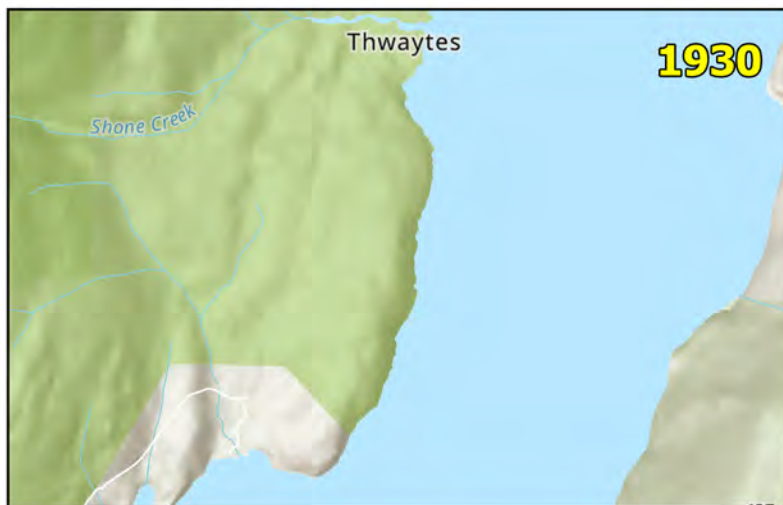


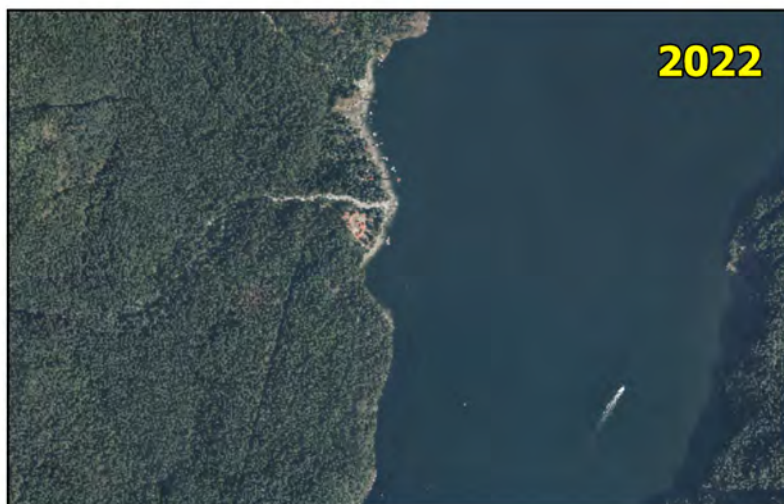


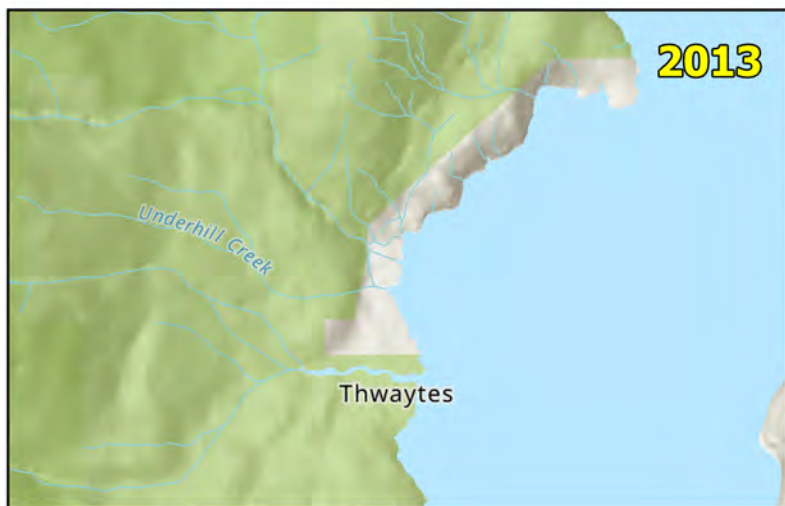
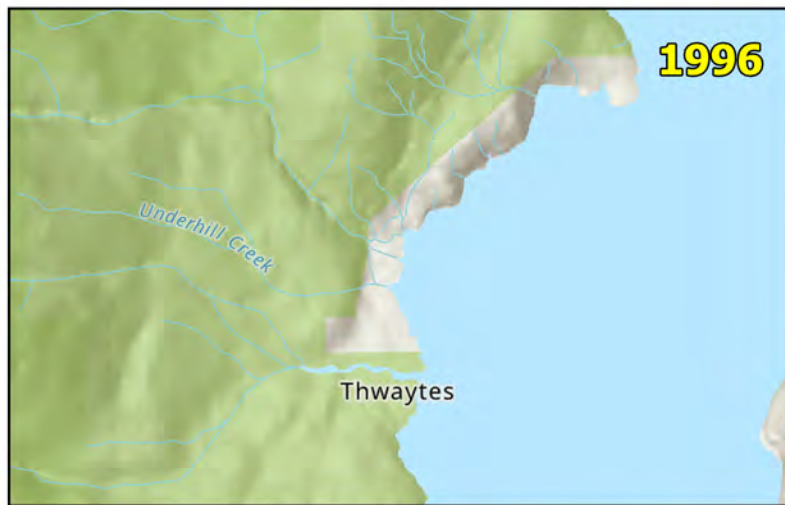
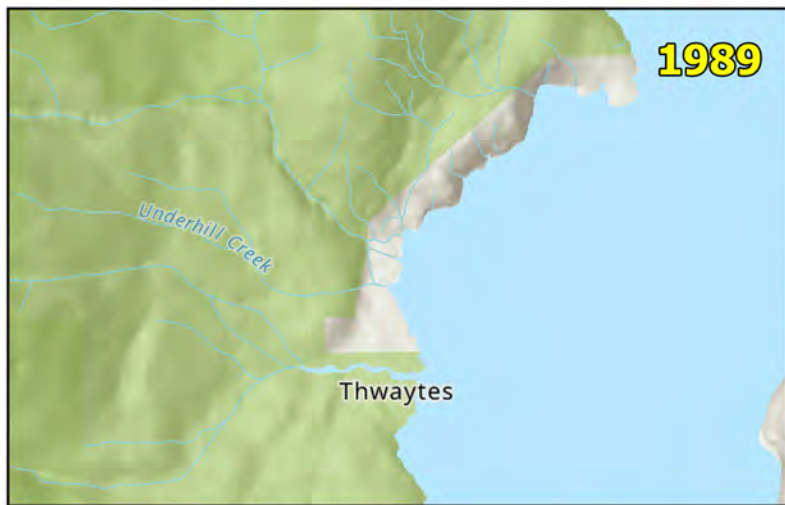
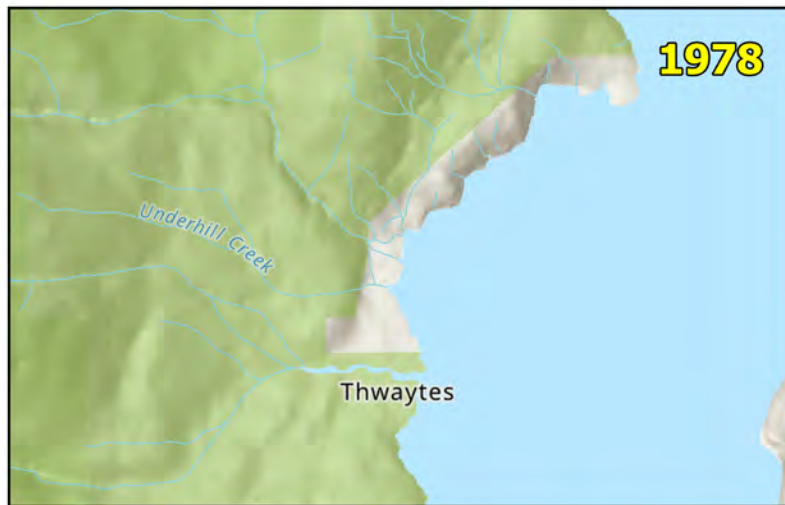
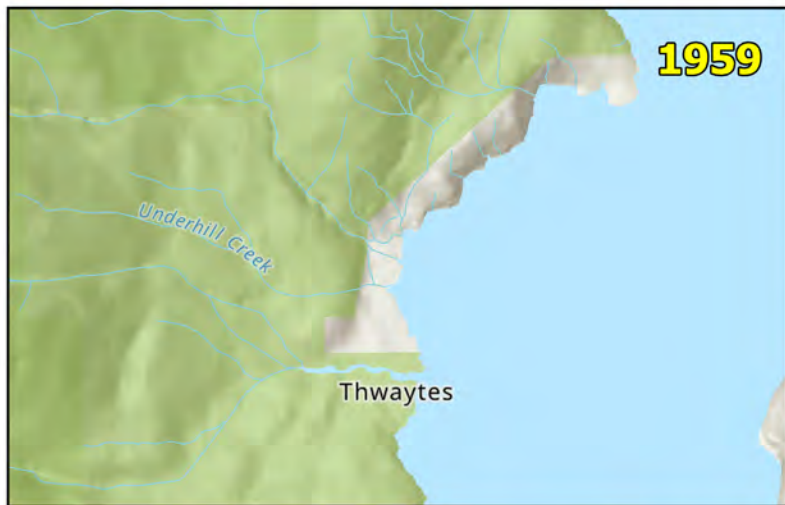
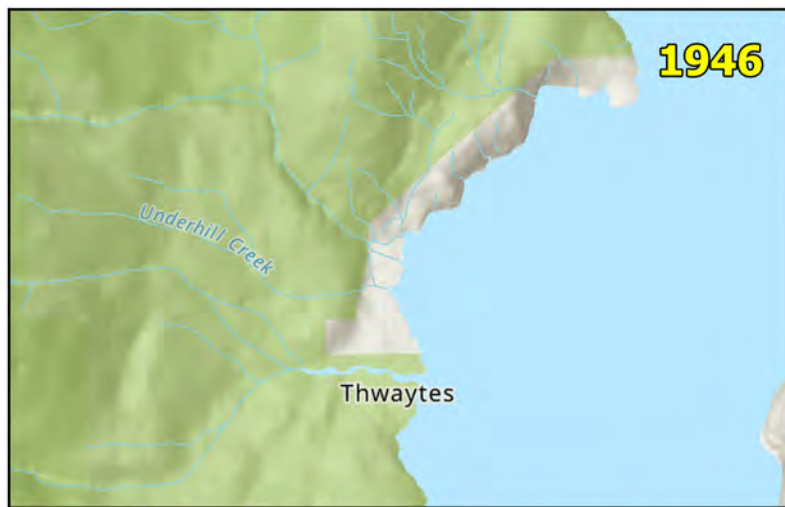
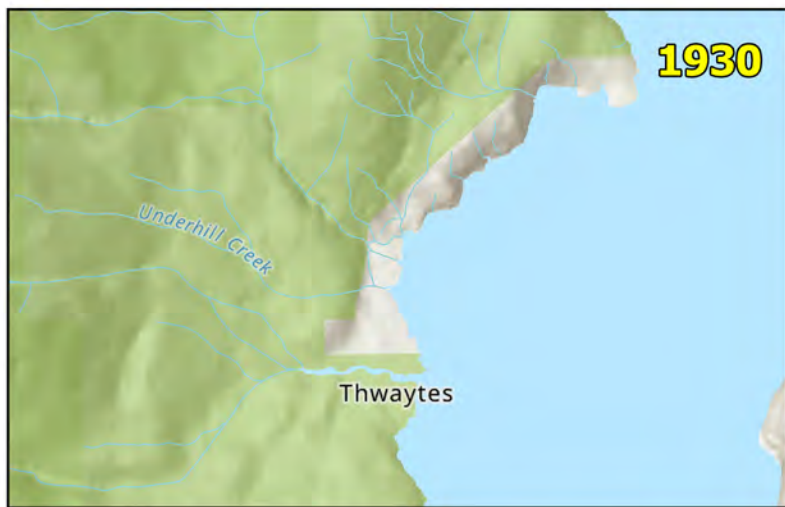


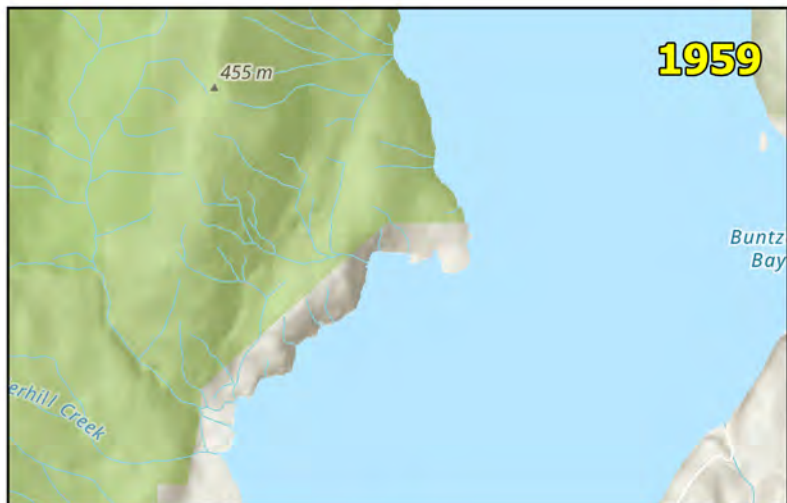


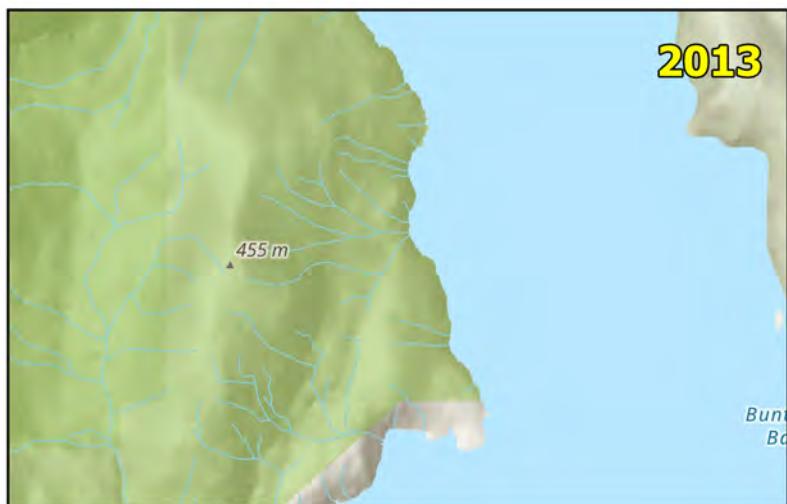
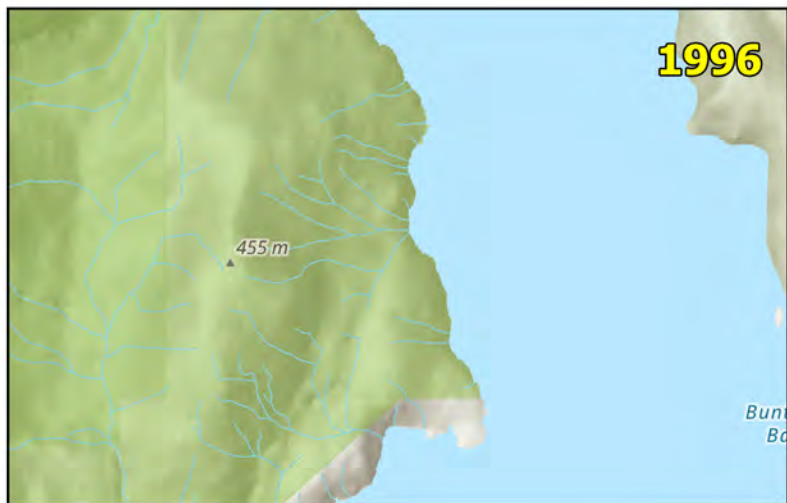
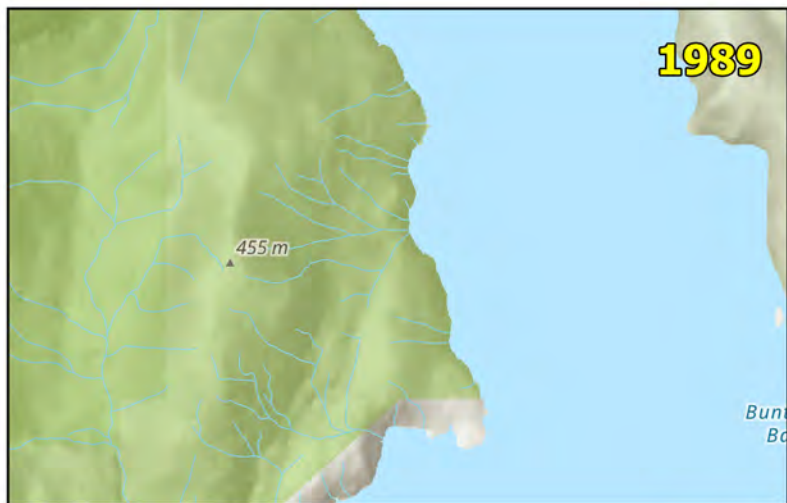
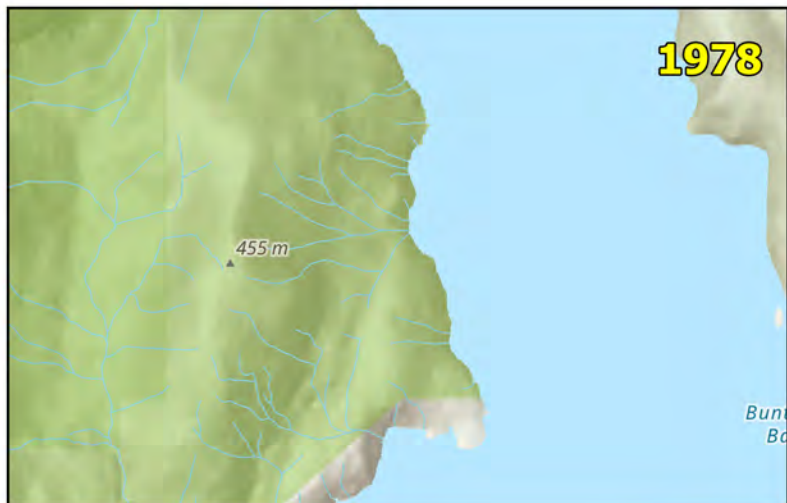
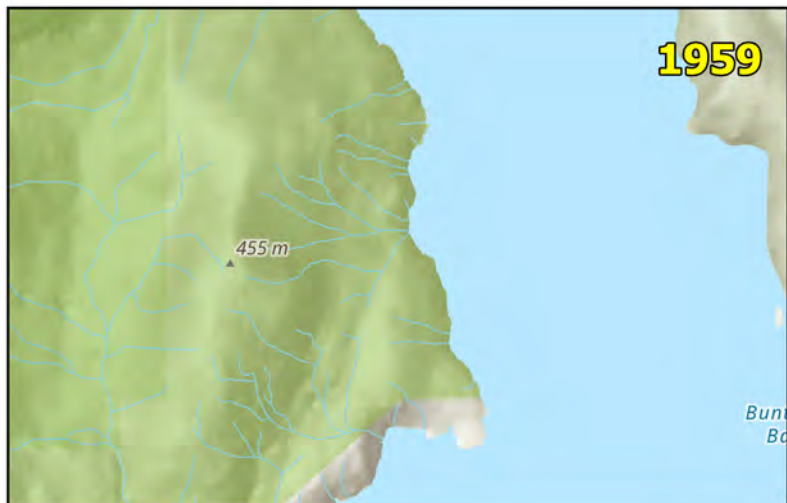
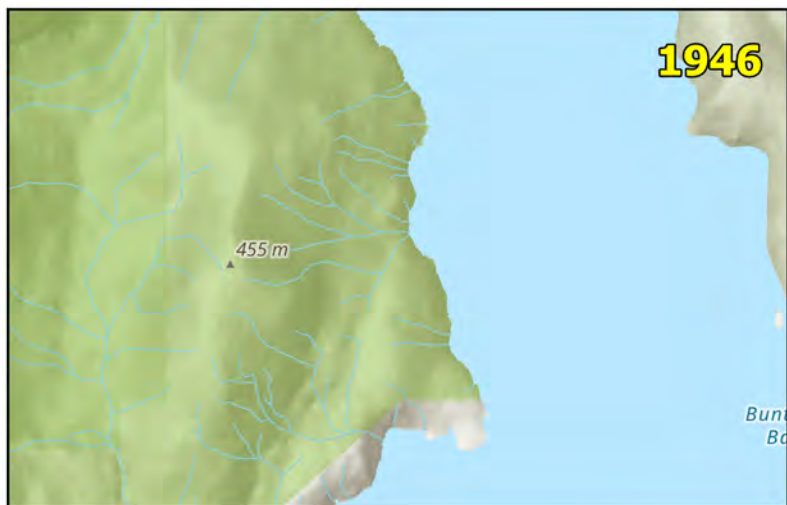


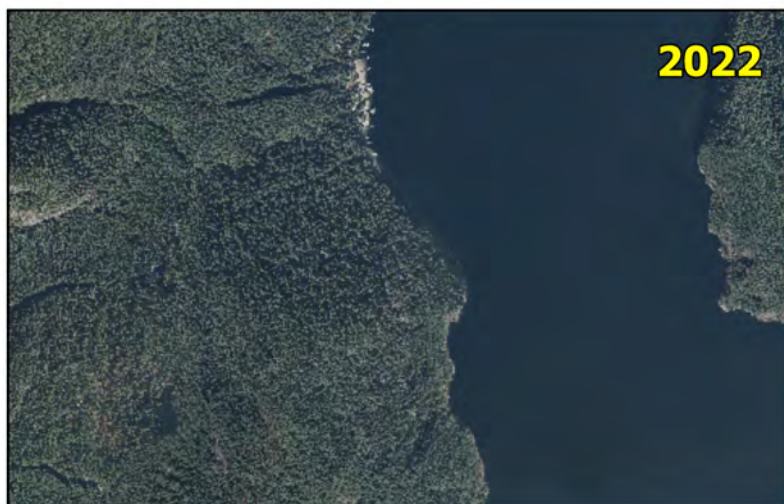
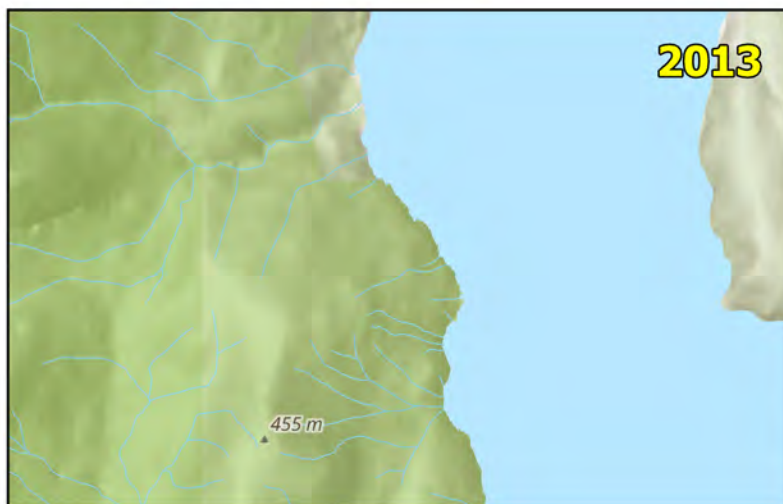
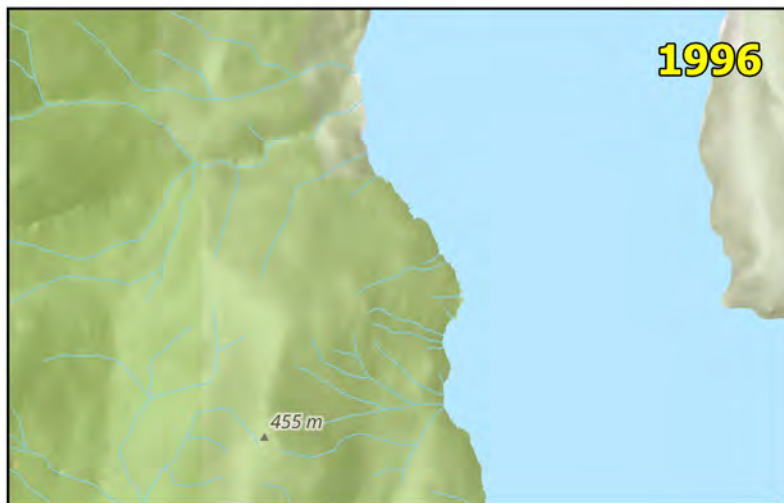
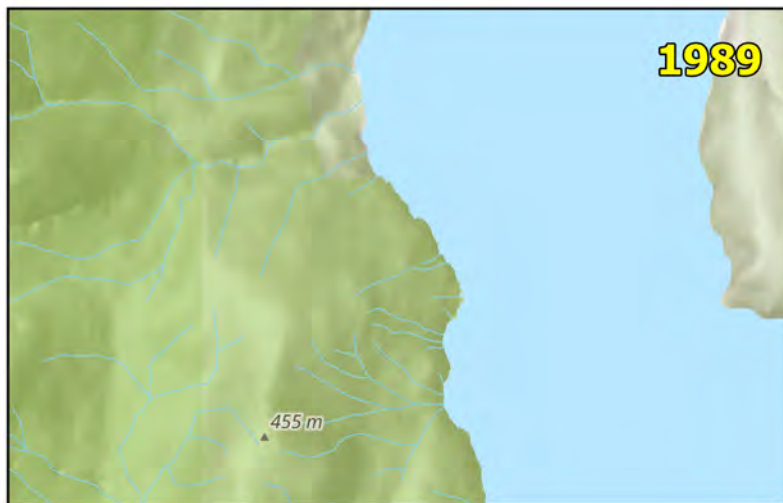
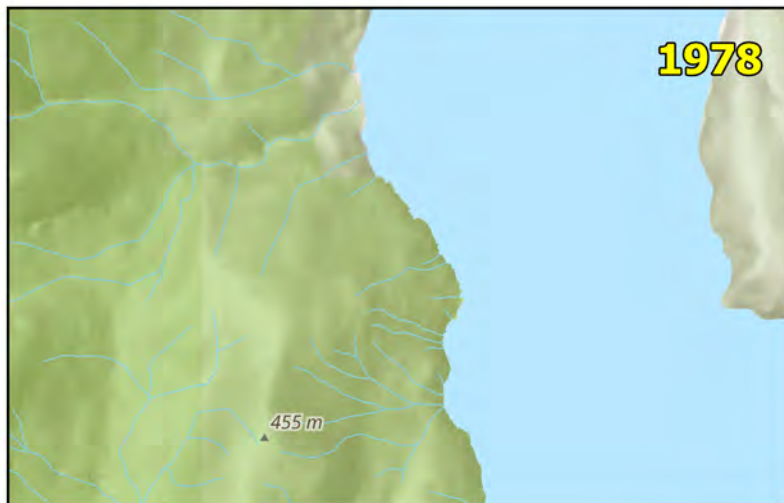
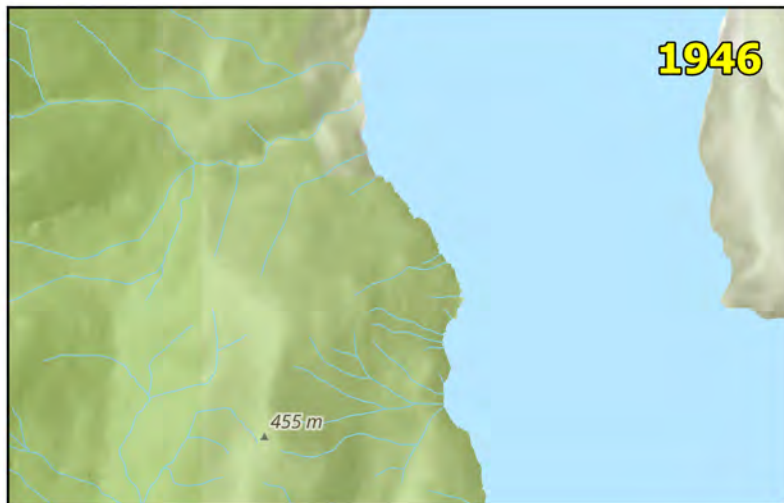
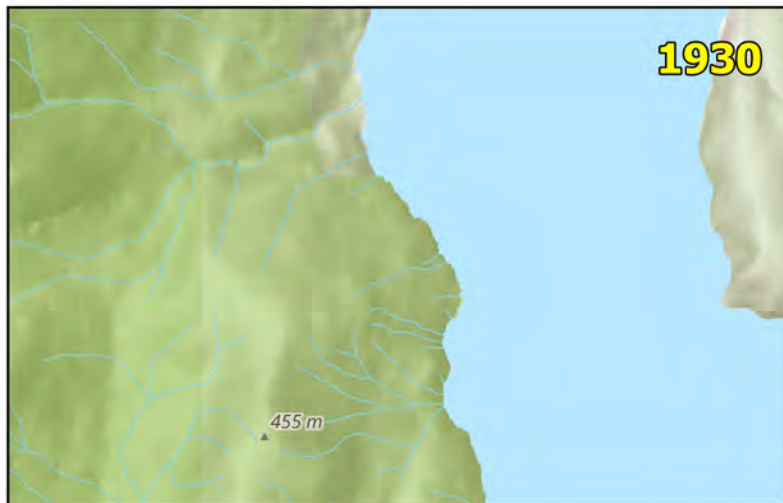


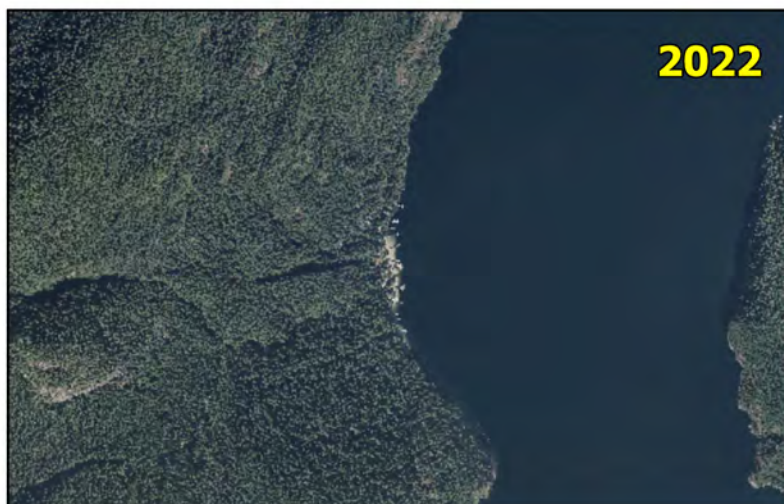
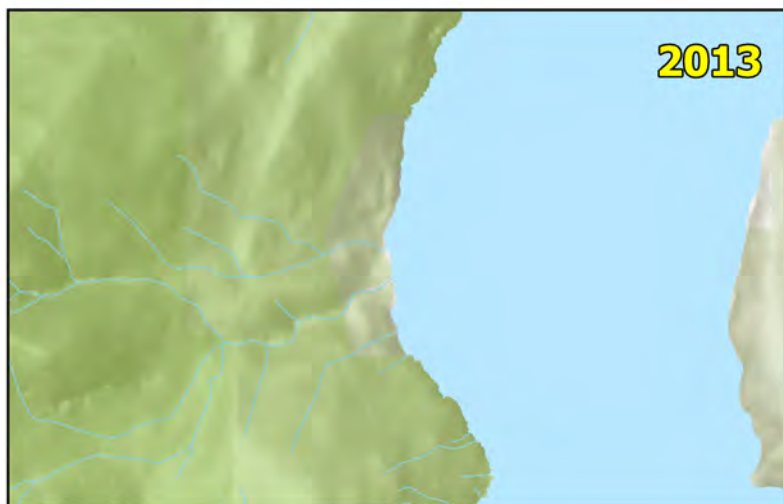
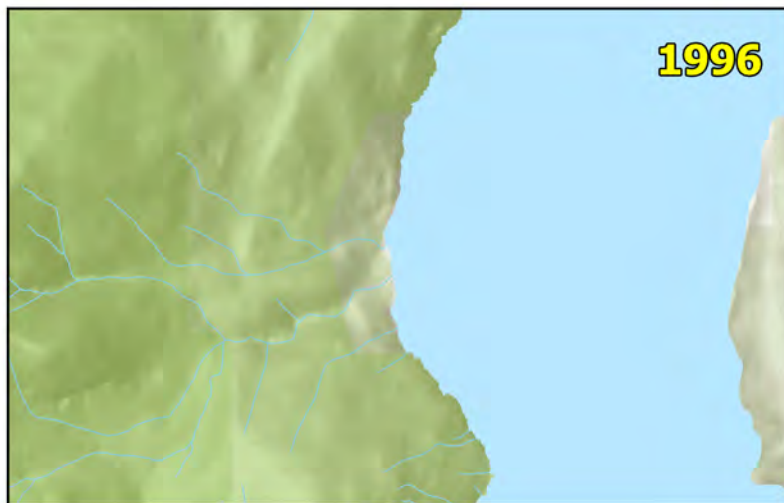
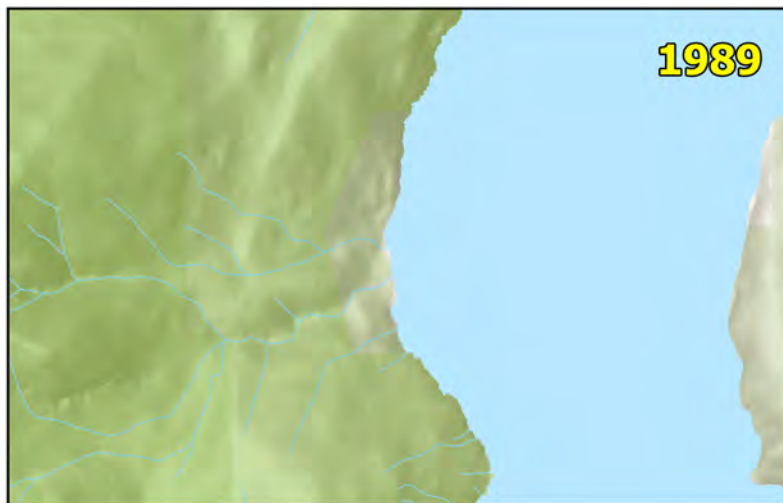
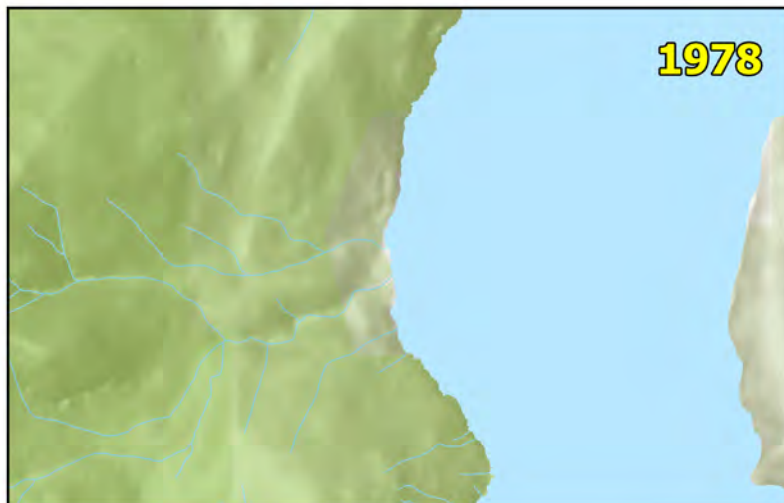
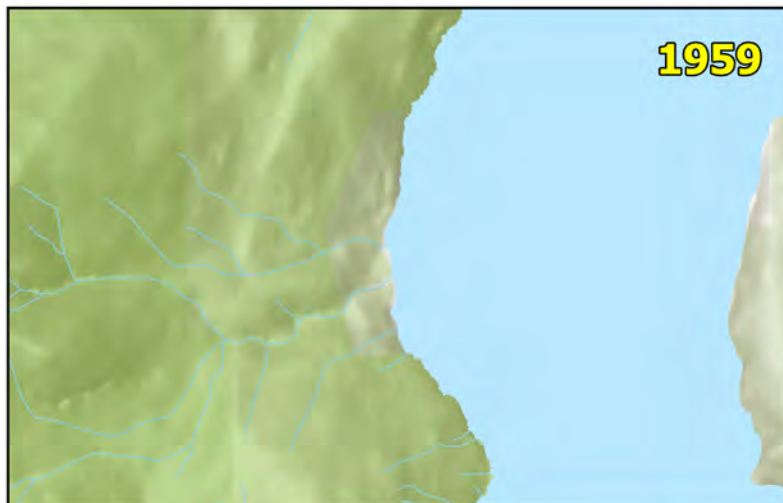
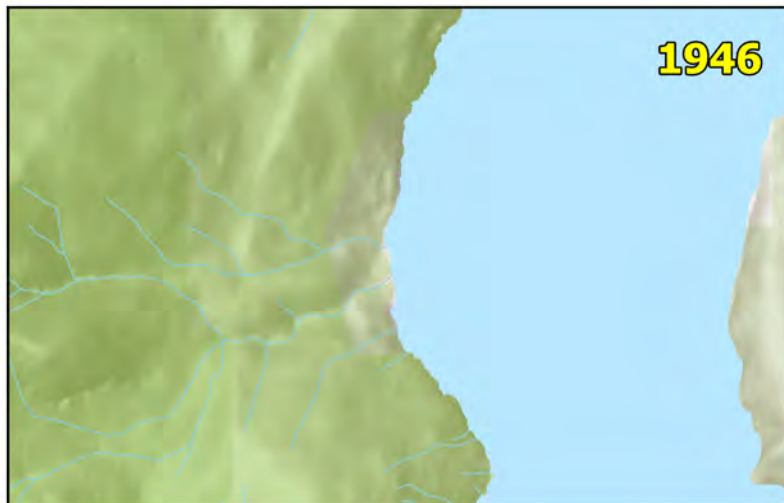
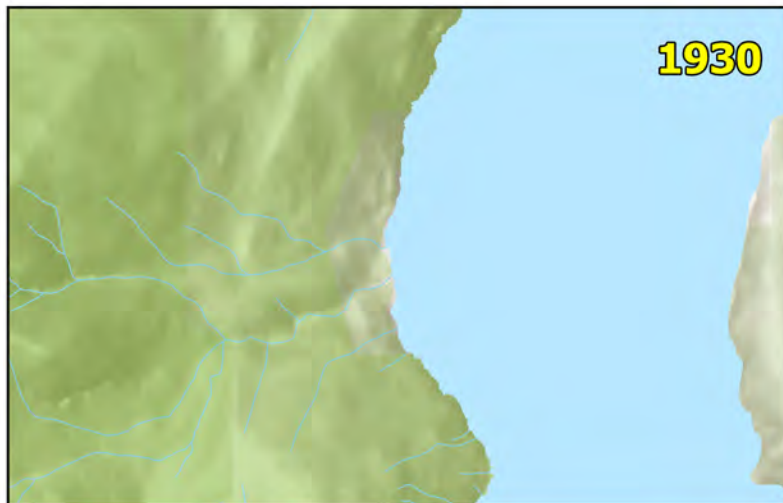


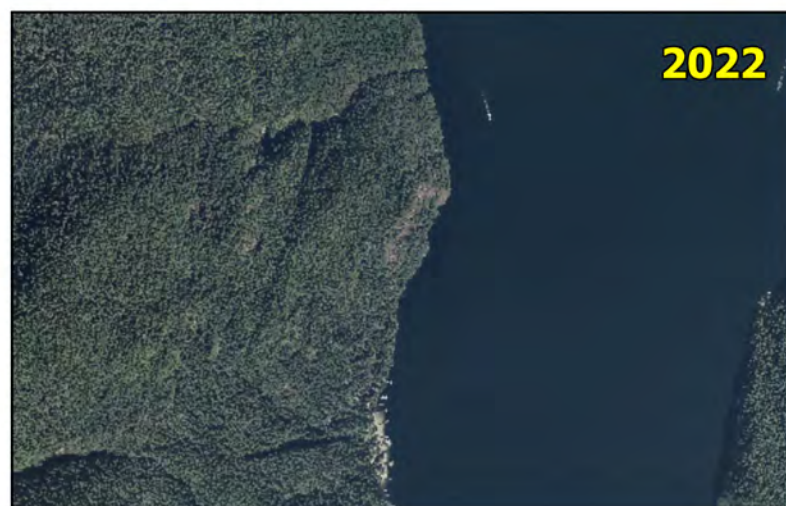
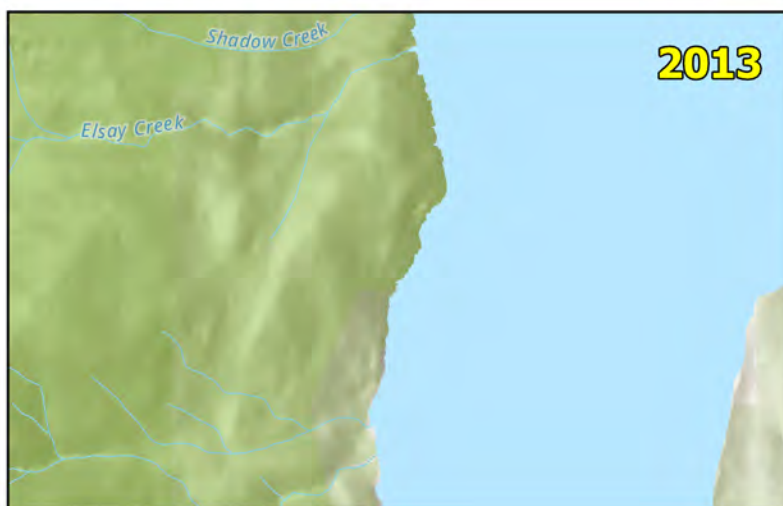
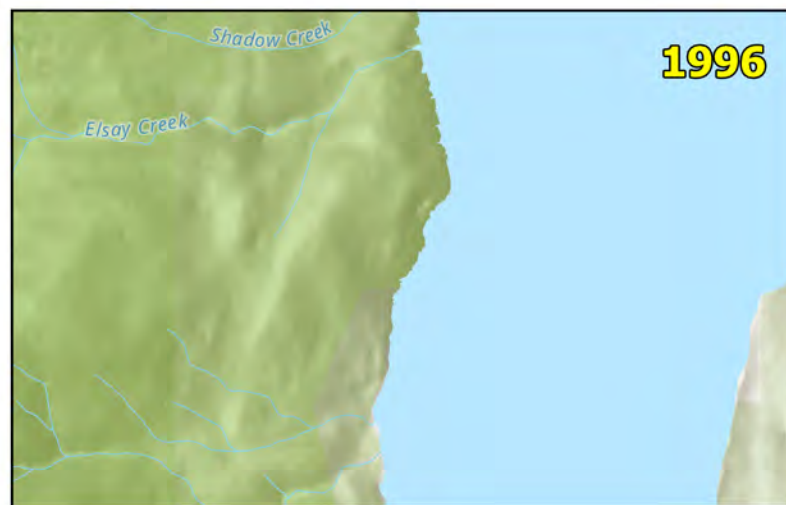
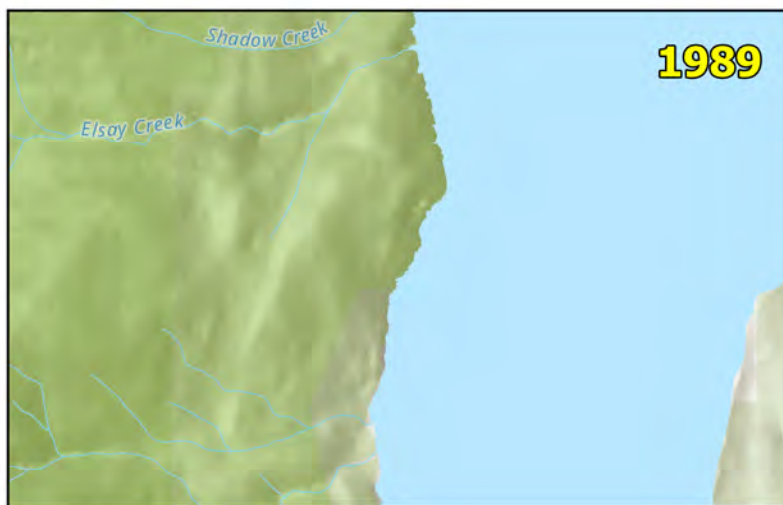
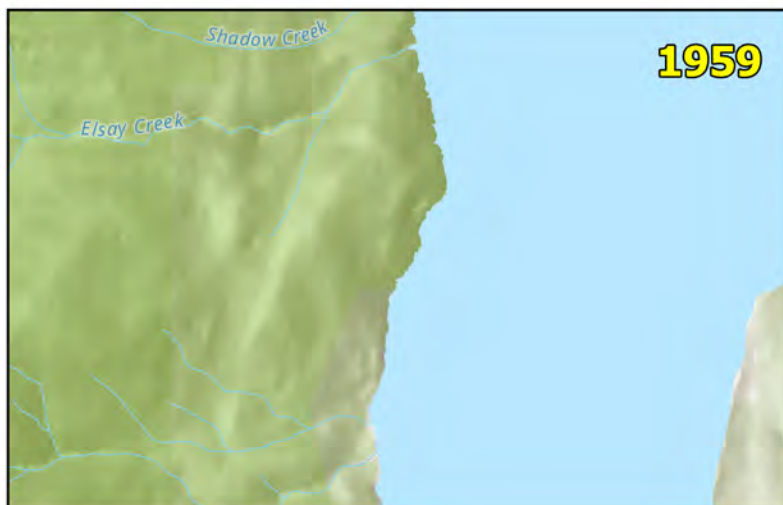
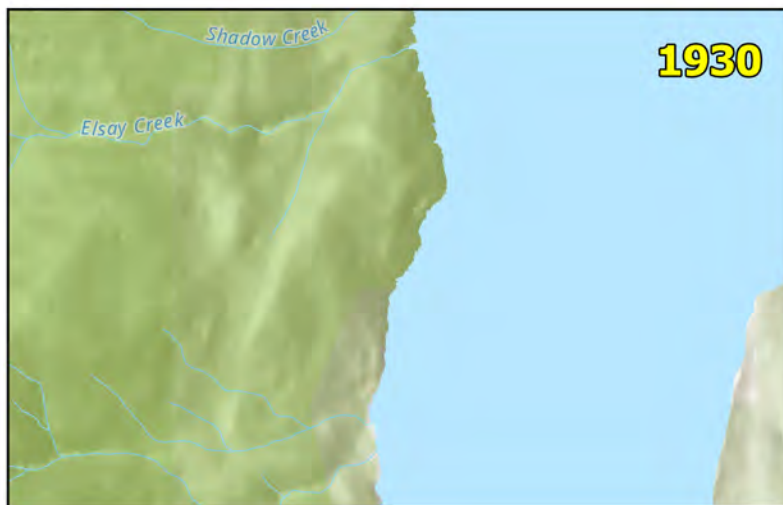


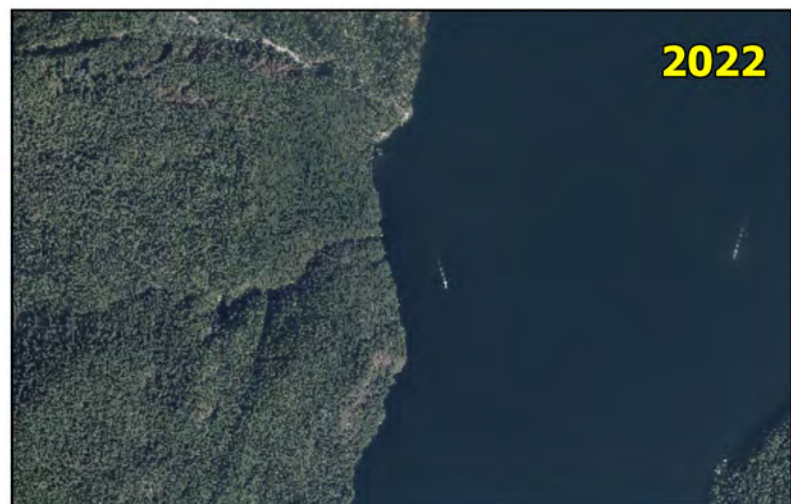
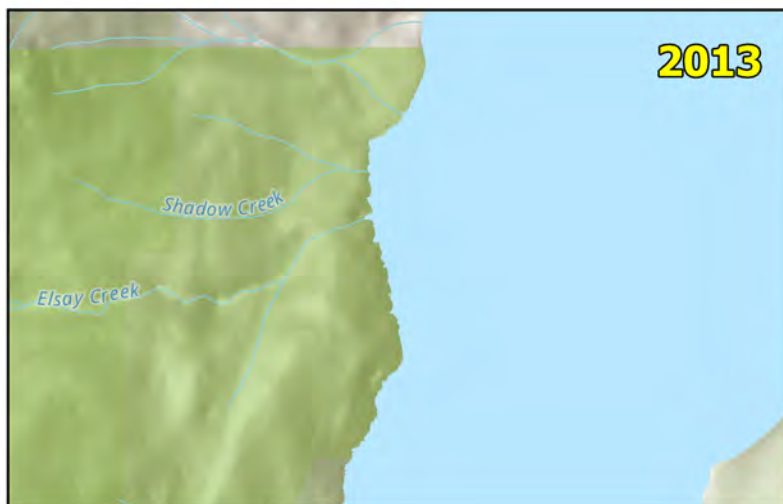


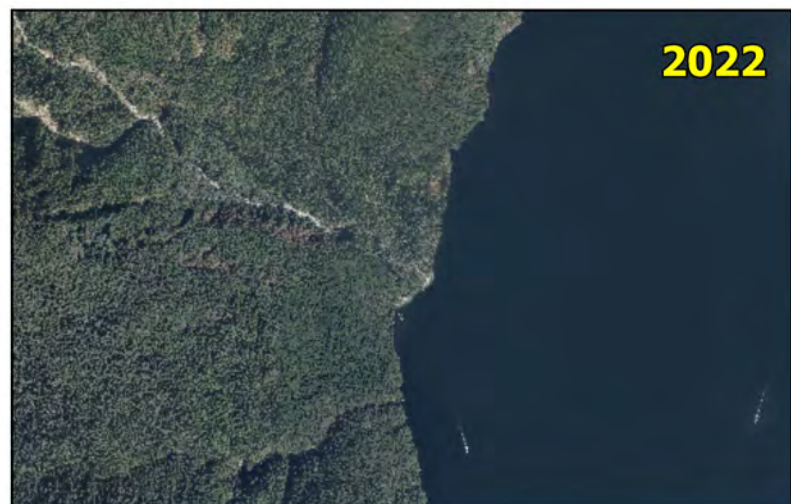




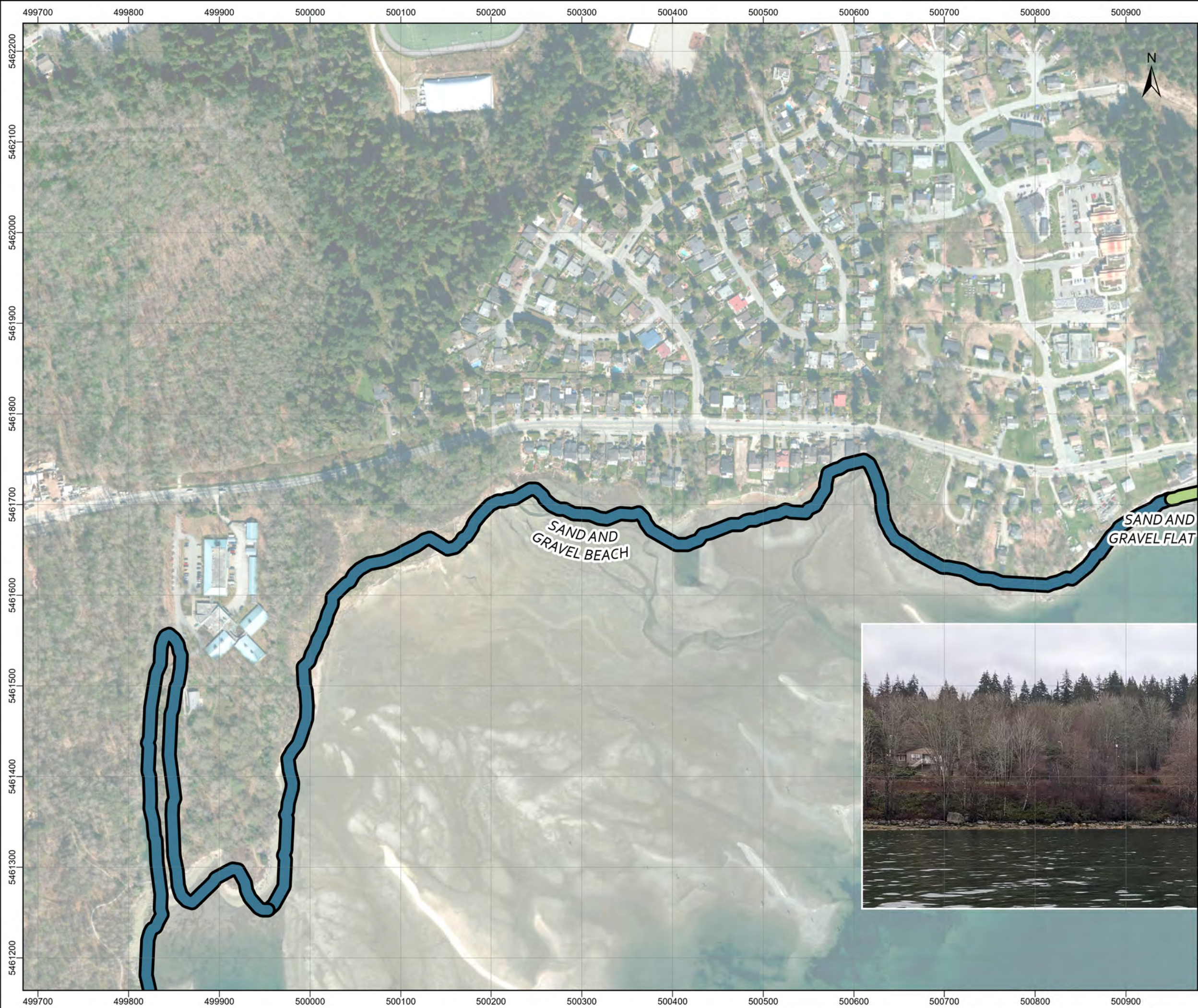








Appendix E.2 Shoreline Features



Overview:
These maps have been developed by DHI Water & Environment Inc. (DHI) for the District of North Vancouver to support the 2024 Consultancy for Coastal Flood Hazard Mapping.

Notes:
1. The maps have been developed using the methodologies outlined in the report entitled: District of North Vancouver Coastal Flood Hazard Mapping Study, issued by DHI, June 2024. The report should be consulted for a detailed outline of the methods, assumptions and limitations of the study to develop the flood hazard maps presented herein.
2. Imagery captured by DHI during a project site visit conducted on January 24, 2024.
3. Shoreline classification developed using the British Columbia Coastal Resource Information Management System (CRIMS) as described by D. Howes, et al. (1995). Shoreline classification has been validated using recent aerial imagery, site photos, and site visit.
4. For consistency, shoreline classification categories have been retained as presented by CRIMS.

Data Sources:
- Satellite imagery supplied by Esri and orthophotos by the District of North Vancouver (2016)
- Infrastructure Footprints, natural and administrative boundaries provided by the District of North Vancouver GIS Department.
- D. Howes, J. Harper, E. Owens (1995), Physical Shore-Zone Mapping System for British Columbia, Ministry of Environment and Climate Change Strategy, 0-7726-3577-3
- B.C. Gov (2024) Coastal Resource Information Management System (CRIMS), February 9, 2024. The data set is licensed under Open Government Licence - British Columbia

Scale Disclaimer: The map scale of 1:4,000 is only valid on a 11"x17" print.

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PCS: Projected Coordinate System
CGVD2013: Canadian Geodetic Vertical Datum of 2013
EPSG: European Petroleum Survey Group
CSRS: Canadian Spatial Reference System

Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

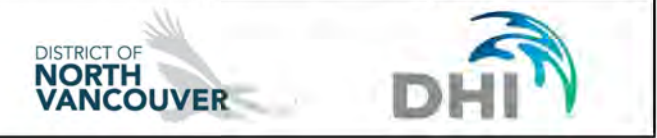
Estuary, Marsh or Lagoon	Rock Cliff
Gravel Beach	Rock with Gravel Beach
Gravel Flat	Rock with Sand Beach
Man-made	Rock, Sand and Gravel Beach
Mud Flat	Sand and Gravel Beach
	Sand and Gravel Flat
	Sand Beach
	Sand Flat

TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 1 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
 Meters

DATE	2024-03-13	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





Overview:
These maps have been developed by DHI Water & Environment Inc. (DHI) for the District of North Vancouver to support the 2024 Consultancy for Coastal Flood Hazard Mapping.

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- B.C. Gov (2024) Coastal Resource Information Management System (CRIMS), February 9, 2024. The data set is licensed under Open Government Licence - British Columbia

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CGVD2013: Canadian Geodetic Vertical Datum of 2013
EPSG: European Petroleum Survey Group
CSRS: Canadian Spatial Reference System

Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

Estuary, Marsh or Lagoon	Rock Cliff
Gravel Beach	Rock with Gravel Beach
Gravel Flat	Rock with Sand Beach
Man-made	Rock, Sand and Gravel Beach
Mud Flat	Sand and Gravel Beach
	Sand and Gravel Flat
	Sand Beach
	Sand Flat

TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 2 of 25

PCS: NAD 1983 UTM Zone 10N	Scale: 1:4,000
EPSG: 26910	0 25 50 100
Datum: CGVD2013	Meters
Map Units: Meter	

DATE	2024-03-13	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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PCS: Projected Coordinate System
CGVD2013: Canadian Geodetic Vertical Datum of 2013
EPSG: European Petroleum Survey Group
CSRS: Canadian Spatial Reference System

Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

- Estuary, Marsh or Lagoon
- Gravel Beach
- Gravel Flat
- Man-made
- Mud Flat

- Rock Cliff
- Rock with Gravel Beach
- Rock with Sand Beach
- Rock, Sand and Gravel Beach
- Sand and Gravel Beach
- Sand and Gravel Flat
- Sand Beach
- Sand Flat

TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 3 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-03-13	AUTHOR	SSIN	APPROVER	DANK
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CSRS: Canadian Spatial Reference System

Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

- Estuary, Marsh or Lagoon
- Gravel Beach
- Gravel Flat
- Man-made
- Mud Flat

- Rock Cliff
- Rock with Gravel Beach
- Rock with Sand Beach
- Rock, Sand and Gravel Beach
- Sand and Gravel Beach
- Sand and Gravel Flat
- Sand Beach
- Sand Flat

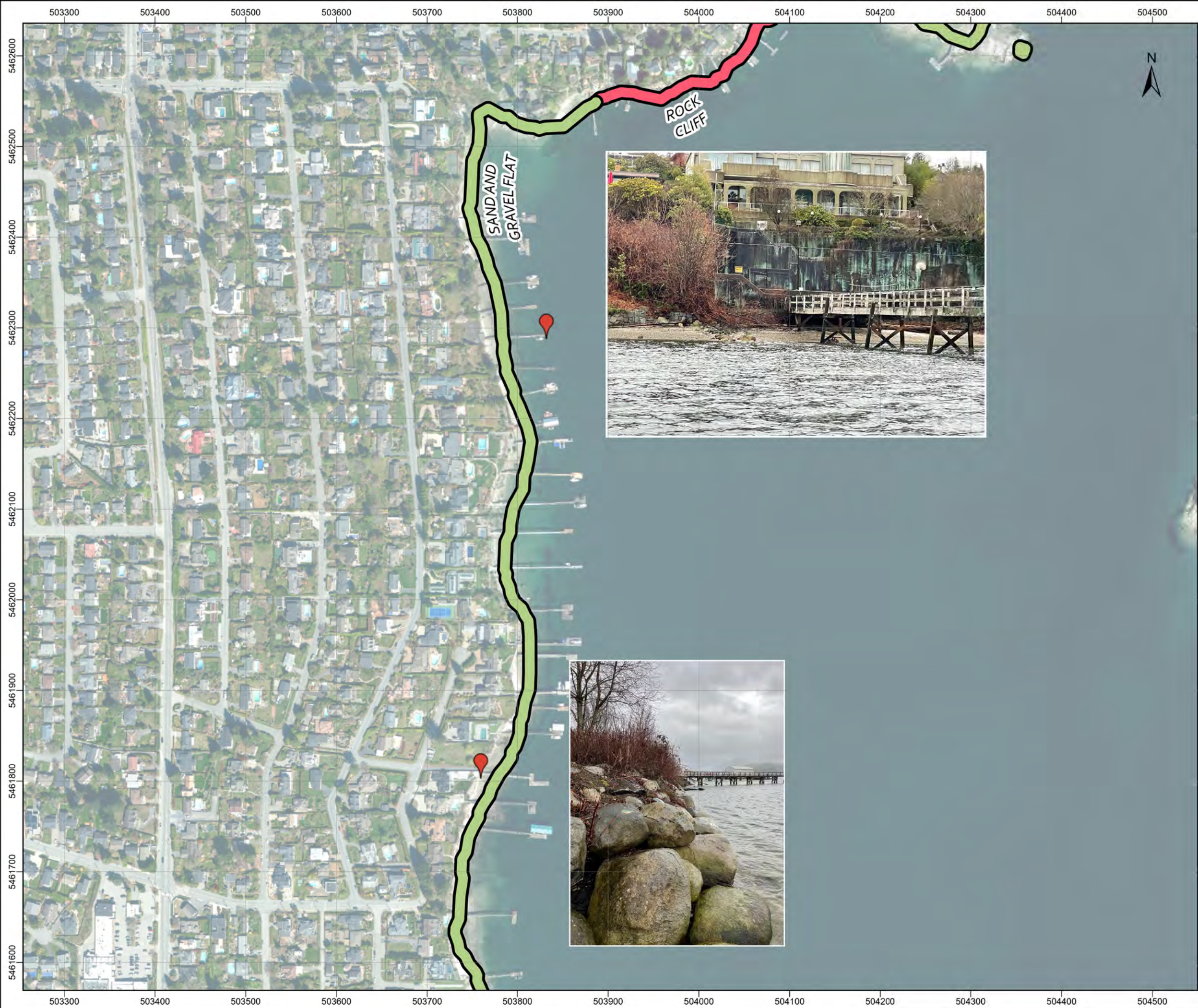
TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 4 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-03-13	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

- Estuary, Marsh or Lagoon
- Gravel Beach
- Gravel Flat
- Man-made
- Mud Flat

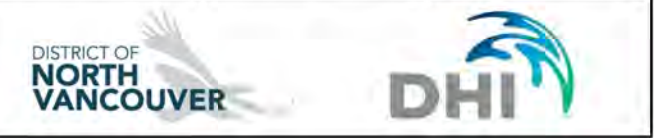
- Rock Cliff
- Rock with Gravel Beach
- Rock with Sand Beach
- Rock, Sand and Gravel Beach
- Sand and Gravel Beach
- Sand and Gravel Flat
- Sand Beach
- Sand Flat

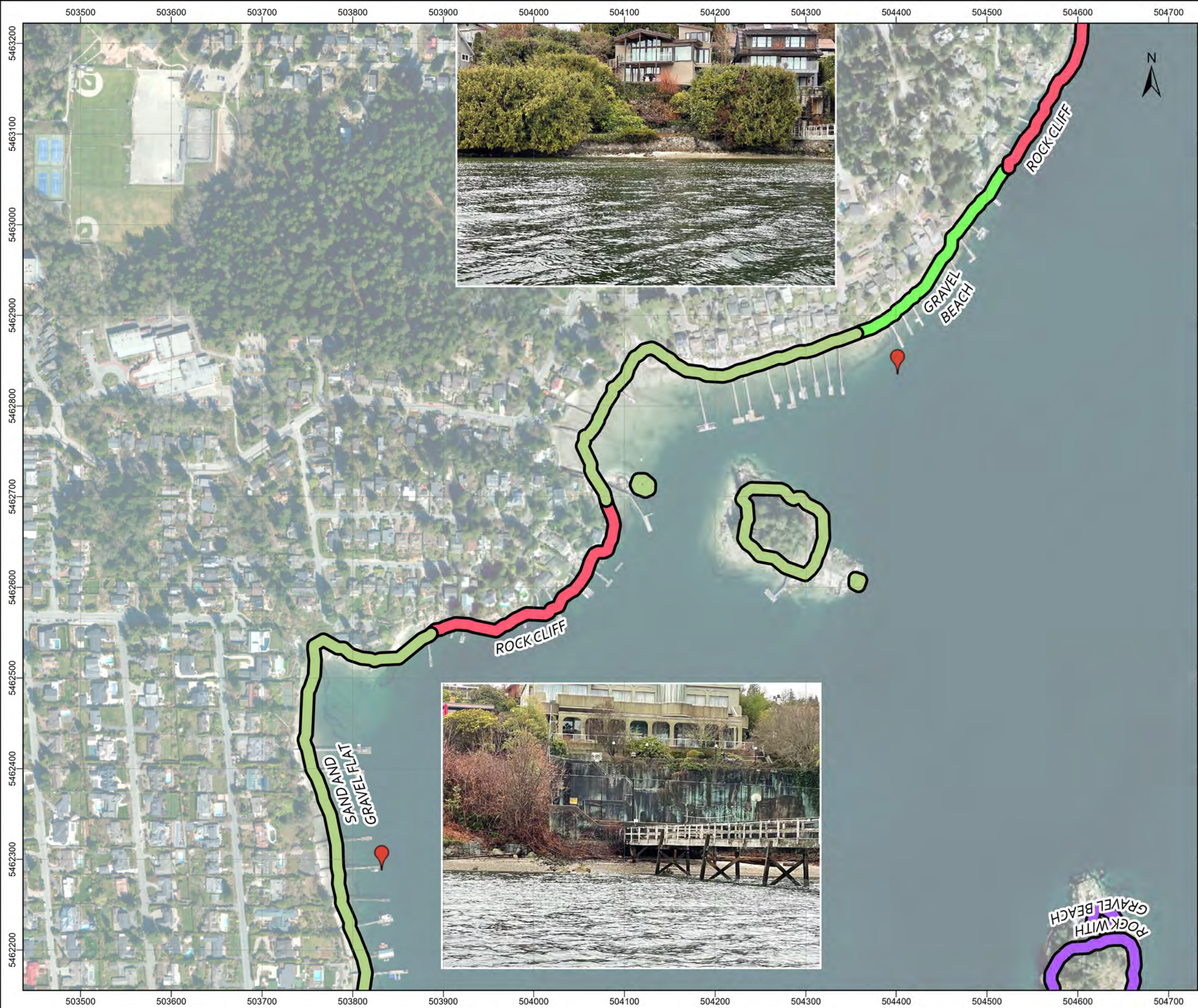
TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 5 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
 Meters

DATE	2024-03-13	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

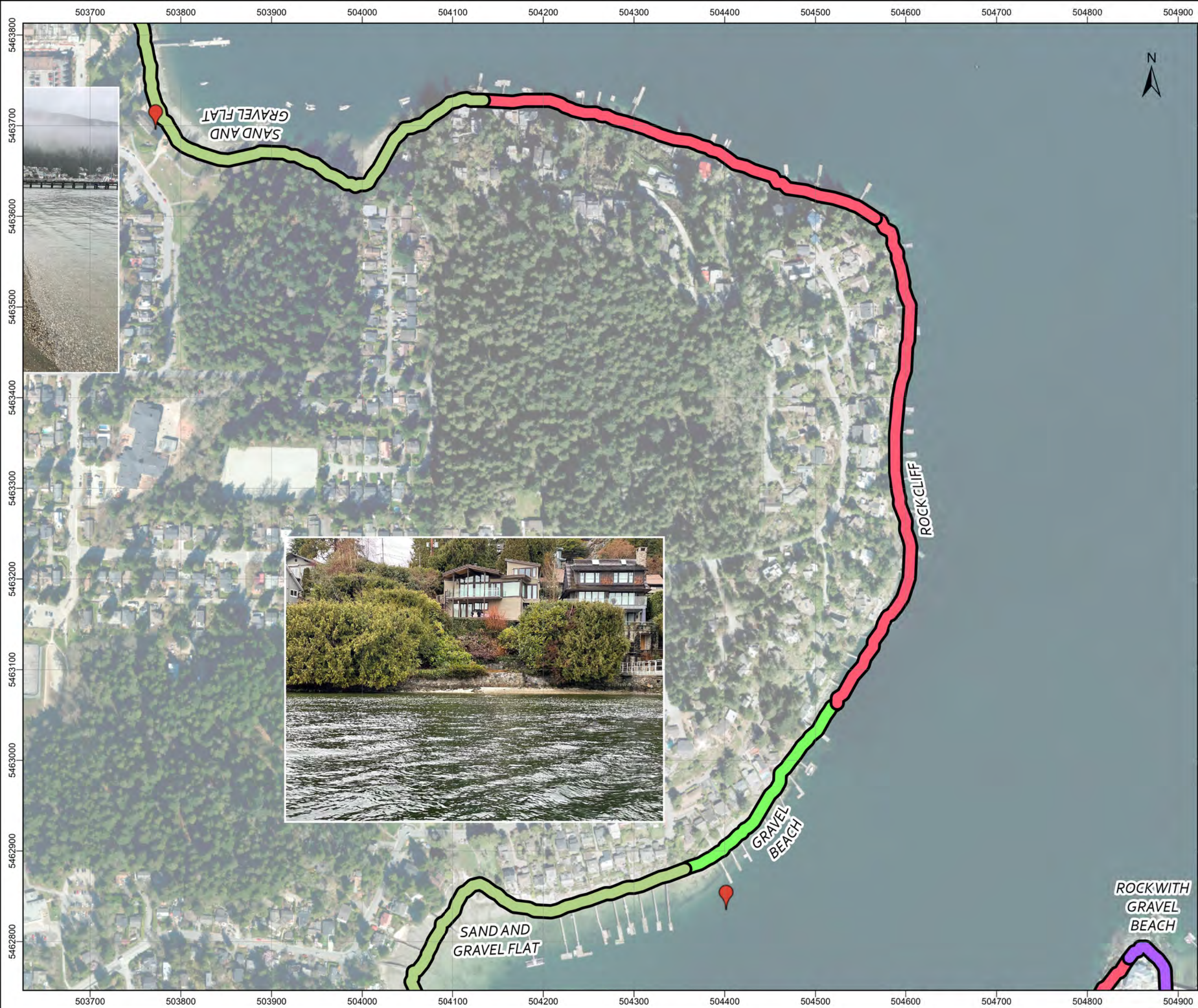
Estuary, Marsh or Lagoon	Rock Cliff
Gravel Beach	Rock with Gravel Beach
Gravel Flat	Rock with Sand Beach
Man-made	Rock, Sand and Gravel Beach
Mud Flat	Sand and Gravel Beach
	Sand and Gravel Flat
	Sand Beach
	Sand Flat

TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 6 of 25

PCS: NAD 1983 UTM Zone 10N	Scale: 1:4,000
EPSG: 26910	0 25 50 100
Datum: CGVD2013	Meters
Map Units: Meter	

DATE	2024-03-13	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

- Estuary, Marsh or Lagoon
- Gravel Beach
- Gravel Flat
- Man-made
- Mud Flat

- Rock Cliff
- Rock with Gravel Beach
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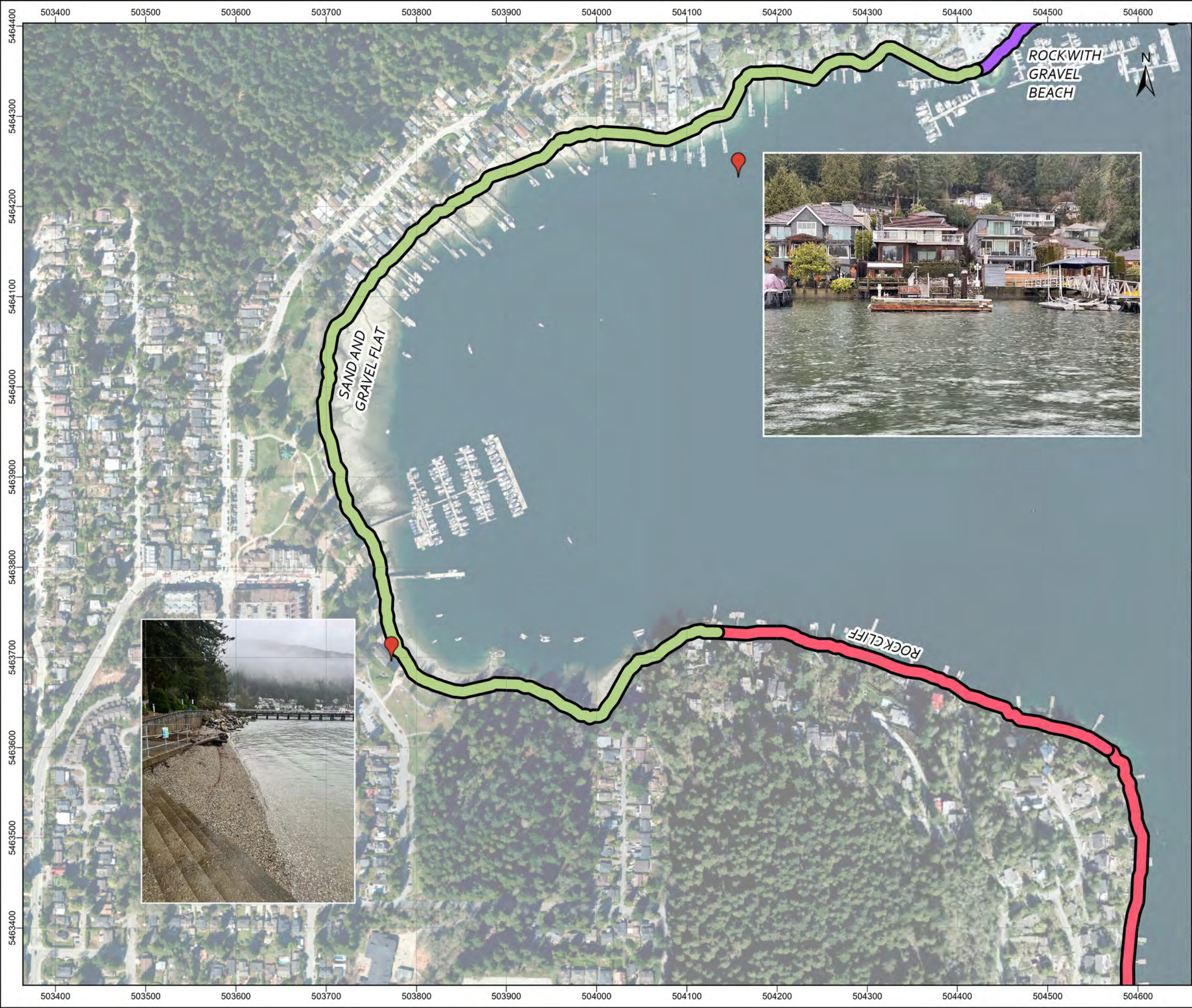
TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 7 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-03-13	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

Estuary, Marsh or Lagoon	Rock Cliff
Gravel Beach	Rock with Gravel Beach
Gravel Flat	Rock with Sand Beach
Man-made	Rock, Sand and Gravel Beach
Mud Flat	Sand and Gravel Beach
	Sand and Gravel Flat
	Sand Beach
	Sand Flat

TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 8 of 25

PCS: NAD 1983 UTM Zone 10N	Scale: 1:4,000
EPSG: 26910	0 25 50 100
Datum: CGVD2013	Meters
Map Units: Meter	

DATE	2024-03-13	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

- Estuary, Marsh or Lagoon
- Gravel Beach
- Gravel Flat
- Man-made
- Mud Flat

- Rock Cliff
- Rock with Gravel Beach
- Rock with Sand Beach
- Rock, Sand and Gravel Beach
- Sand and Gravel Beach
- Sand and Gravel Flat
- Sand Beach
- Sand Flat

TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 9 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

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Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

- Estuary, Marsh or Lagoon
- Gravel Beach
- Gravel Flat
- Man-made
- Mud Flat

- Rock Cliff
- Rock with Gravel Beach
- Rock with Sand Beach
- Rock, Sand and Gravel Beach
- Sand and Gravel Beach
- Sand and Gravel Flat
- Sand Beach
- Sand Flat

TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 10 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

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REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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PCS: Projected Coordinate System
CGVD2013: Canadian Geodetic Vertical Datum of 2013
EPSG: European Petroleum Survey Group
CSRS: Canadian Spatial Reference System

Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

Estuary, Marsh or Lagoon	Rock Cliff
Gravel Beach	Rock with Gravel Beach
Gravel Flat	Rock with Sand Beach
Man-made	Rock, Sand and Gravel Beach
Mud Flat	Sand and Gravel Beach
	Sand and Gravel Flat
	Sand Beach
	Sand Flat

TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 11 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-03-13	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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Site Visit Jan 25, 2024

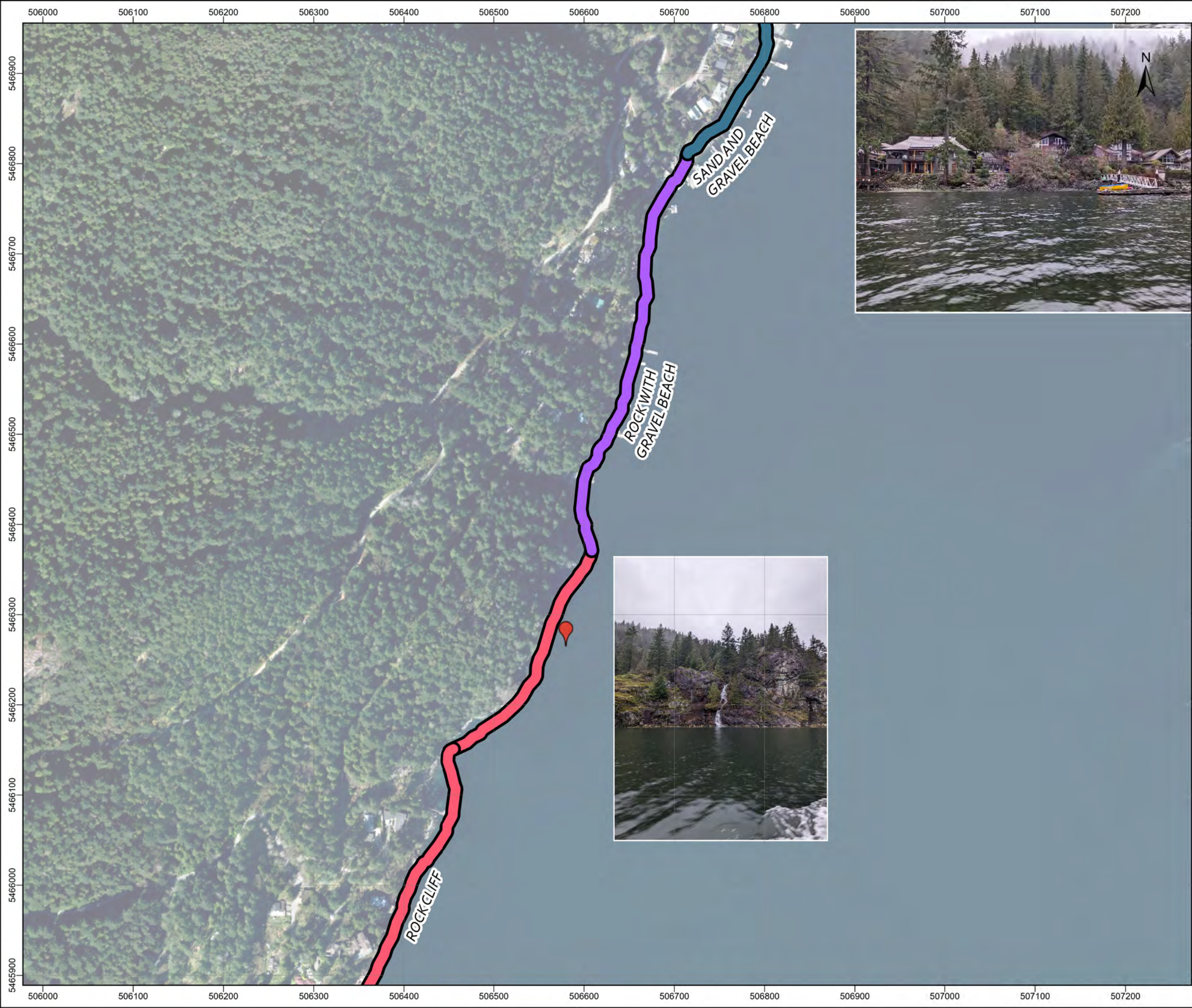
Vantage Point

Shoreline Classification (CRIMS)

Estuary, Marsh or Lagoon	Rock Cliff
Gravel Beach	Rock with Gravel Beach
Gravel Flat	Rock with Sand Beach
Man-made	Rock, Sand and Gravel Beach
Mud Flat	Sand and Gravel Beach
	Sand and Gravel Flat
	Sand Beach
	Sand Flat

TITLE				
District of North Vancouver - Coastal Flood Hazard Maps				
Map 12 of 25				
PCS: NAD 1983 UTM Zone 10N		Scale: 1:4,000		
EPSG: 26910		0 25 50 100		
Datum: CGVD2013				
Map Units: Meter		Meters		
DATE	2024-03-13	AUTHOR	SSIN	APPROVER DANK
REVISION 1		REVIEWER	DANK	DHI PROJECT NUMBER 42804121





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Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

Estuary, Marsh or Lagoon	Rock Cliff
Gravel Beach	Rock with Gravel Beach
Gravel Flat	Rock with Sand Beach
Man-made	Rock, Sand and Gravel Beach
Mud Flat	Sand and Gravel Beach
	Sand and Gravel Flat
	Sand Beach
	Sand Flat

TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 13 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-03-13	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

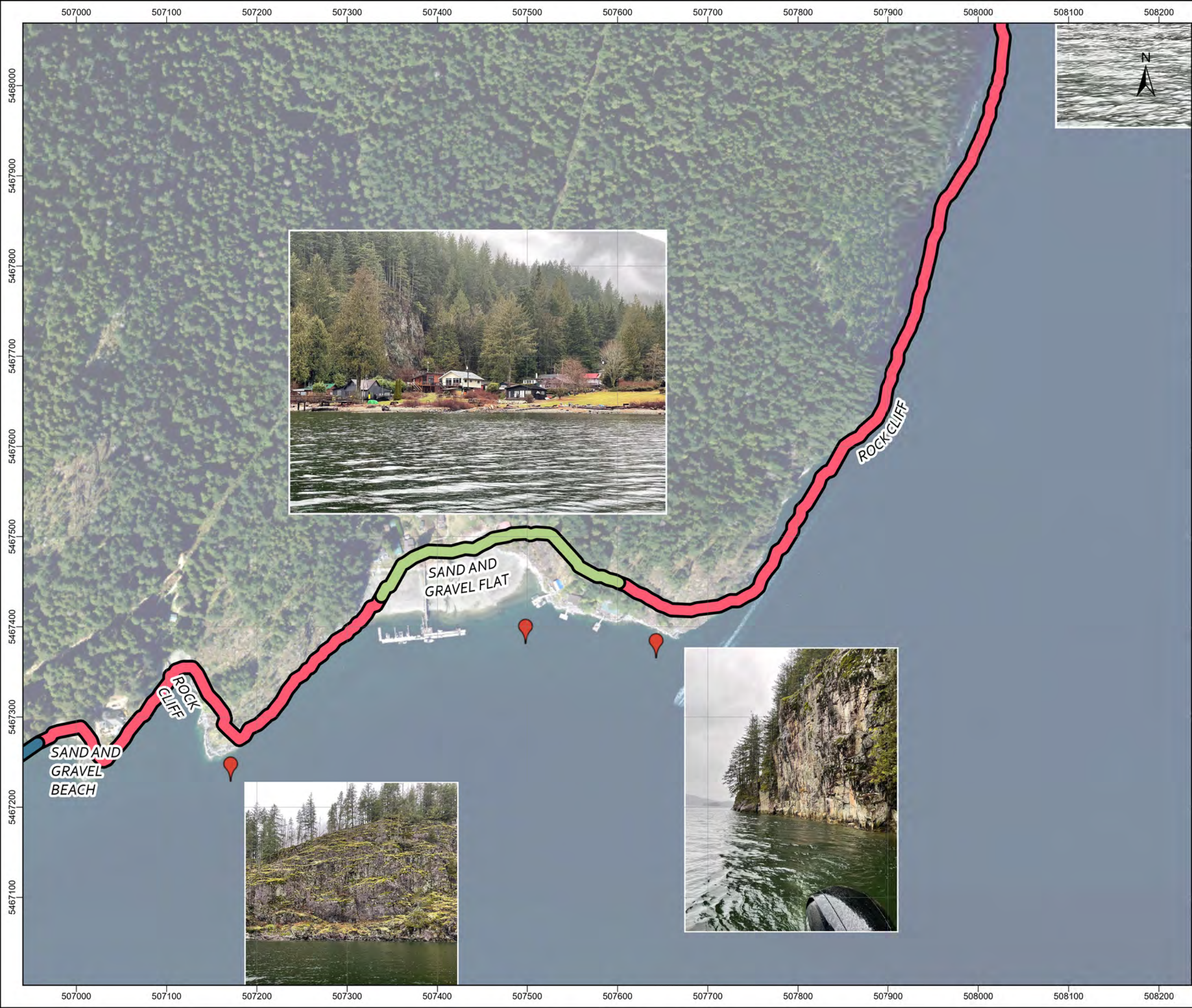
Estuary, Marsh or Lagoon	Rock Cliff
Gravel Beach	Rock with Gravel Beach
Gravel Flat	Rock with Sand Beach
Man-made	Rock, Sand and Gravel Beach
Mud Flat	Sand and Gravel Beach
	Sand and Gravel Flat
	Sand Beach
	Sand Flat

TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 14 of 25

PCS: NAD 1983 UTM Zone 10N	Scale: 1:4,000
EPSG: 26910	0 25 50 100
Datum: CGVD2013	Meters
Map Units: Meter	

DATE	2024-03-13	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

- Estuary, Marsh or Lagoon
- Gravel Beach
- Gravel Flat
- Man-made
- Mud Flat

- Rock Cliff
- Rock with Gravel Beach
- Rock with Sand Beach
- Rock, Sand and Gravel Beach
- Sand and Gravel Beach
- Sand and Gravel Flat
- Sand Beach
- Sand Flat

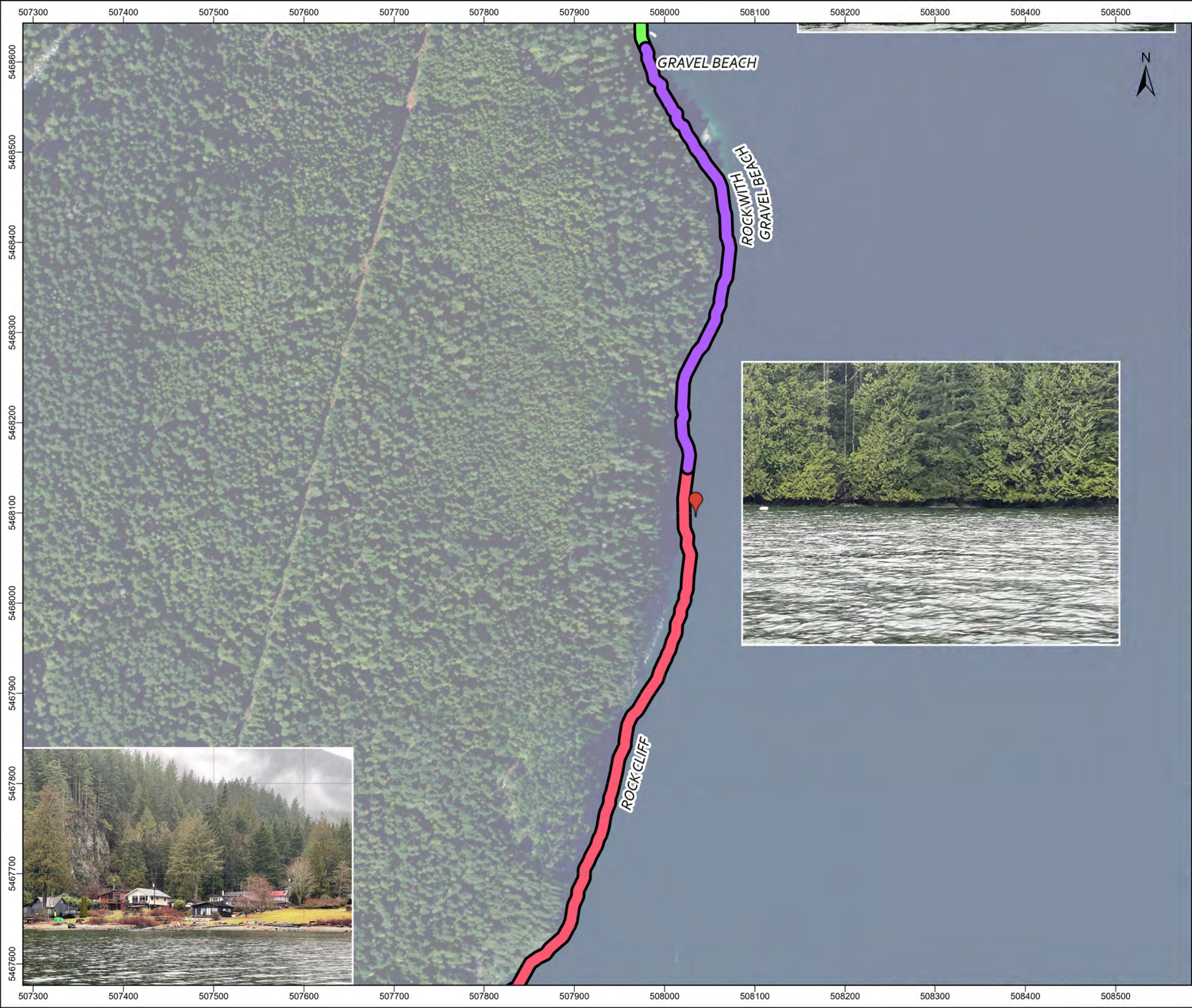
TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 15 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-03-13	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

Estuary, Marsh or Lagoon	Rock Cliff
Gravel Beach	Rock with Gravel Beach
Gravel Flat	Rock with Sand Beach
Man-made	Rock, Sand and Gravel Beach
Mud Flat	Sand and Gravel Beach
	Sand and Gravel Flat
	Sand Beach
	Sand Flat

TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 16 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-03-13	AUTHOR	SSIN	APPROVER	DANK
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Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

Estuary, Marsh or Lagoon	Rock Cliff
Gravel Beach	Rock with Gravel Beach
Gravel Flat	Rock with Sand Beach
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Mud Flat	Sand and Gravel Beach
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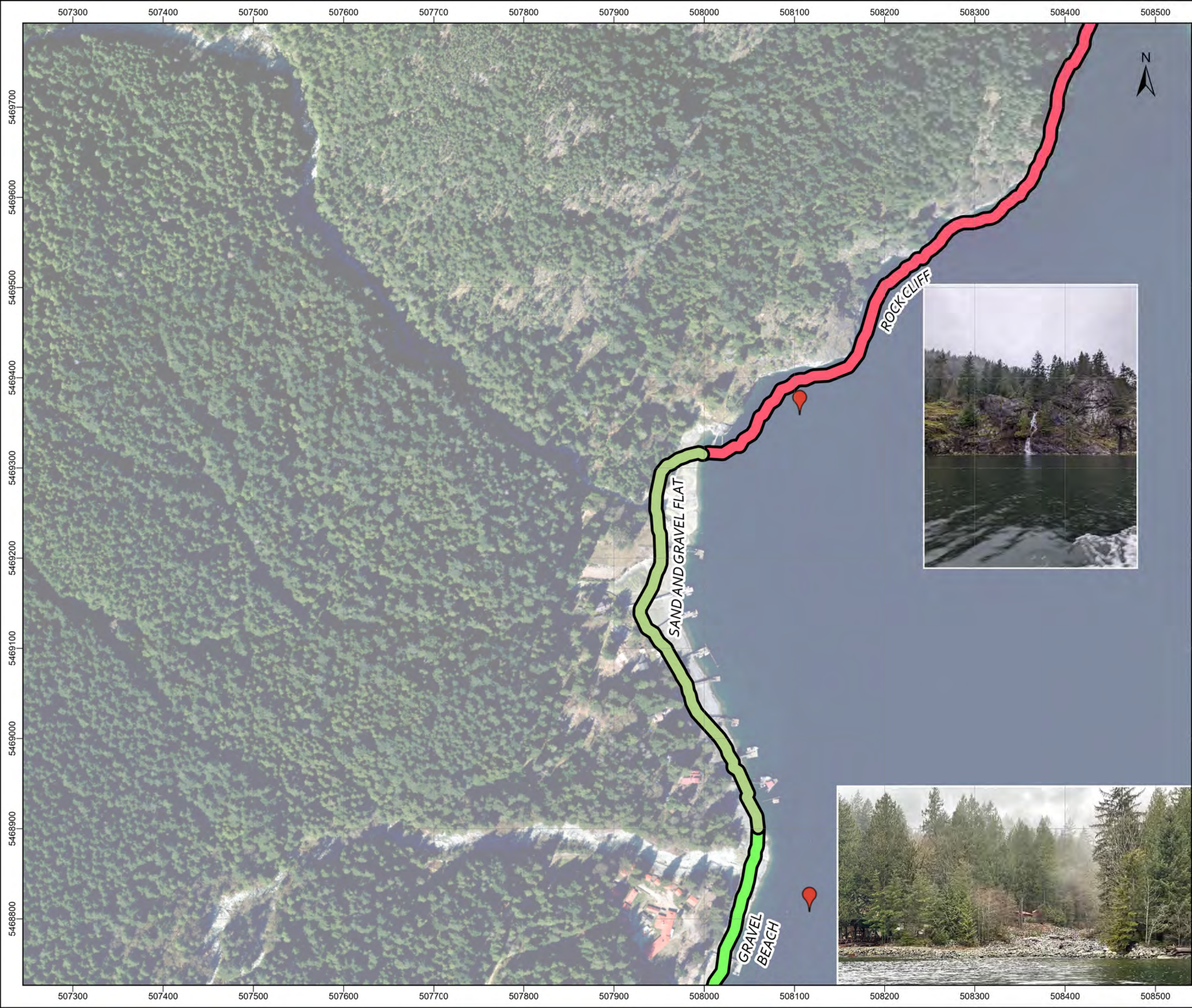
TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 17 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-03-13	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

- Estuary, Marsh or Lagoon
- Gravel Beach
- Gravel Flat
- Man-made
- Mud Flat

- Rock Cliff
- Rock with Gravel Beach
- Rock with Sand Beach
- Rock, Sand and Gravel Beach
- Sand and Gravel Beach
- Sand and Gravel Flat
- Sand Beach
- Sand Flat

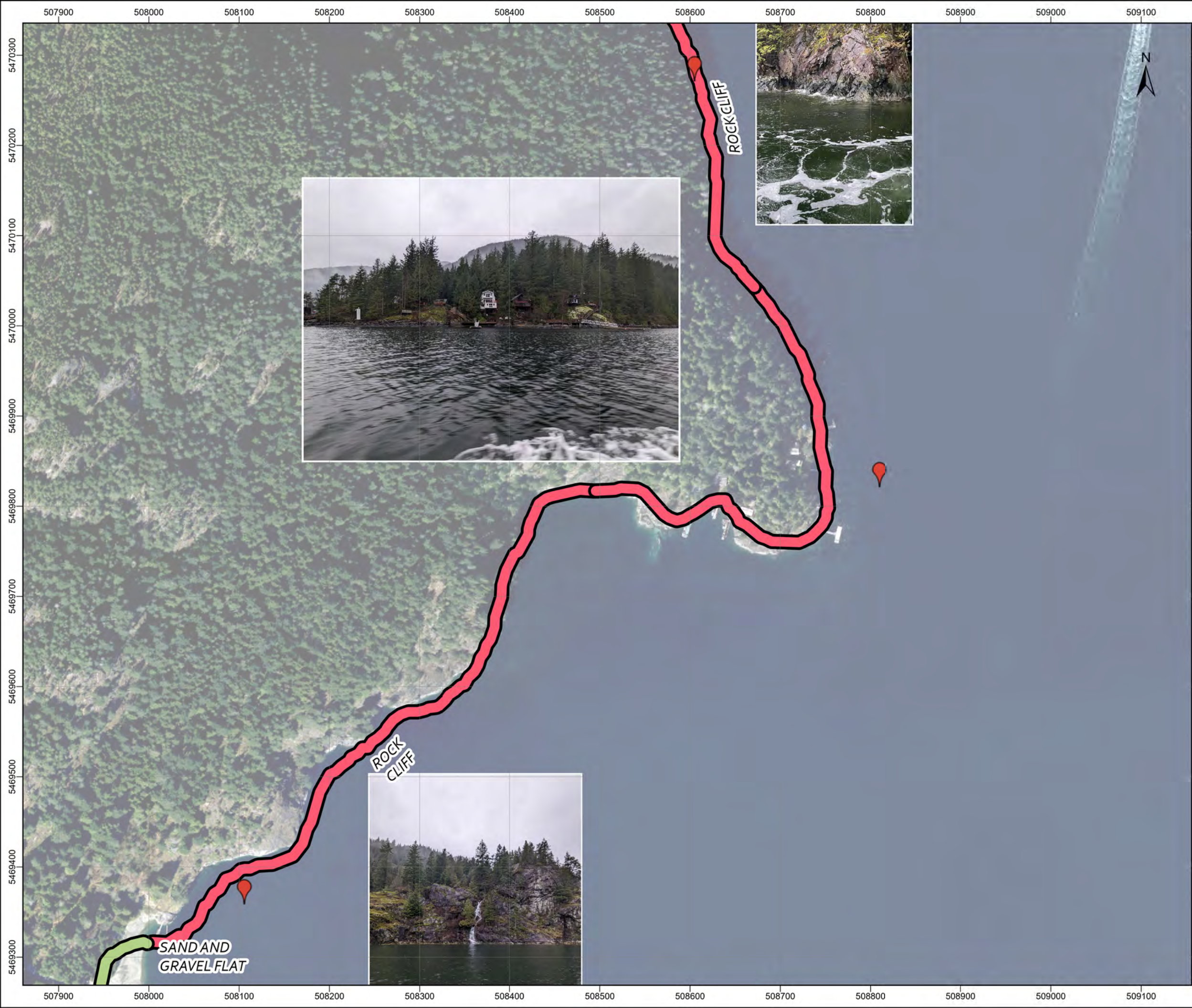
TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 18 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

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REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

- Estuary, Marsh or Lagoon
- Gravel Beach
- Gravel Flat
- Man-made
- Mud Flat

- Rock Cliff
- Rock with Gravel Beach
- Rock with Sand Beach
- Rock, Sand and Gravel Beach
- Sand and Gravel Beach
- Sand and Gravel Flat
- Sand Beach
- Sand Flat

TITLE

District of North Vancouver - Coastal Flood Hazard Maps
Map 19 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-03-13	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



Overview:
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- Notes:**
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PCS: Projected Coordinate System
CGVD2013: Canadian Geodetic Vertical Datum of 2013
EPSG: European Petroleum Survey Group
CSRS: Canadian Spatial Reference System

Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

Estuary, Marsh or Lagoon	Rock Cliff
Gravel Beach	Rock with Gravel Beach
Gravel Flat	Rock with Sand Beach
Man-made	Rock, Sand and Gravel Beach
Mud Flat	Sand and Gravel Beach
	Sand and Gravel Flat
	Sand Beach
	Sand Flat

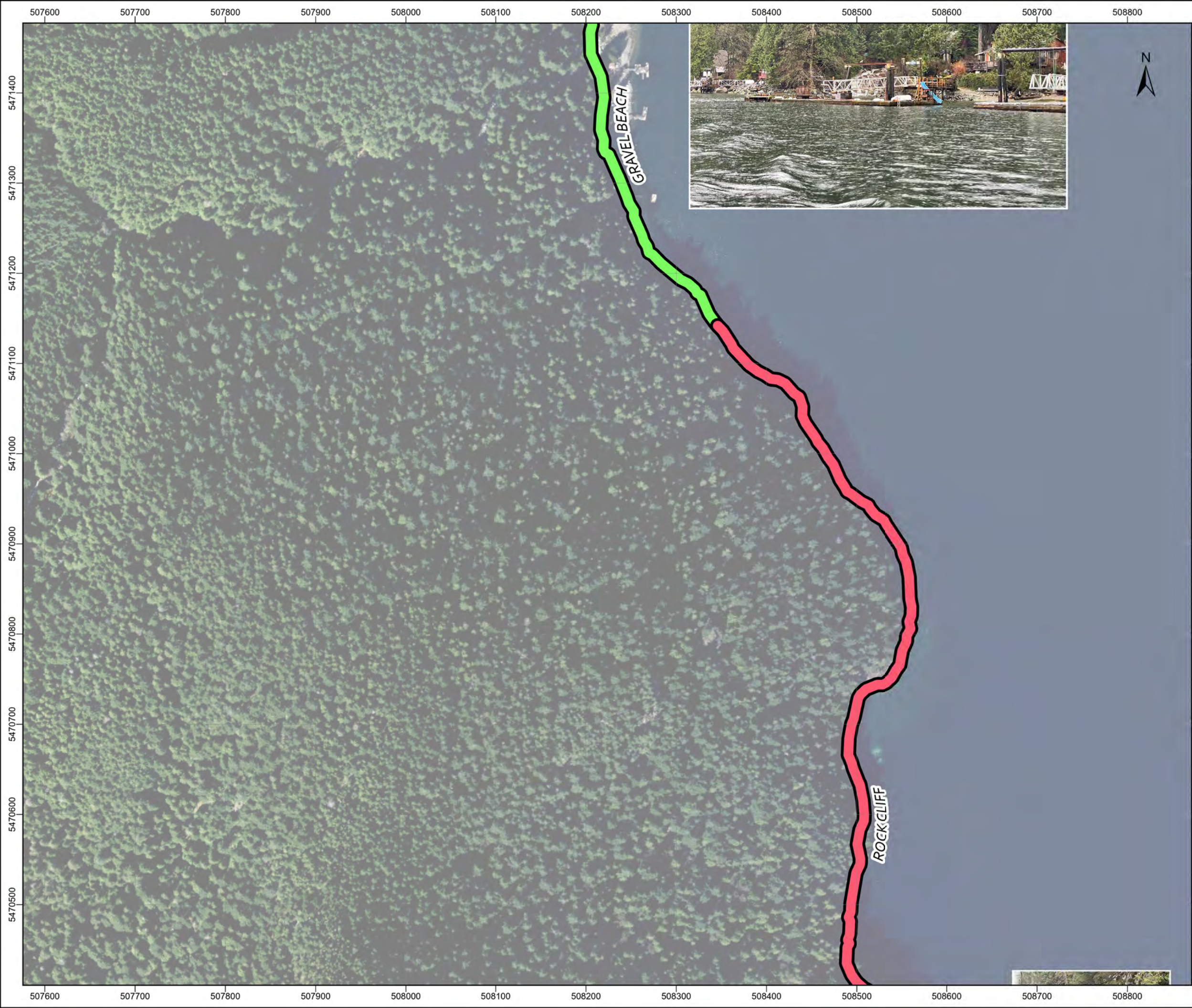
TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 20 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-03-13	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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CSRS: Canadian Spatial Reference System

Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

- Estuary, Marsh or Lagoon
- Gravel Beach
- Gravel Flat
- Man-made
- Mud Flat

- Rock Cliff
- Rock with Gravel Beach
- Rock with Sand Beach
- Rock, Sand and Gravel Beach
- Sand and Gravel Beach
- Sand and Gravel Flat
- Sand Beach
- Sand Flat

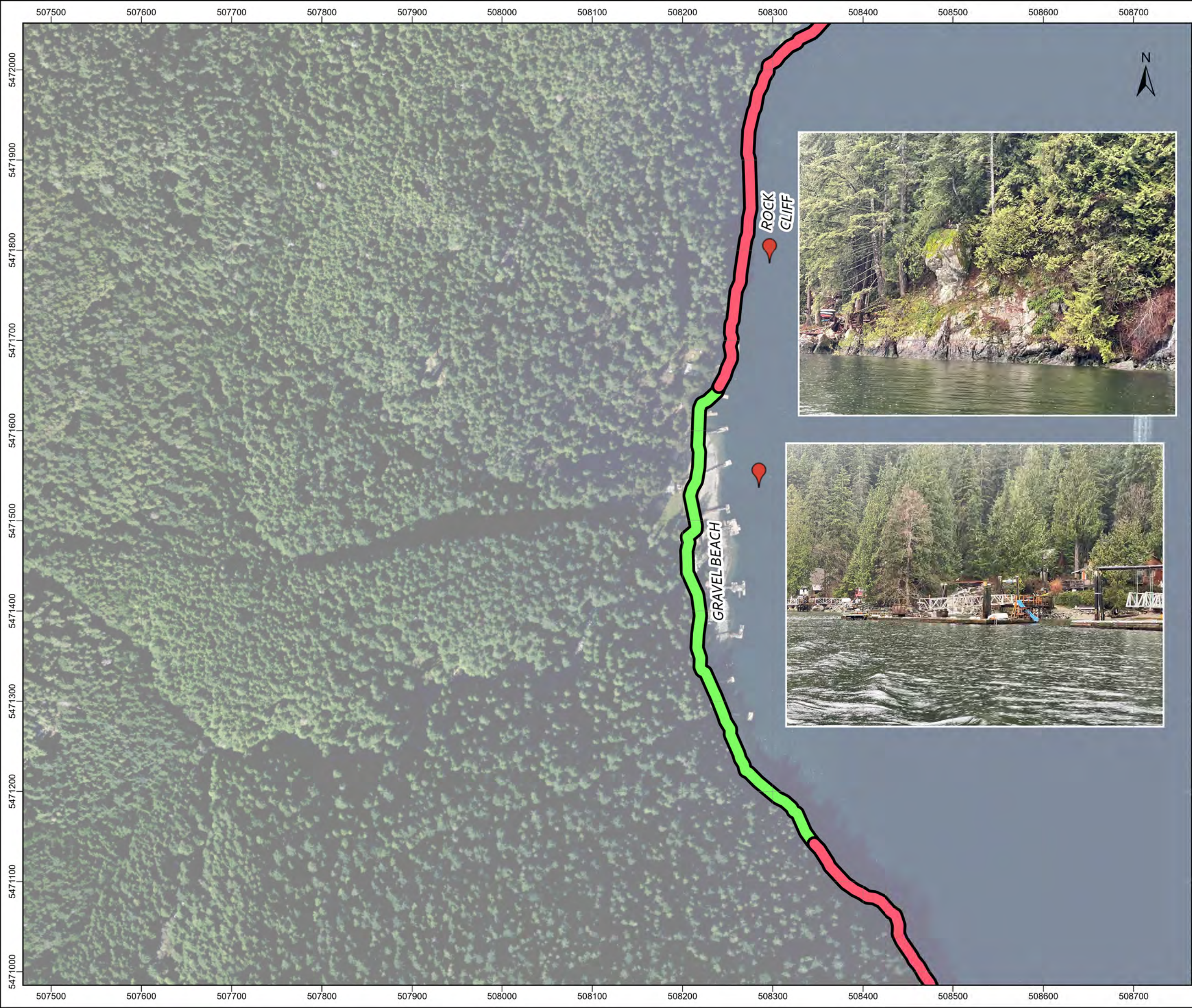
TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 21 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-03-13	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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PCS: Projected Coordinate System
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CSRS: Canadian Spatial Reference System

Site Visit Jan 25, 2024			Rock Cliff
		Vantage Point	Rock with Gravel Beach
Shoreline Classification (CRIMS)			Rock with Sand Beach
		Estuary, Marsh or Lagoon	Rock, Sand and Gravel Beach
		Gravel Beach	Sand and Gravel Beach
		Gravel Flat	Sand and Gravel Flat
		Man-made	Sand Beach
		Mud Flat	Sand Flat

TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 22 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-03-13	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

Estuary, Marsh or Lagoon	Rock Cliff
Gravel Beach	Rock with Gravel Beach
Gravel Flat	Rock with Sand Beach
Man-made	Rock, Sand and Gravel Beach
Mud Flat	Sand and Gravel Beach
	Sand and Gravel Flat
	Sand Beach
	Sand Flat

TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 23 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-03-13	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

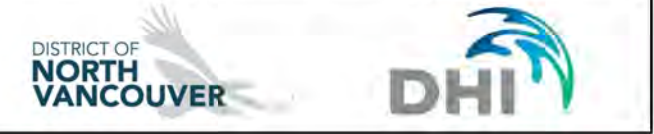
Estuary, Marsh or Lagoon	Rock Cliff
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Gravel Flat	Rock with Sand Beach
Man-made	Rock, Sand and Gravel Beach
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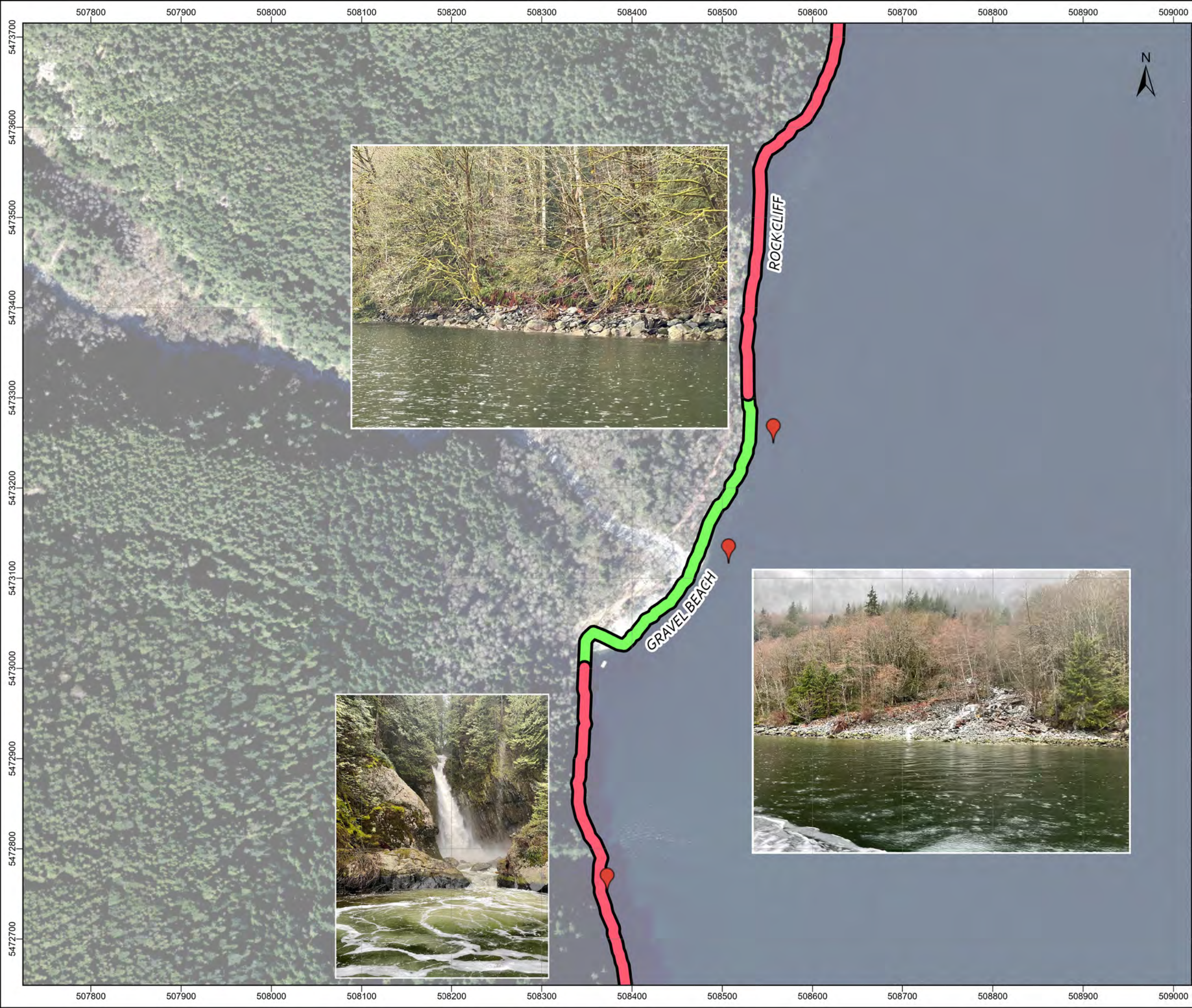
TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 24 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-03-13	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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Site Visit Jan 25, 2024

Vantage Point

Shoreline Classification (CRIMS)

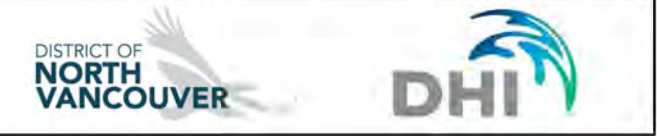
Estuary, Marsh or Lagoon	Rock Cliff
Gravel Beach	Rock with Gravel Beach
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Man-made	Rock, Sand and Gravel Beach
Mud Flat	Sand and Gravel Beach
	Sand and Gravel Flat
	Sand Beach
	Sand Flat

TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Map 25 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

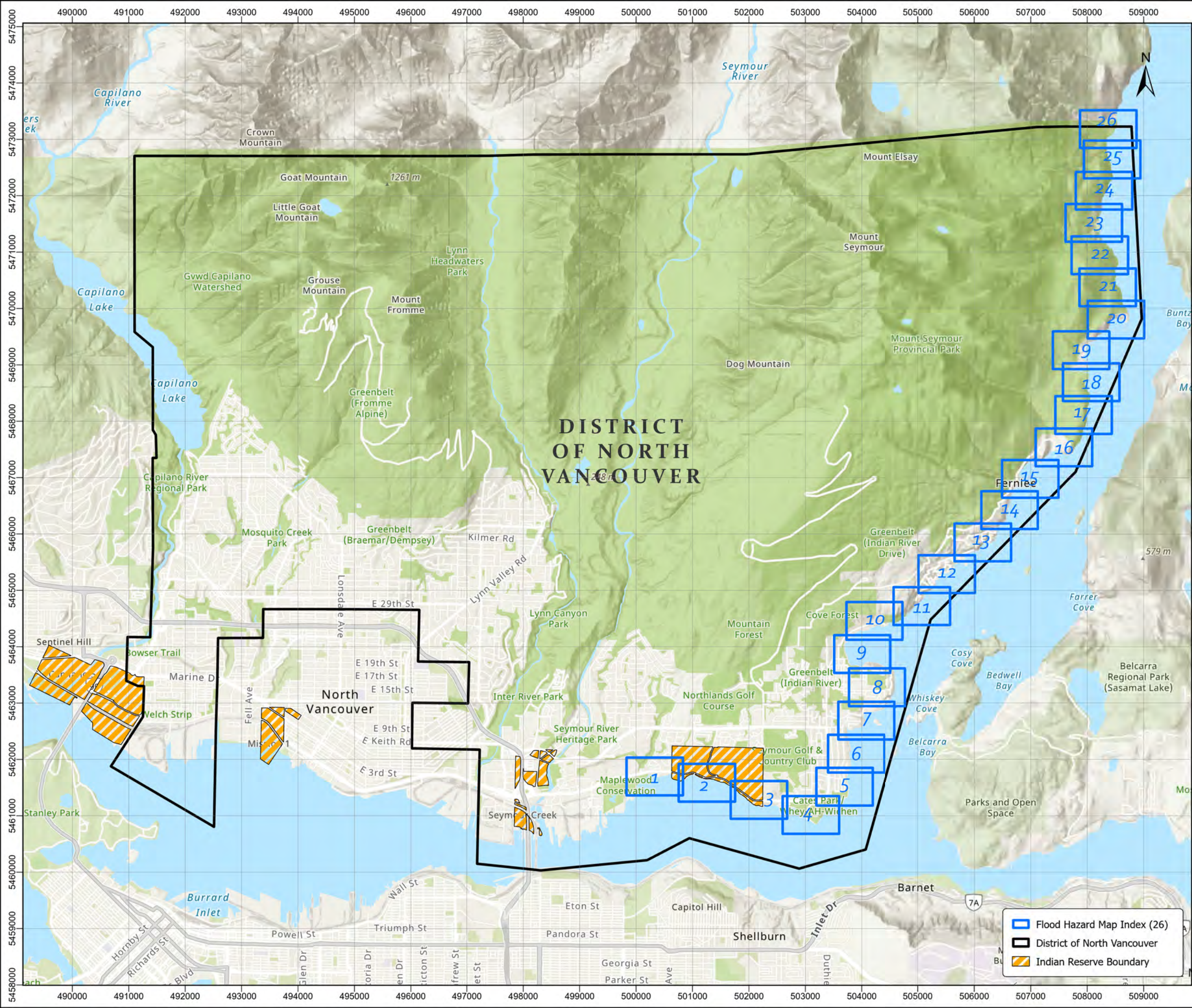
Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-03-13	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



Appendix F. Flood Inundation Maps

Appendix F.1 Flood Hazard Maps Index



Overview:
These maps have been developed by DHI Water & Environment Inc. (DHI) for the District of North Vancouver to provide Flood Construction Reference Plane (CFRP) and Flood Construction Level (FCL) guidance. Notably, these mapping products incorporate wave effects to establish the flood hazard.

Notes:
1. The maps have been developed using the methodologies outlined in the report entitled: District of North Vancouver Coastal Flood Mapping Study, issued by DHI, June 2024. The report should be consulted for a detailed outline of the methods, assumptions and limitations of the study to develop the flood hazard maps presented herein.
2. Still Water Level (SWL) is the 0.5% AEP joint-probability estimate of tide and storm surge plus wave effects (variable across the study domain) and freeboard (600 mm).
3. Flood Construction Level is the 0.5% AEP joint-probability estimate of total water level (including tide and storm surge) plus wave effects and freeboard (600 mm).
4. Adopted Sea Level Rise is guided by Ausenco-Sandwell (2011) Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use: Guidelines for Management of Coastal Flood Hazard Land Use. Prepared by Ausenco-Sandwell for BC Ministry of Environment, and the Technical Advisory Group.
5. 2013, 2018 and 2022 LIDAR data provided by the District of North Vancouver was combined with CHS NONNA bathymetric survey data, and corrected to common datum (CGVD2013), to create a Digital Elevation Model (DEM) for the study area. The flood levels are based on this DEM.
6. Erosion, riverine hazards and overland flood effects are not included.

Use and Limitations:
1. Inundation limits are based on consideration of coastal processes only and do not incorporate flooding from pluvial and fluvial sources.
2. Users must note the dates of base mapping, aerial photography, ground or bathymetric surveys and issue of mapping relevant to dates of development in the map area. Subsequent developments or changes within the floodplain or channel will affect flood levels and render site-specific map information obsolete.
3. Under the provisions of the Flood Hazard Statutes Amendment Act, 2003 (Bill 56), local governments have the role and responsibility for making decisions about local floodplain development practices, including decisions about floodplain bylaws within their communities. Information on floodplain management guidelines can be found in the BC Flood Hazard Area Land Use Management Guidelines.
4. The accuracy of the location of a floodplain boundary as shown on this map is limited by the base topography.
5. The floodplain limits are not established on the ground by legal survey. A site survey is required to reconcile property location, ground elevations and designated flood level information.
6. Erosion, riverine hazards and overland flood effects are not included.

Data Sources:
- 2018 Canadian Hydrographic Service (CHS) NON-Navigational (NONNA) data.
- 2022 District of North Vancouver LIDAR data.
- 2018 LIDAR (Province of BC), supplemented with 2013 LIDAR data (District of North Vancouver).
- Satellite imagery supplied by Esri and orthophotos by the District of North Vancouver (2016)
- Infrastructure Footprints, natura and administrative boundaries provided by the District of North Vancouver GIS Department.

Scale Disclaimer: The map scale of 1:7,000 is only valid on a 11"x17" print.

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TITLE
District of North Vancouver - Coastal Flood Hazard Maps
Cover Map (Index)

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

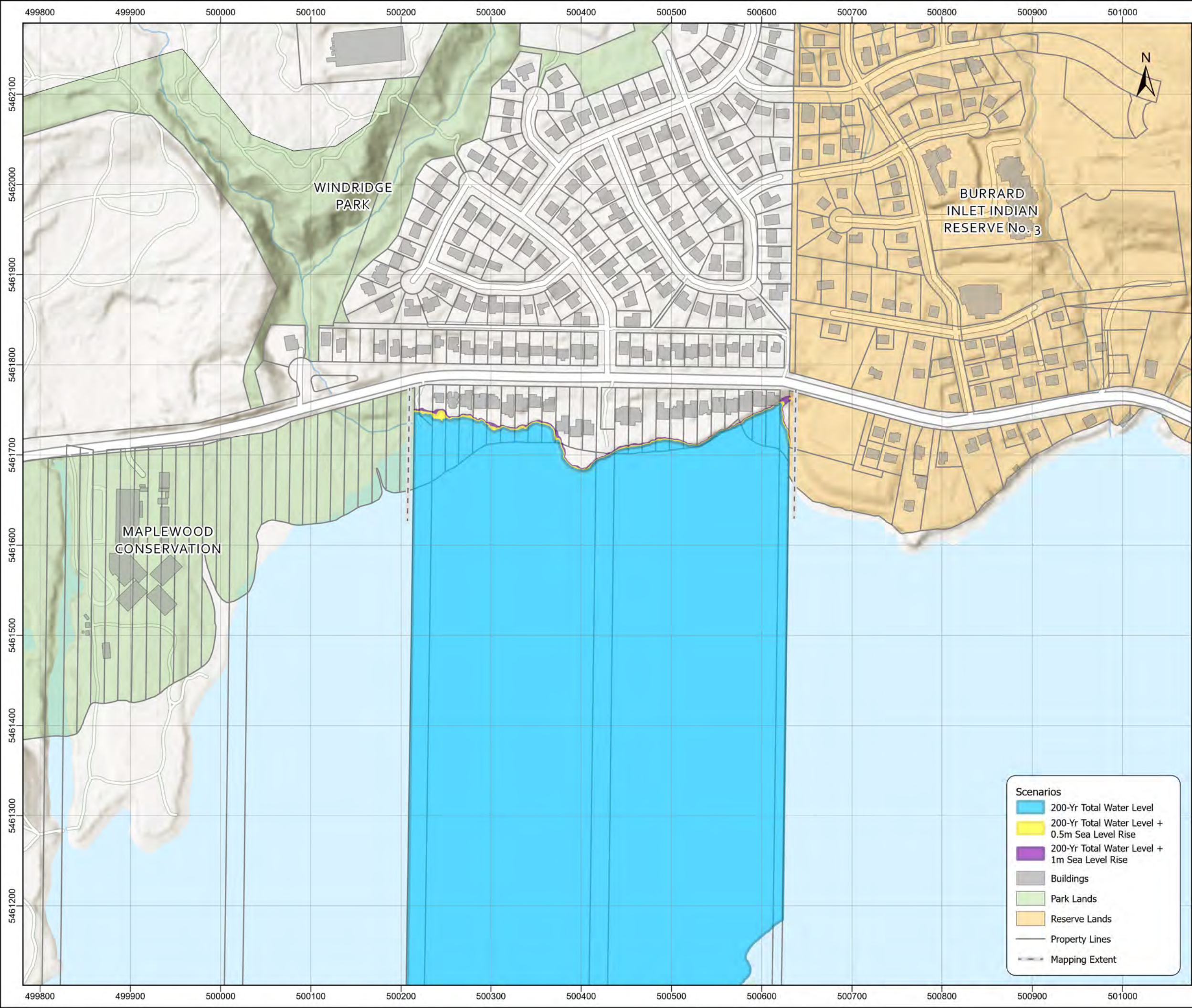
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0 0.5 1 2
Kilometers

DATE	2024-01-19	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



-  Flood Hazard Map Index (26)
-  District of North Vancouver
-  Indian Reserve Boundary

Appendix F.2 Total Water Level



Overview:
These maps have been developed by DHI Water & Environment Inc. (DHI) for the District of North Vancouver to provide Flood Construction Reference Plane (CFRP) and Flood Construction Level (FCL) guidance. Notably, these mapping products incorporate wave effects to establish the flood hazard.

Notes:
1. The maps have been developed using the methodologies outlined in the report entitled: District of North Vancouver Coastal Flood Hazard Mapping Study, issued by DHI, June 2024. The report should be consulted for a detailed outline of the methods, assumptions and limitations of the study to develop the flood hazard maps presented herein.
2. Still Water Level (SWL) is the 0.5% AEP joint-probability estimate of tide and storm surge plus wave effects (variable across the study domain) and freeboard (600 mm).
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4. Adopted Sea Level Rise is guided by Ausenco-Sandwell (2011) Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use: Guidelines for Management of Coastal Flood Hazard Land Use. Prepared by Ausenco-Sandwell for BC Ministry of Environment, and the Technical Advisory Group.
5. 2022 LIDAR data provided by the District of North Vancouver was combined with CHS NONNA bathymetric survey data, and corrected to common datum (CGVD2013), to create a Digital Elevation Model (DEM) for the study area. The flood levels are based on this DEM.

Use and Limitations:
1. Inundation limits are based on consideration of coastal processes only and do not incorporate flooding from pluvial and fluvial sources.
2. Users must note the dates of base mapping, aerial photography, ground or bathymetric surveys and issue of mapping relevant to dates of development in the map area. Subsequent developments or changes within the floodplain or channel will affect flood levels and render site-specific map information obsolete.
3. Under the provisions of the Flood Hazard Statutes Amendment Act, 2003 (Bill 56), local governments have the role and responsibility for making decisions about local floodplain development practices, including decisions about floodplain bylaws within their communities. Information on floodplain management guidelines can be found in the BC Flood Hazard Area Land Use Management Guidelines.
4. The accuracy of the location of a floodplain boundary as shown on this map is limited by the base topography.
5. The floodplain limits are not established on the ground by legal survey. A site survey is required to reconcile property location, ground elevations and designated flood level information.
6. Erosion, riverine hazards and overland flood effects are not included.
7. Results and mapping are appropriate and applicable on a reach-scale, for planning purposes only. Detailed site specific (i.e. lot level) FCL studies are highly recommended, as required, on a case-by-case basis to refine FCL limits for infrastructure specific purposes.

Data Sources:
- 2018 Canadian Hydrographic Service (CHS) NON-Navigational (NONNA) data.
- 2022 District of North Vancouver LIDAR data.
- Background imagery supplied by Esri and orthophotos by the District of North Vancouver (2016)
- Infrastructure Footprints, natural and administrative boundaries provided by the District of North Vancouver GIS Department.

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PCS: Projected Coordinate System
CGVD2013: Canadian Geodetic Vertical Datum of 2013
EPSG: European Petroleum Survey Group
CSRS: Canadian Spatial Reference System
TWL: Total Water Level
SLR: Sea Level Rise

TITLE
District of North Vancouver - Total Water Level Maps
Map 1 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



Overview:
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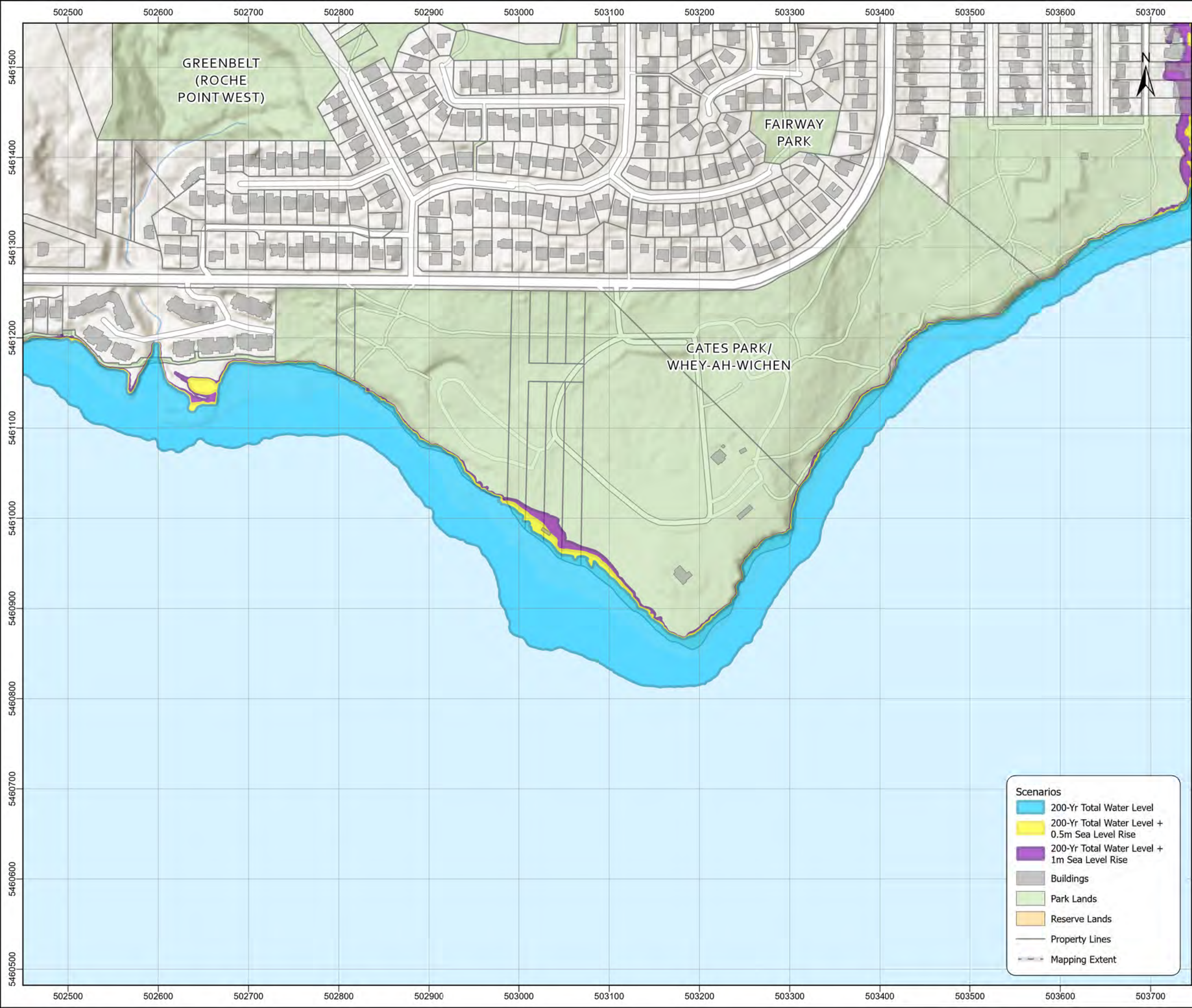
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TITLE
District of North Vancouver - Total Water Level Maps
Map 2 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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TITLE

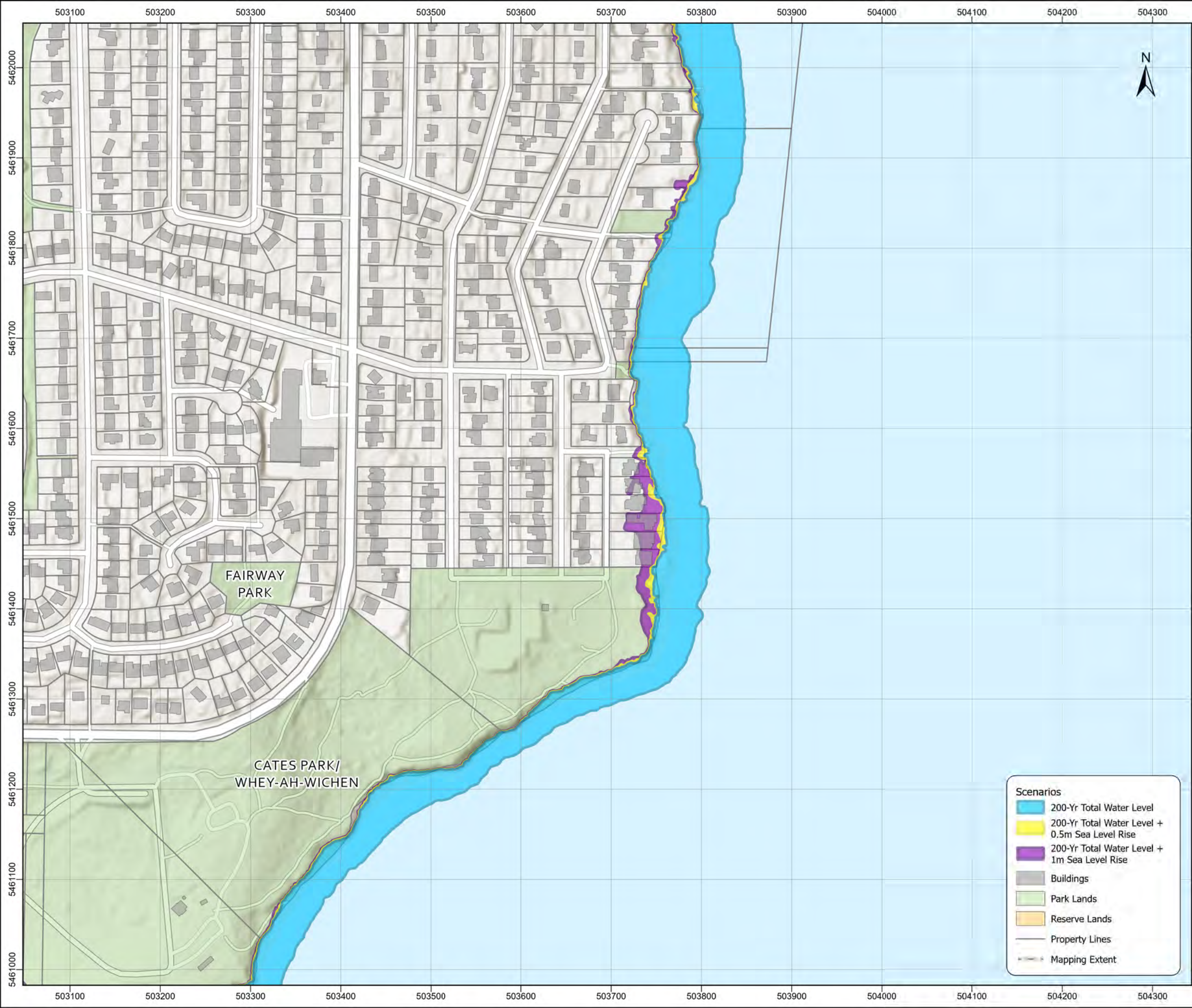
District of North Vancouver - Total Water Level Maps

Map 3 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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CSRS: Canadian Spatial Reference System
TWL: Total Water Level
SLR: Sea Level Rise

TITLE

District of North Vancouver - Total Water Level Maps

Map 4 of 25

PCS: NAD 1983 UTM Zone 10N

EPSG: 26910

Datum: CGVD2013

Map Units: Meter

Scale: 1:4,000

0 25 50 100

Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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TITLE

District of North Vancouver - Total Water Level Maps

Map 5 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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TITLE					
District of North Vancouver - Total Water Level Maps					
Map 6 of 25					
PCS: NAD 1983 UTM Zone 10N		Scale: 1:4,000			
EPSG: 26910		0 25 50 100			
Datum: CGVD2013					
Map Units: Meter		Meters			
DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
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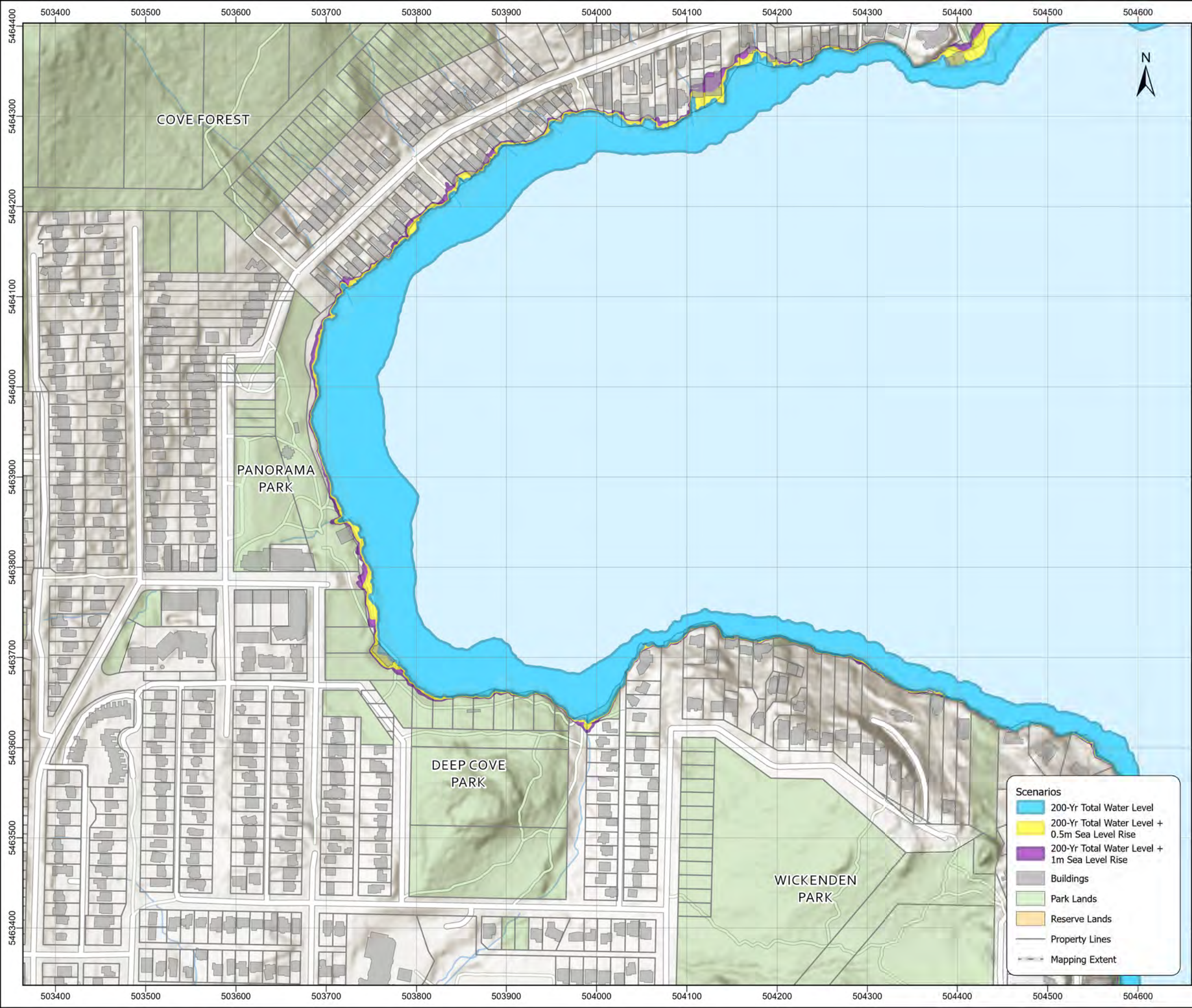
TITLE
District of North Vancouver - Total Water Level Maps
Map 7 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

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CSRS: Canadian Spatial Reference System
TWL: Total Water Level
SLR: Sea Level Rise

TITLE

District of North Vancouver - Total Water Level Maps

Map 8 of 25

PCS: NAD 1983 UTM Zone 10N

EPGS: 26910

Datum: CGVD2013

Map Units: Meter

Scale: 1:4,000

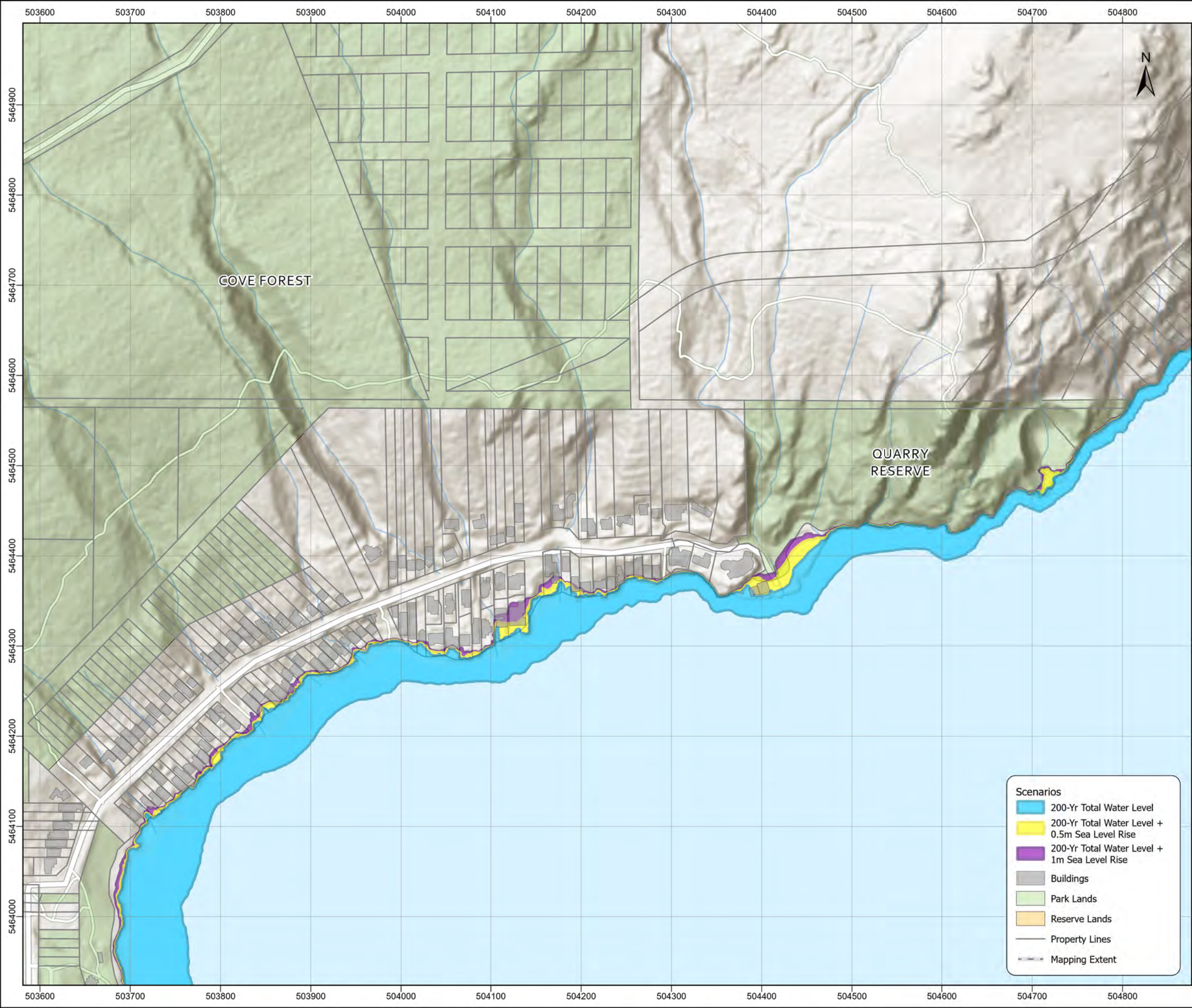
0 25 50 100

Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121

DISTRICT OF NORTH VANCOUVER

DHI



Overview:
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TWL: Total Water Level
SLR: Sea Level Rise

TITLE
District of North Vancouver - Total Water Level Maps
Map 9 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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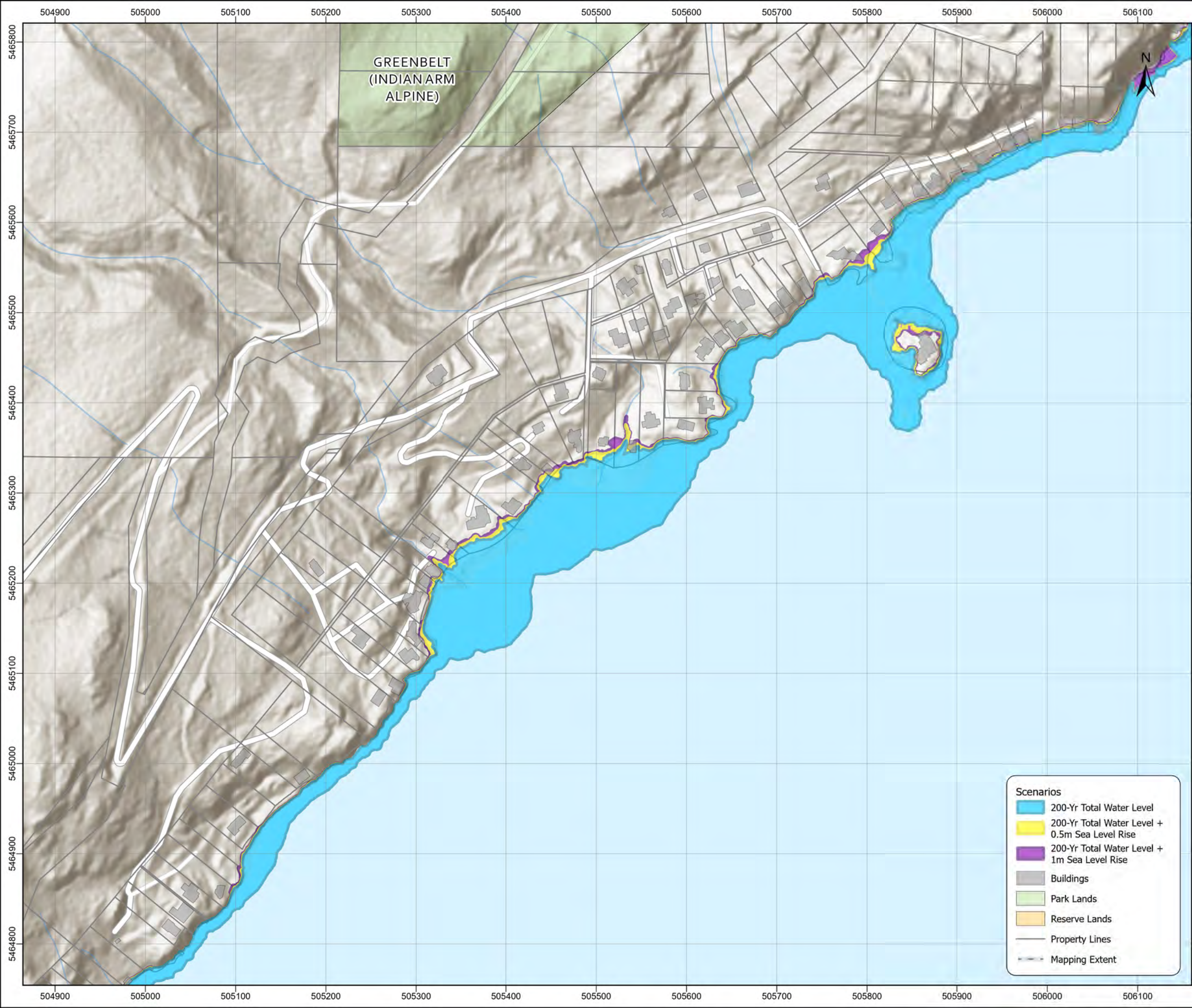
TITLE
District of North Vancouver - Total Water Level Maps
Map 10 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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SLR: Sea Level Rise

TITLE

District of North Vancouver - Total Water Level Maps

Map 11 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



Scenarios

200-Yr Total Water Level

200-Yr Total Water Level + 0.5m Sea Level Rise

200-Yr Total Water Level + 1m Sea Level Rise

Buildings

Park Lands

Reserve Lands

Property Lines

Mapping Extent



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TITLE				
District of North Vancouver - Total Water Level Maps				
Map 12 of 25				
PCS: NAD 1983 UTM Zone 10N		Scale: 1:4,000		
EPSG: 26910		0 25 50 100		
Datum: CGVD2013		 Meters		
Map Units: Meter				
DATE	2024-05-24	AUTHOR	SSIN	APPROVER DANK
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TITLE

District of North Vancouver - Total Water Level Maps

Map 13 of 25

PCS: NAD 1983 UTM Zone 10N
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Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

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CGVD2013: Canadian Geodetic Vertical Datum of 2013
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CSRS: Canadian Spatial Reference System
TWL: Total Water Level
SLR: Sea Level Rise

TITLE

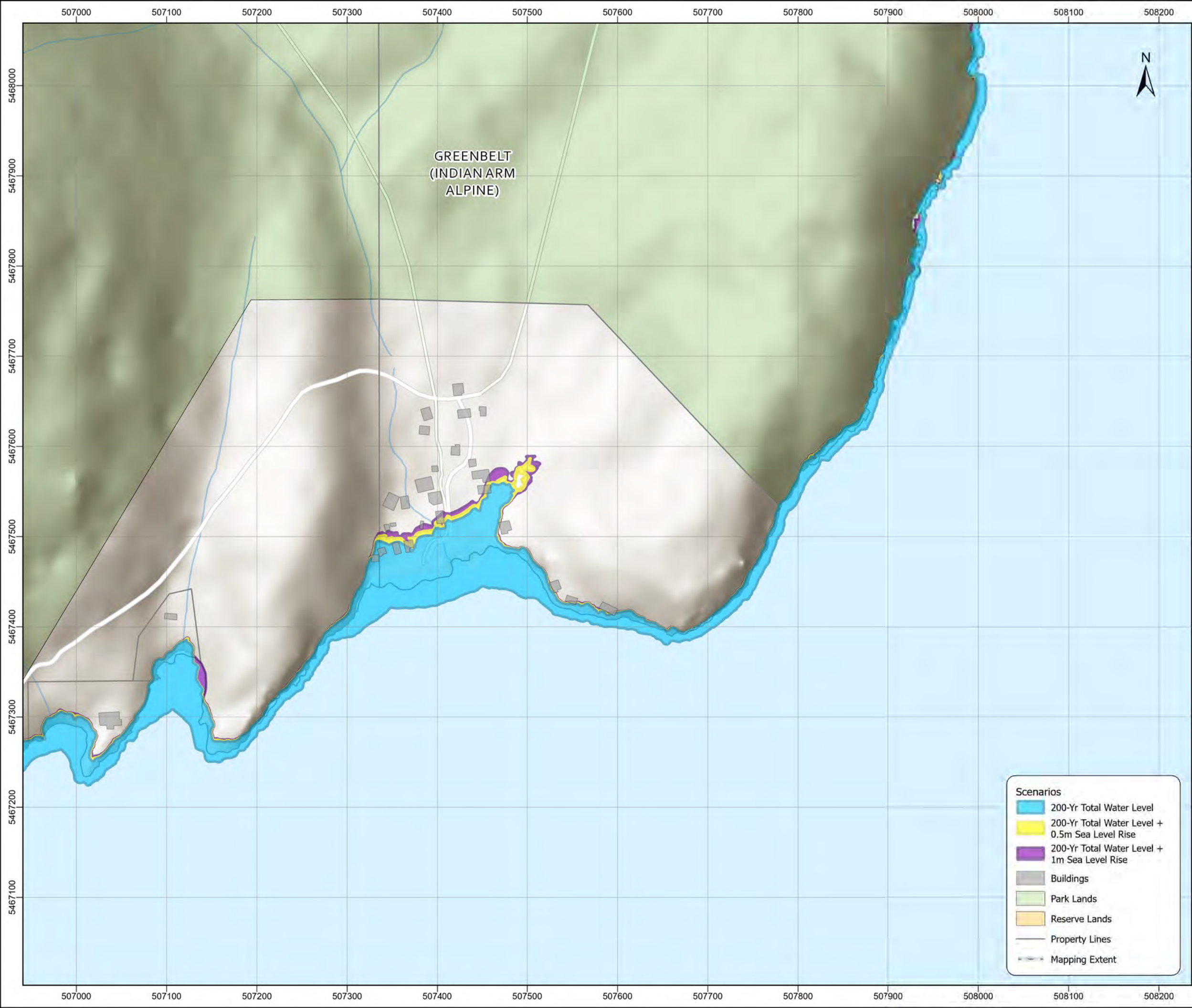
District of North Vancouver - Total Water Level Maps

Map 14 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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SLR: Sea Level Rise

TITLE
District of North Vancouver - Total Water Level Maps
Map 15 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

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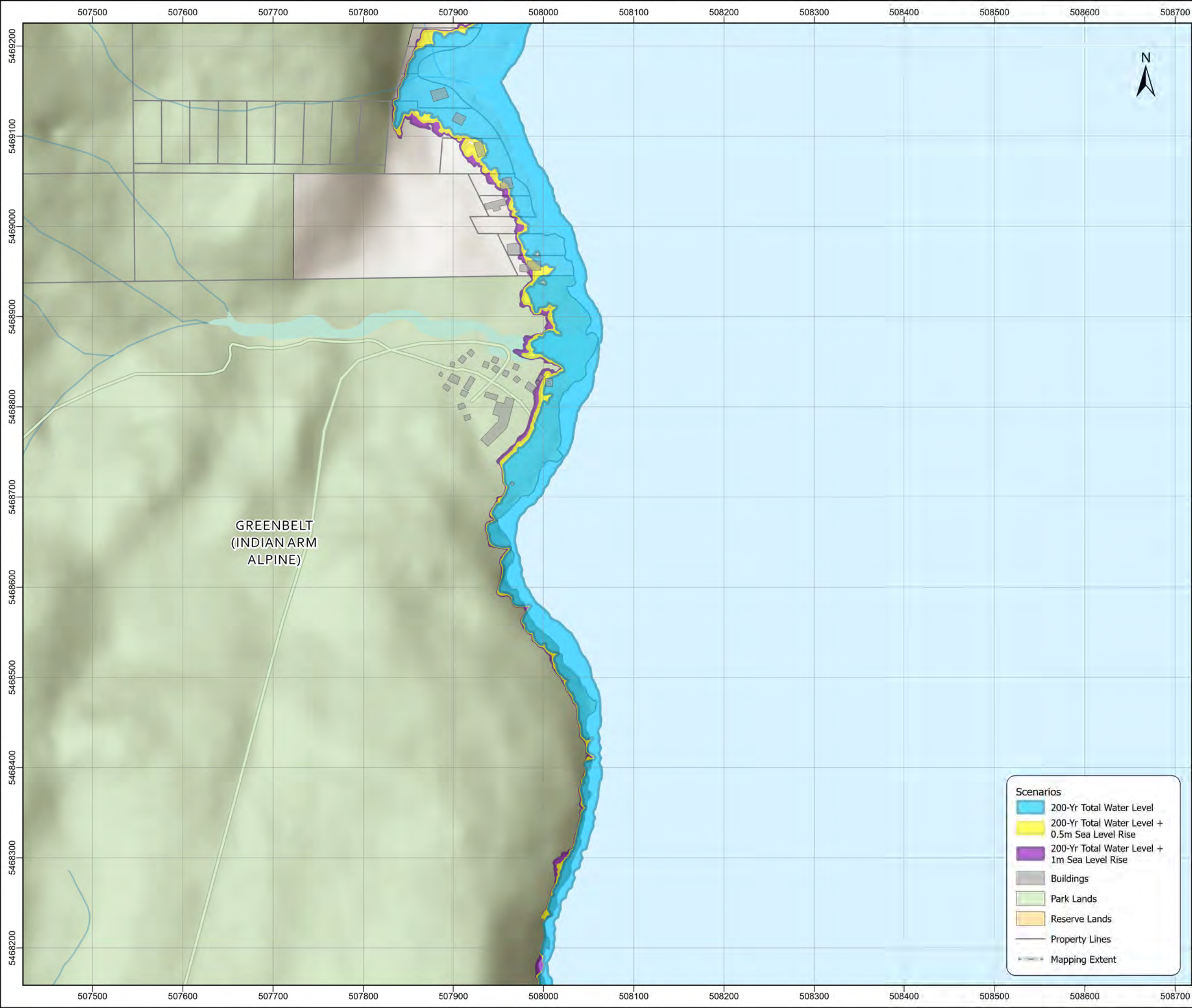
District of North Vancouver - Total Water Level Maps

Map 16 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

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REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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TWL: Total Water Level
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TITLE
District of North Vancouver - Total Water Level Maps
Map 17 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

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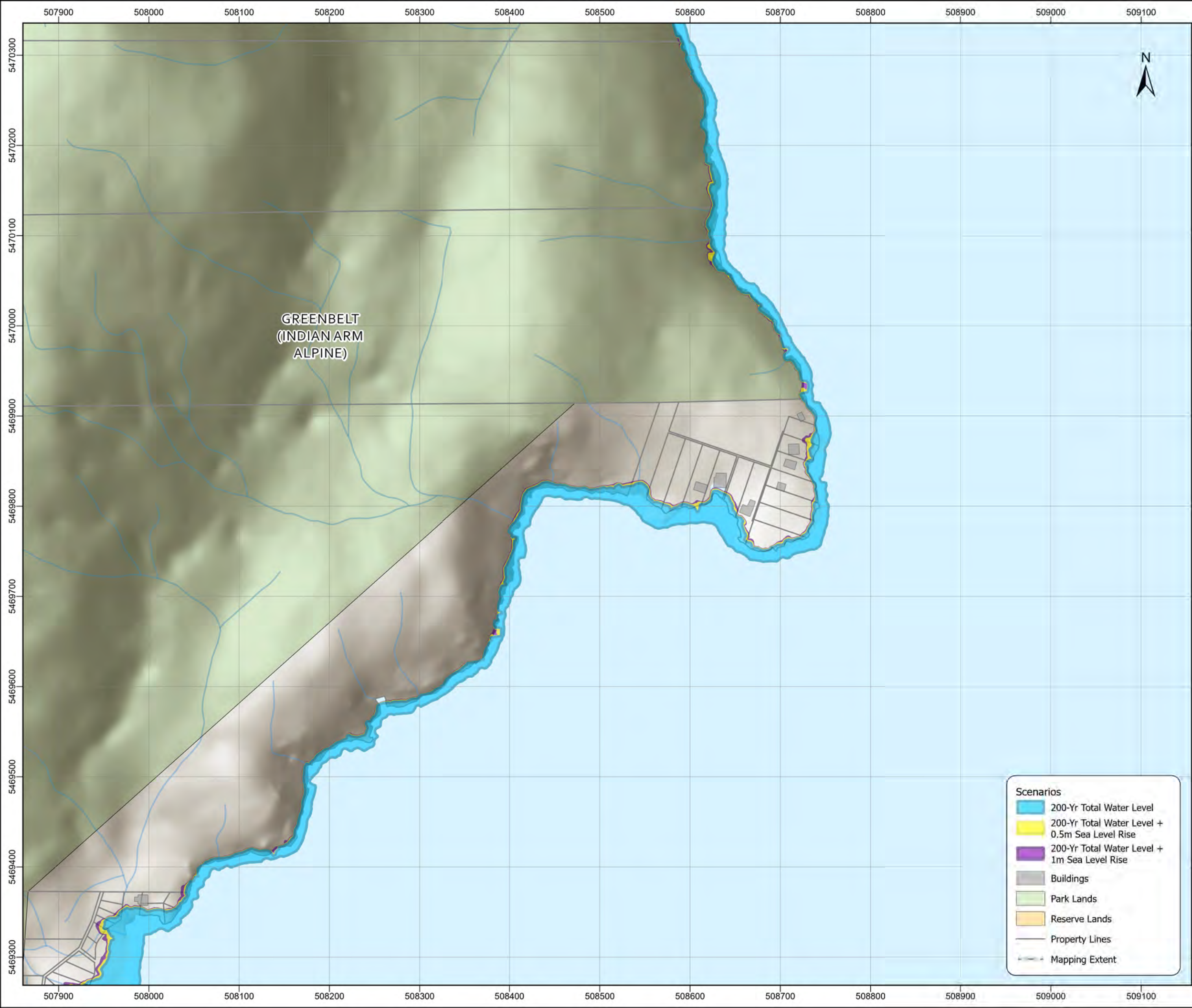
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TITLE
District of North Vancouver - Total Water Level Maps
Map 18 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

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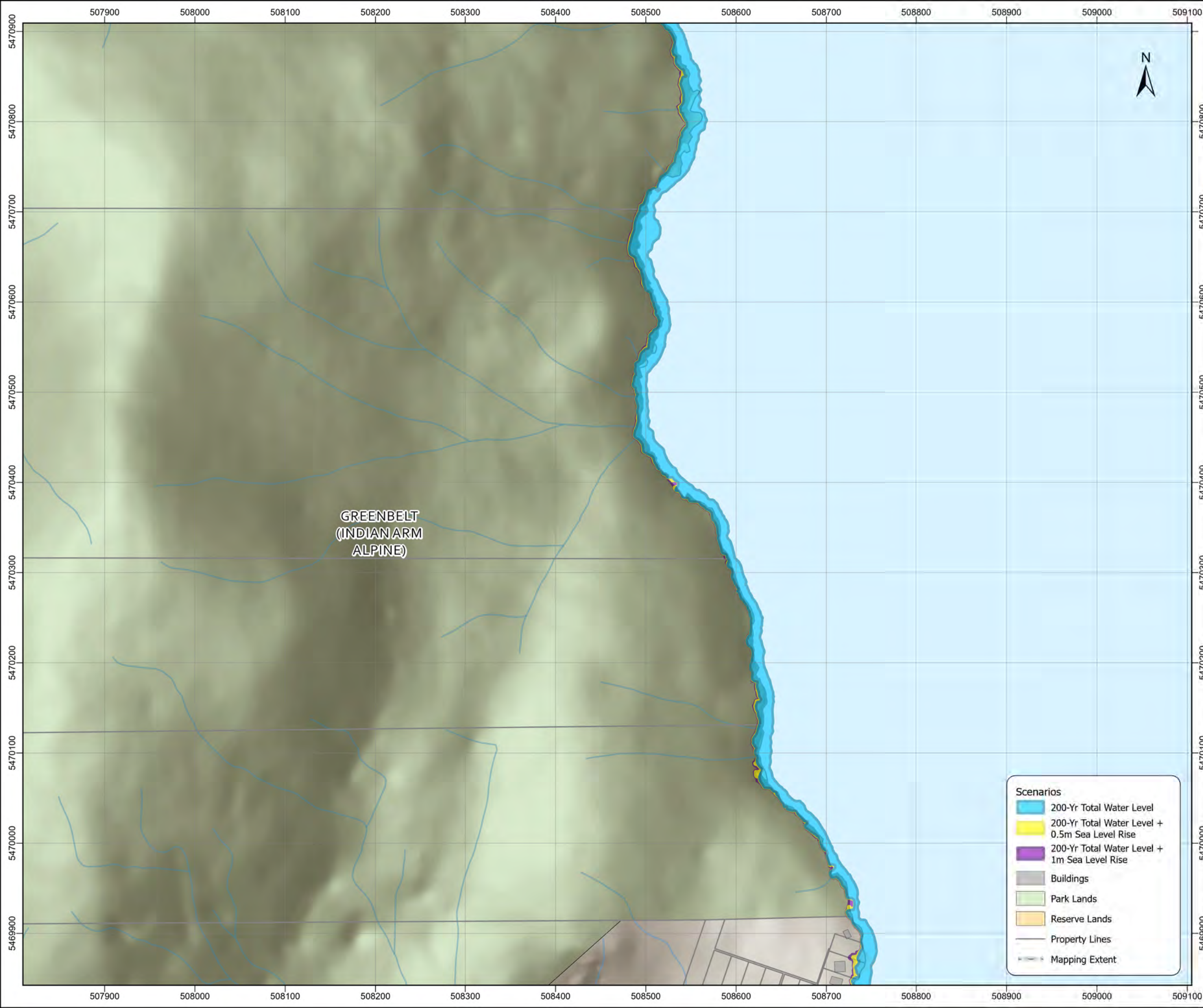
District of North Vancouver - Total Water Level Maps

Map 19 of 25

PCS: NAD 1983 UTM Zone 10N
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Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

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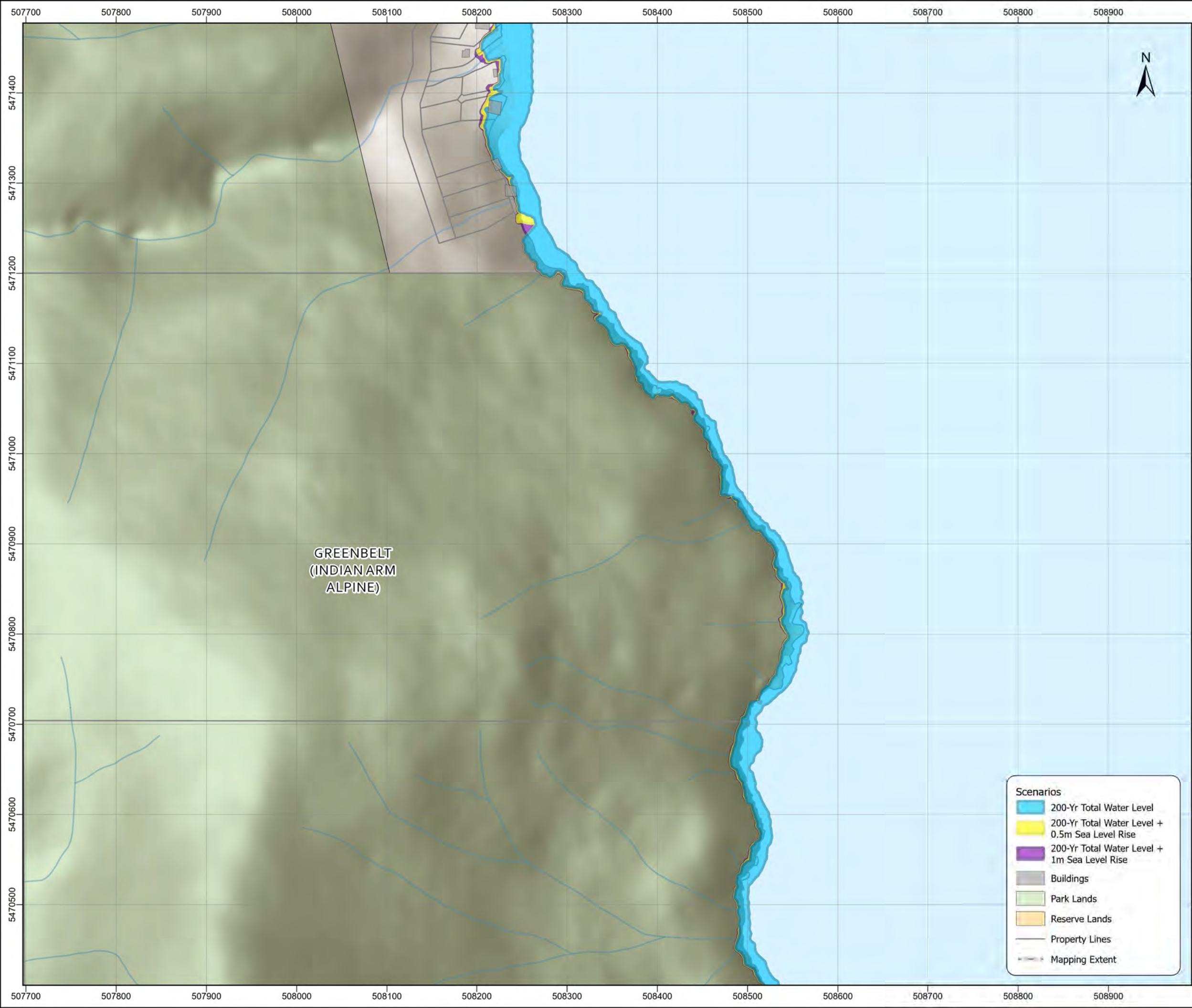
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TITLE
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Map 20 of 25

PCS: NAD 1983 UTM Zone 10N
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CGVD2013: Canadian Geodetic Vertical Datum of 2013
EPSG: European Petroleum Survey Group
CSRS: Canadian Spatial Reference System
TWL: Total Water Level
SLR: Sea Level Rise

TITLE
District of North Vancouver - Total Water Level Maps
Map 21 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



Overview:
These maps have been developed by DHI Water & Environment Inc. (DHI) for the District of North Vancouver to provide Flood Construction Reference Plane (CFRP) and Flood Construction Level (FCL) guidance. Notably, these mapping products incorporate wave effects to establish the flood hazard.

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CSRS: Canadian Spatial Reference System
TWL: Total Water Level
SLR: Sea Level Rise

TITLE

District of North Vancouver - Total Water Level Maps

Map 22 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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TWL: Total Water Level
SLR: Sea Level Rise

TITLE

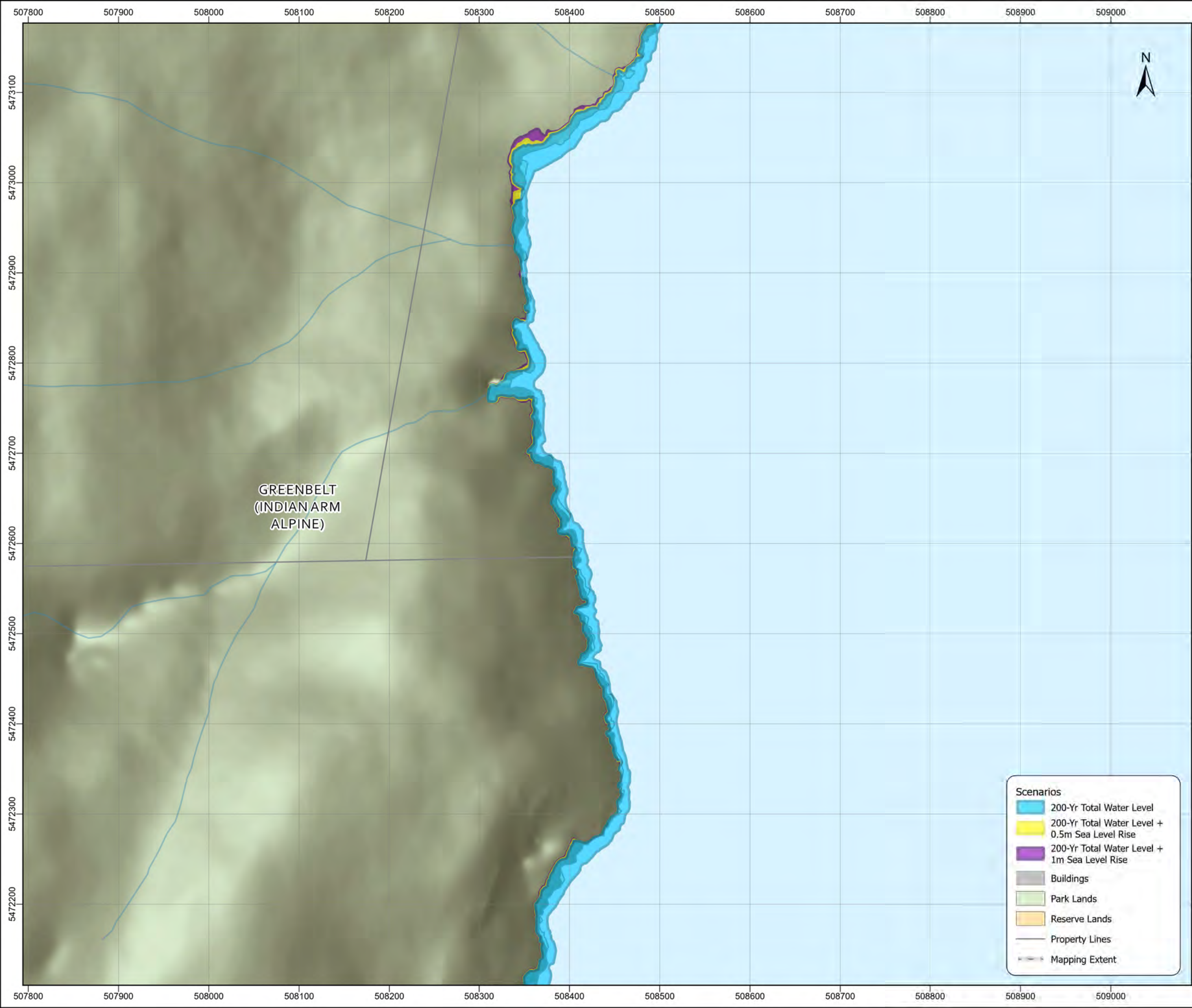
District of North Vancouver - Total Water Level Maps

Map 23 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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TITLE
District of North Vancouver - Total Water Level Maps
Map 24 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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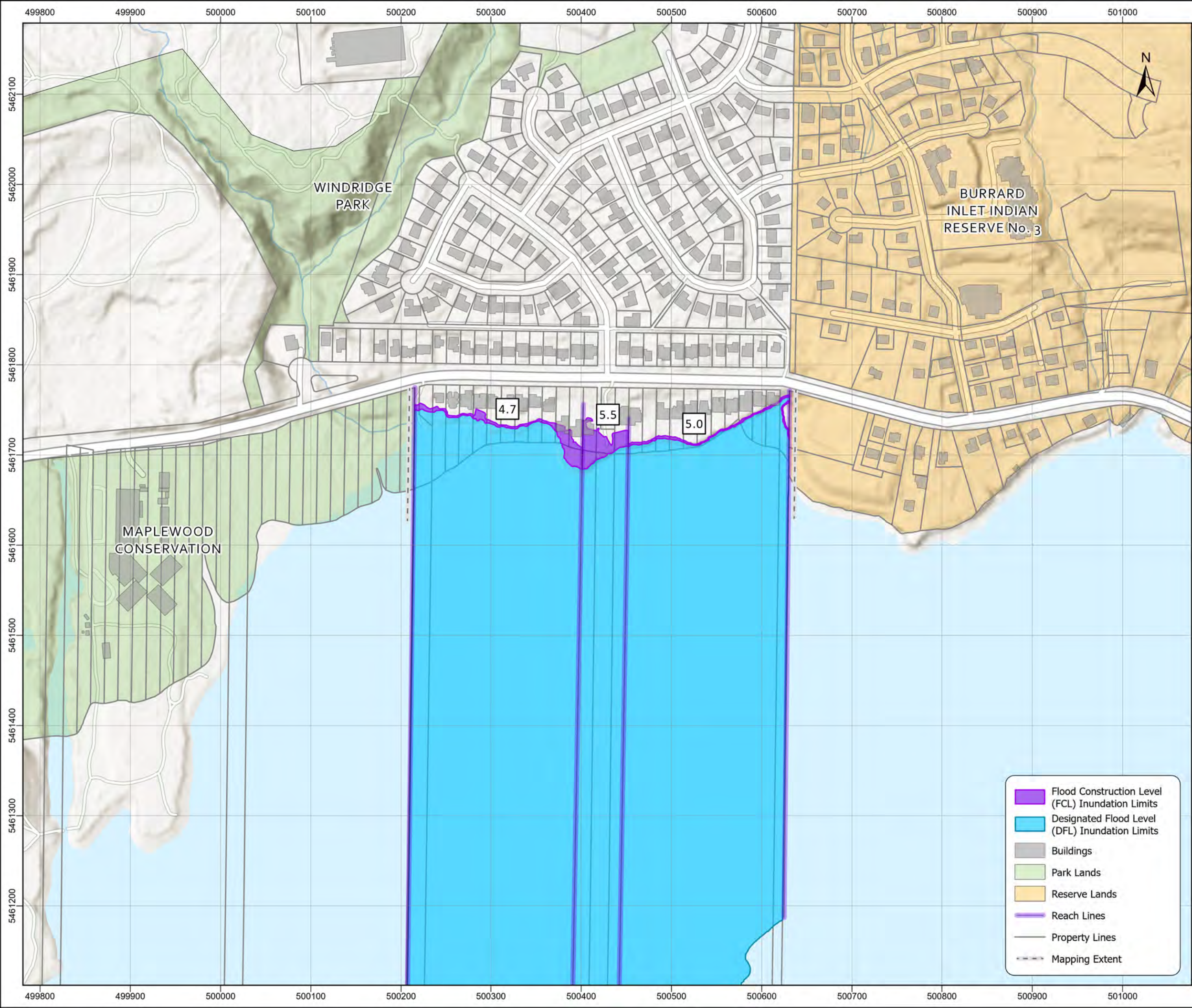
TITLE
District of North Vancouver - Total Water Level Maps
Map 25 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121

Appendix F.3 Flood Construction Level with 0.5 m Sea Level Rise



Overview:
These maps have been developed by DHI Water & Environment Inc. (DHI) for the District of North Vancouver to provide Flood Construction Reference Plane (FCRP) and Flood Construction Level (FCL) guidance. Notably, these mapping products incorporate wave effects.

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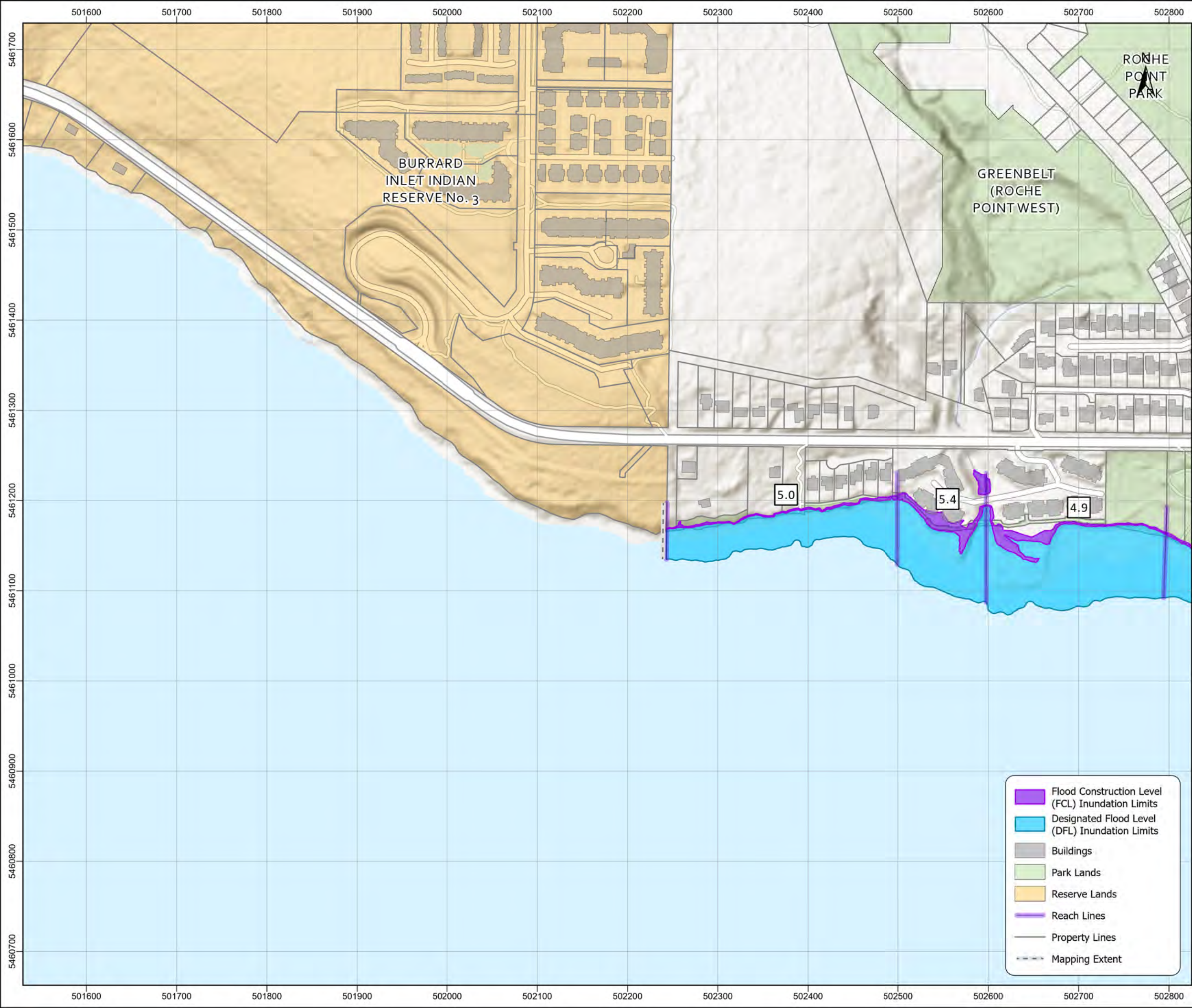
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FCL: Flood Construction Level
SLR: Sea Level Rise

TITLE
District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise
Map 1 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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Legend:

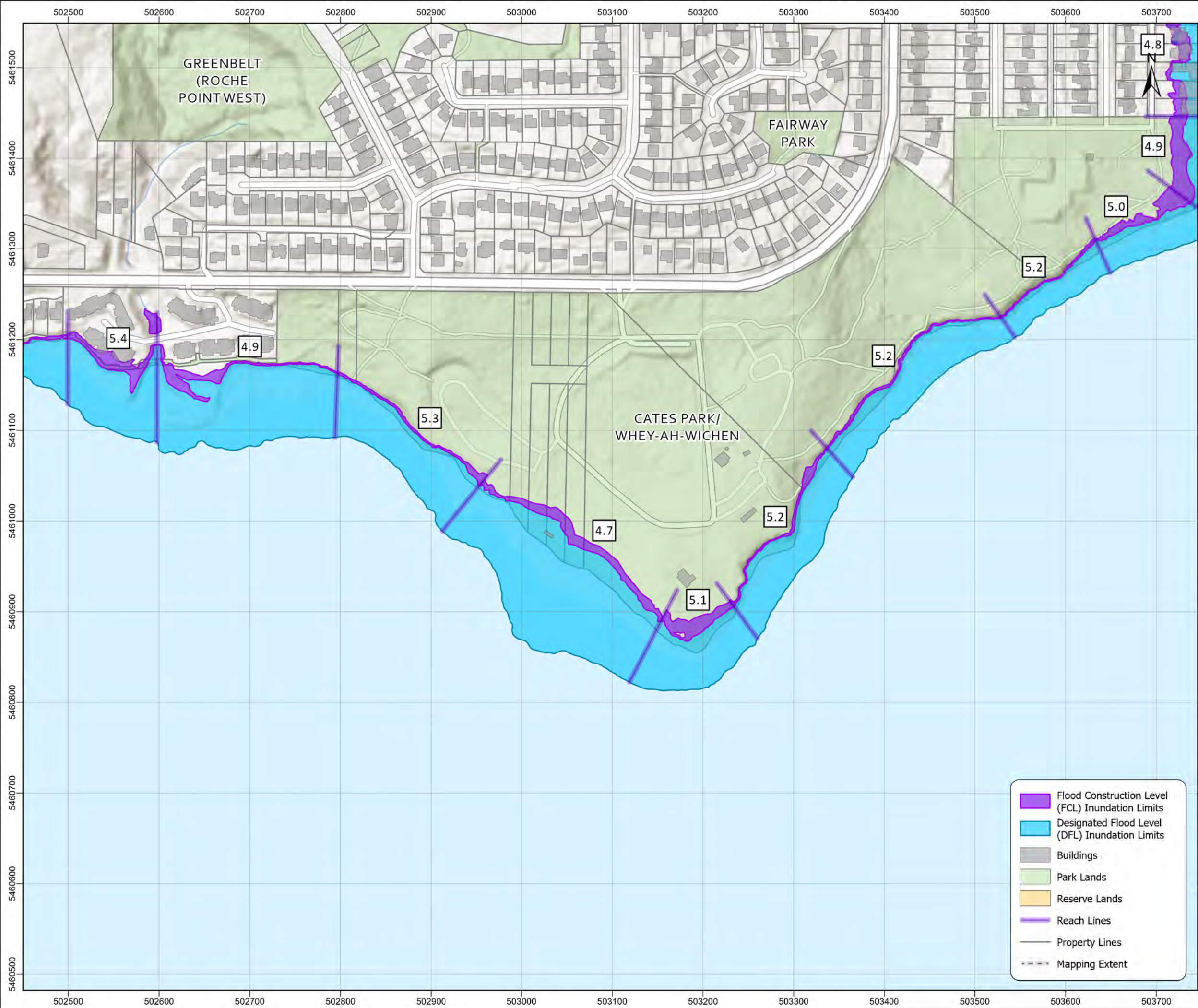
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- EPSG: European Petroleum Survey Group
- CSRS: Canadian Spatial Reference System
- DFL: Designated Flood Level
- FCL: Flood Construction Level
- SLR: Sea Level Rise

TITLE
District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise
Map 2 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



Overview:
These maps have been developed by DHI Water & Environment Inc. (DHI) for the District of North Vancouver to provide Flood Construction Reference Plane (FCRP) and Flood Construction Level (FCL) guidance. Notably, these mapping products incorporate wave effects.

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Use and Limitations:
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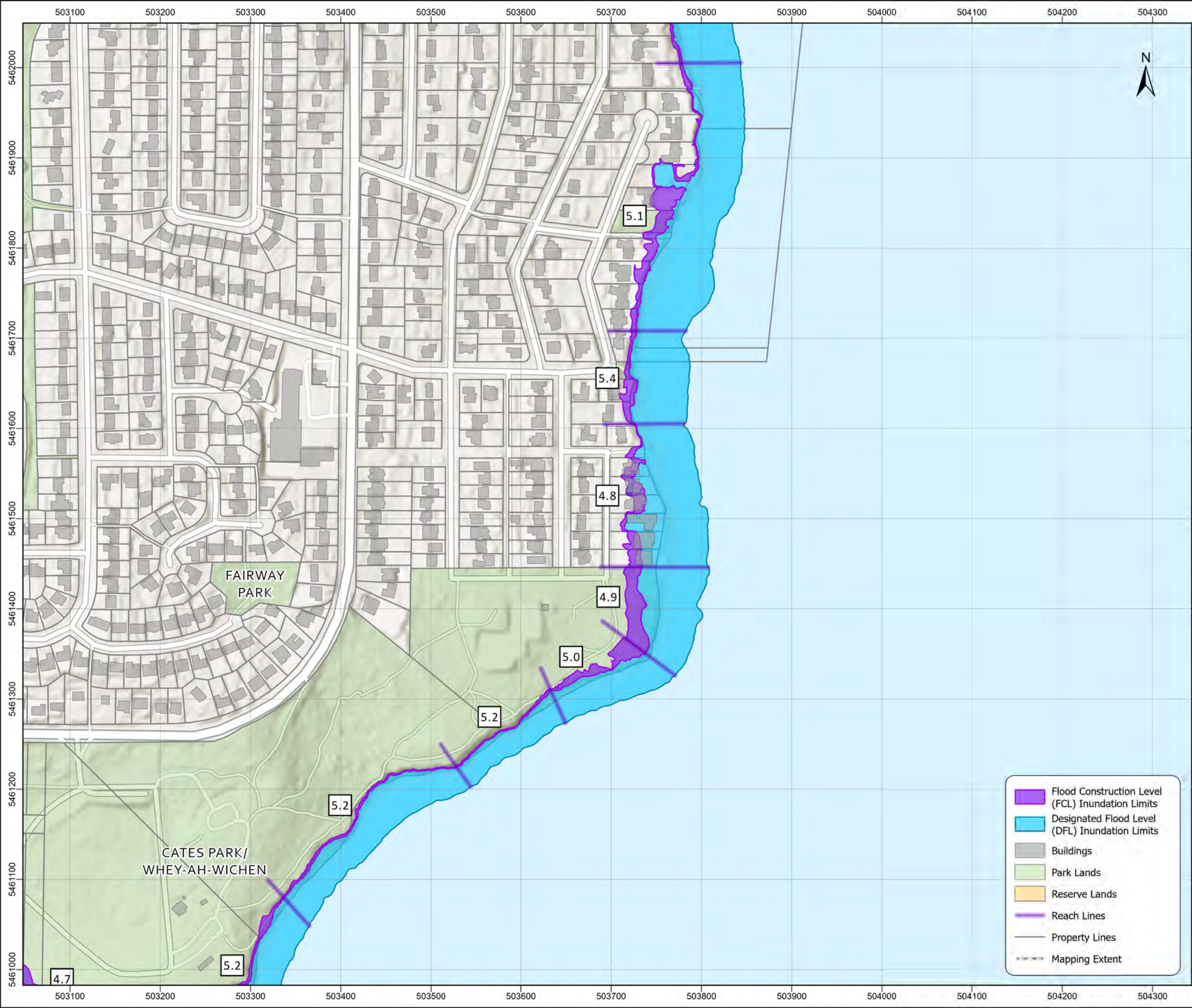
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CSRS: Canadian Spatial Reference System
DFL: Designated Flood Level
FCL: Flood Construction Level
SLR: Sea Level Rise

TITLE
District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise
Map 3 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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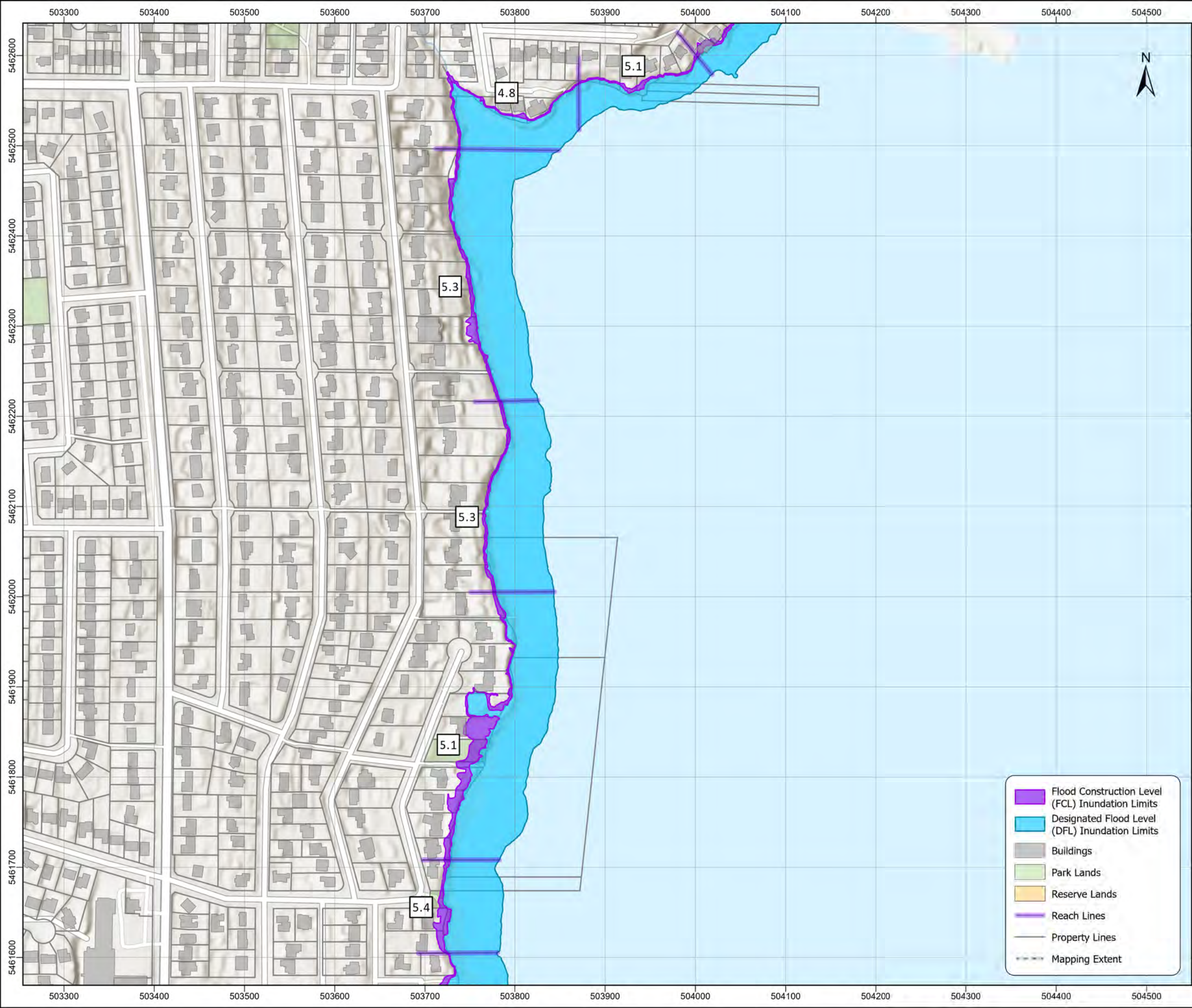
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FCL: Flood Construction Level
SLR: Sea Level Rise

TITLE District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise Map 4 of 25			
PCS: NAD 1983 UTM Zone 10N EPSG: 26910 Datum: CGVD2013 Map Units: Meter		Scale: 1:4,000 0 25 50 100 Meters	
DATE	2024-05-24	AUTHOR	SSIN DANK
REVISION	1	REVIEWER	DANK
		DHI PROJECT NUMBER	42804121



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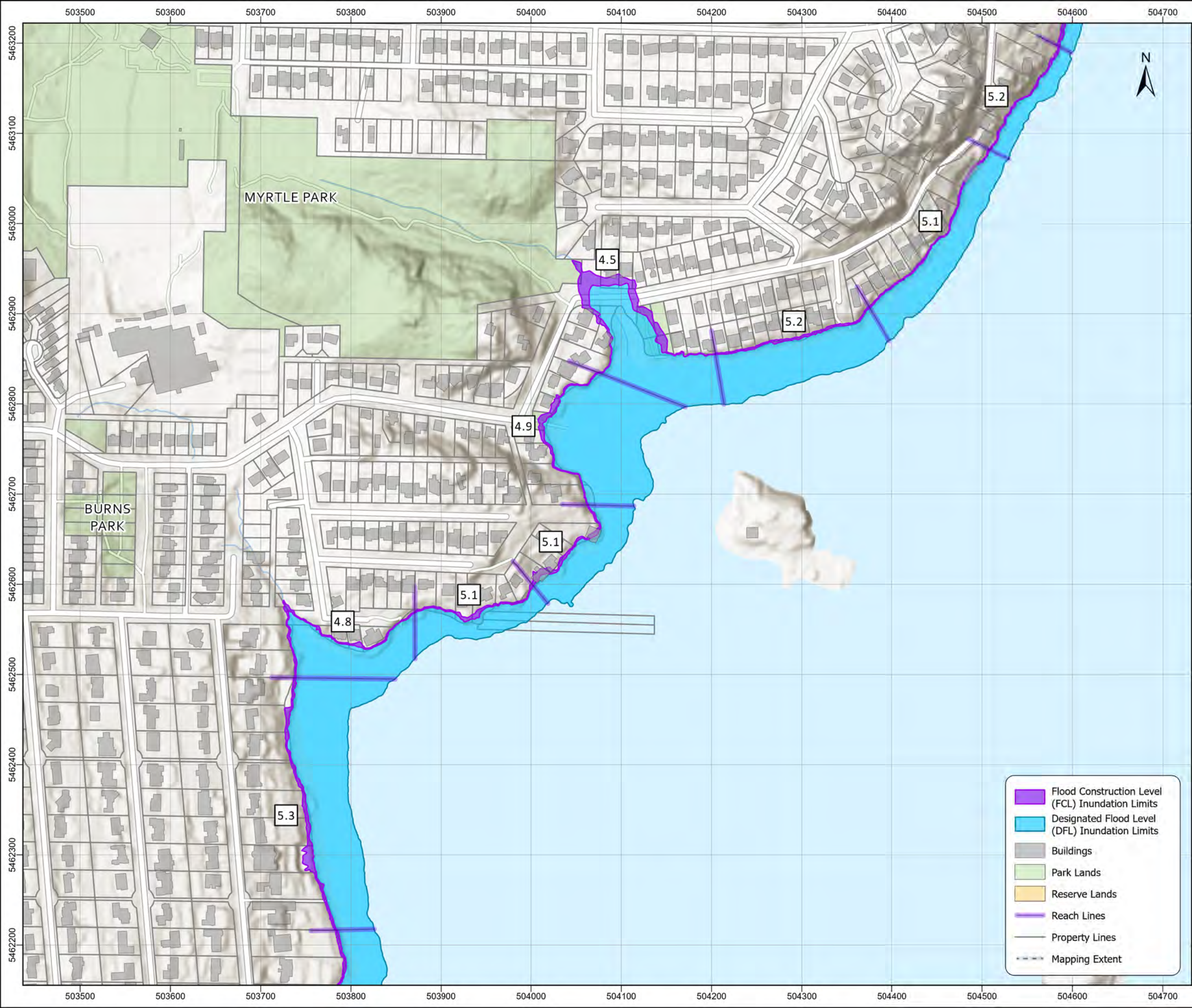
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TITLE District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise Map 5 of 25			
PCS: NAD 1983 UTM Zone 10N EPSG: 26910 Datum: CGVD2013 Map Units: Meter		Scale: 1:4,000 0 25 50 100 Meters	
DATE	2024-05-24	AUTHOR	SSIN DANK
REVISION	1	REVIEWER	DANK
		DHI PROJECT NUMBER	42804121



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TITLE
District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise
Map 6 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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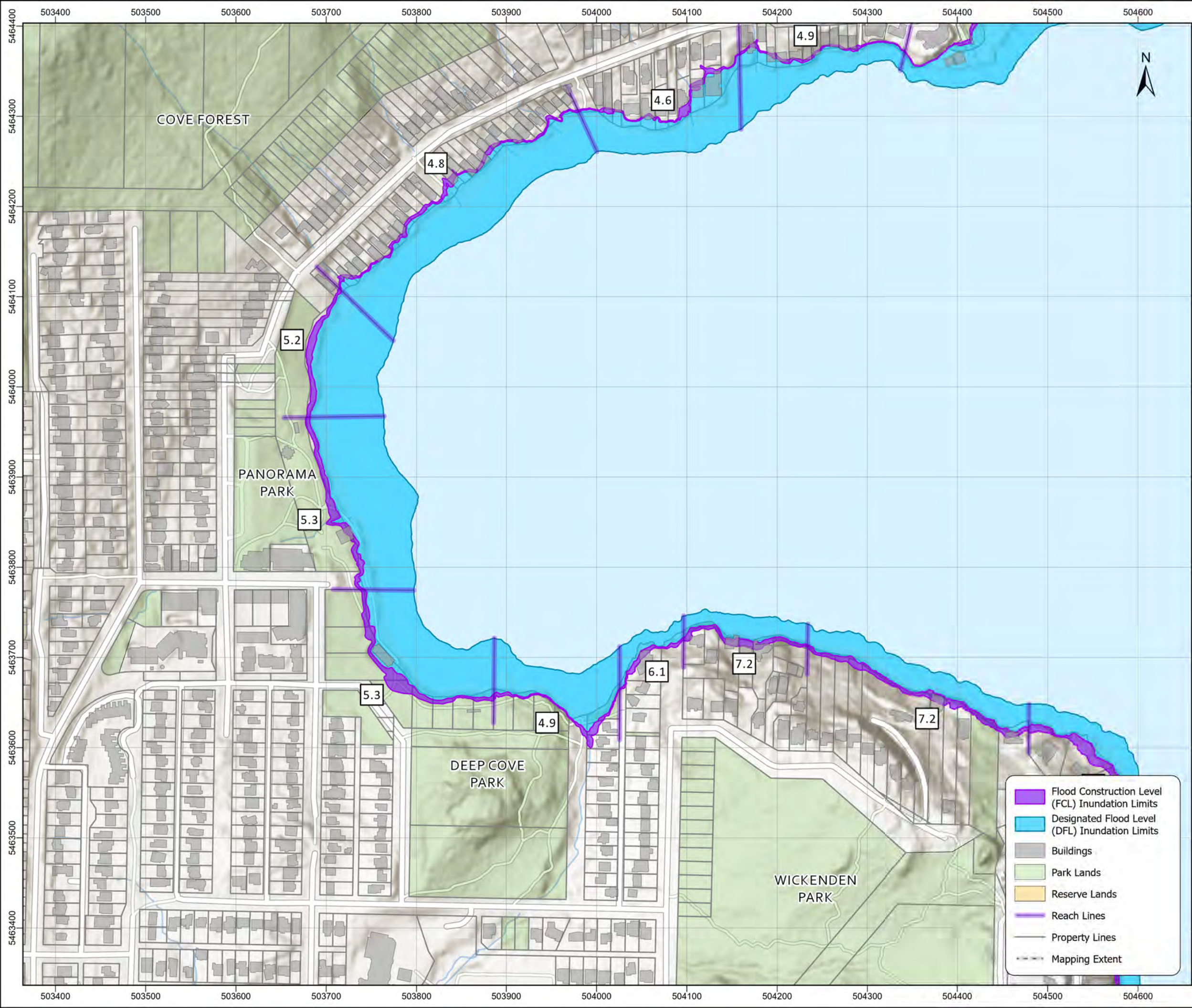
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TITLE District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise Map 7 of 25			
PCS: NAD 1983 UTM Zone 10N EPSG: 26910 Datum: CGVD2013 Map Units: Meter		Scale: 1:4,000 0 25 50 100 Meters	
DATE	2024-05-24	AUTHOR	SSIN
REVISION	1	REVIEWER	DANK
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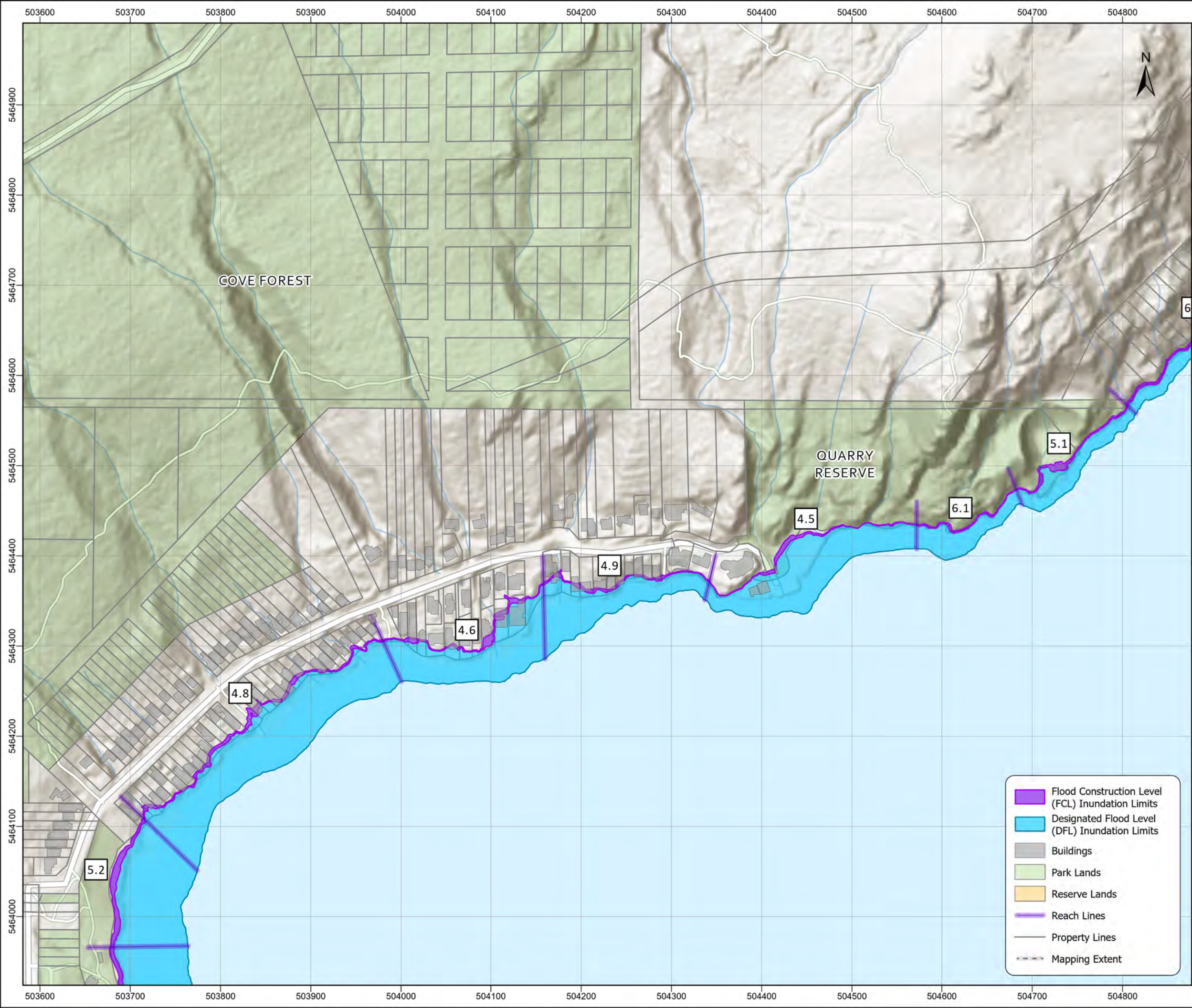
PCS: Projected Coordinate System
CGVD2013: Canadian Geodetic Vertical Datum of 2013
EPSG: European Petroleum Survey Group
CSRS: Canadian Spatial Reference System
DFL: Designated Flood Level
FCL: Flood Construction Level
SLR: Sea Level Rise

TITLE
District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise
Map 8 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



Overview:
These maps have been developed by DHI Water & Environment Inc. (DHI) for the District of North Vancouver to provide Flood Construction Reference Plane (FCRP) and Flood Construction Level (FCL) guidance. Notably, these mapping products incorporate wave effects.

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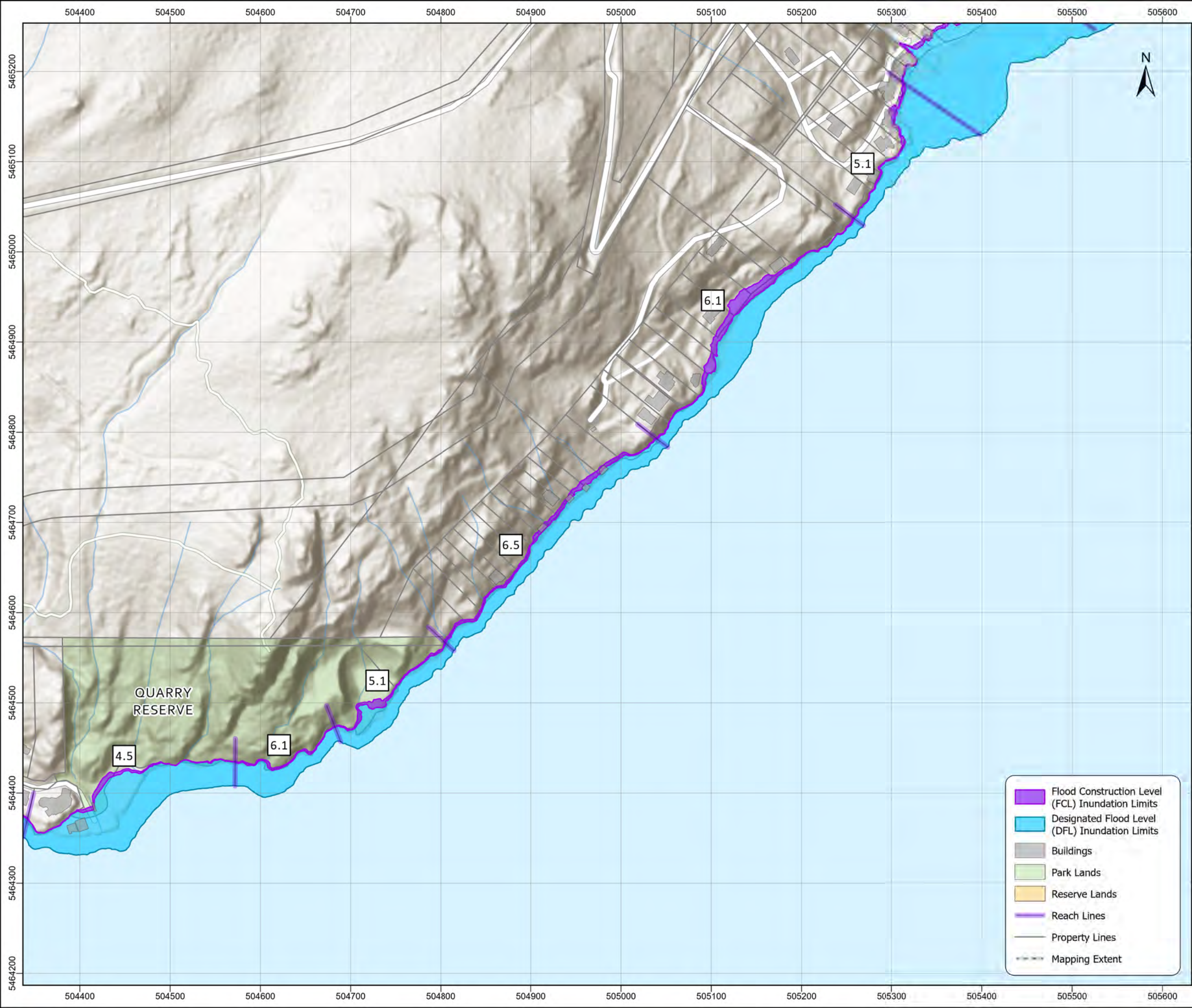
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FCL: Flood Construction Level
SLR: Sea Level Rise

TITLE
District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise
Map 9 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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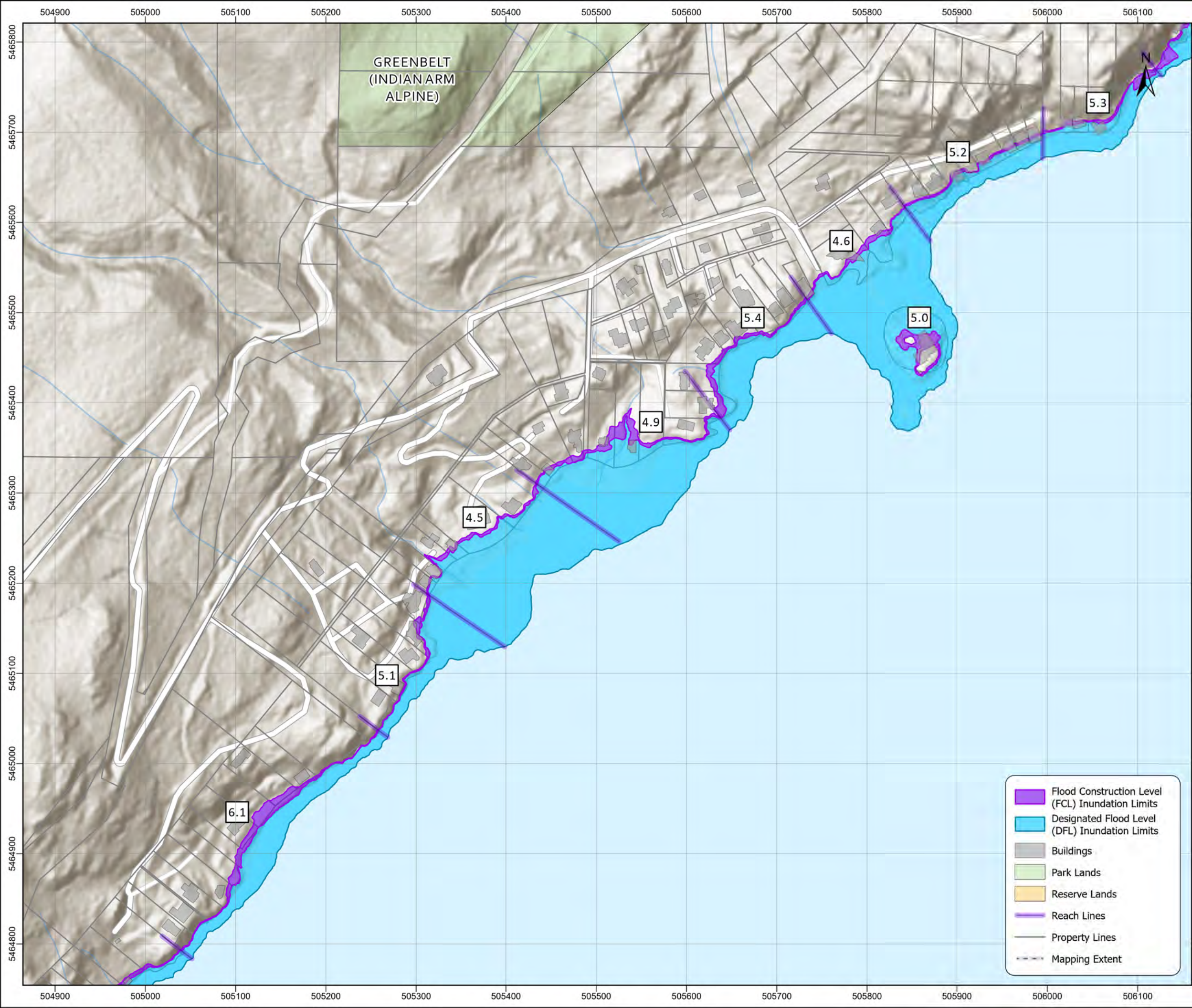
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CSRS: Canadian Spatial Reference System
DFL: Designated Flood Level
FCL: Flood Construction Level
SLR: Sea Level Rise

TITLE District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise Map 10 of 25				
PCS: NAD 1983 UTM Zone 10N EPSG: 26910 Datum: CGVD2013 Map Units: Meter		Scale: 1:4,000 0 25 50 100 Meters		
DATE	2024-05-24	AUTHOR	SSIN	APPROVER DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER 42804121



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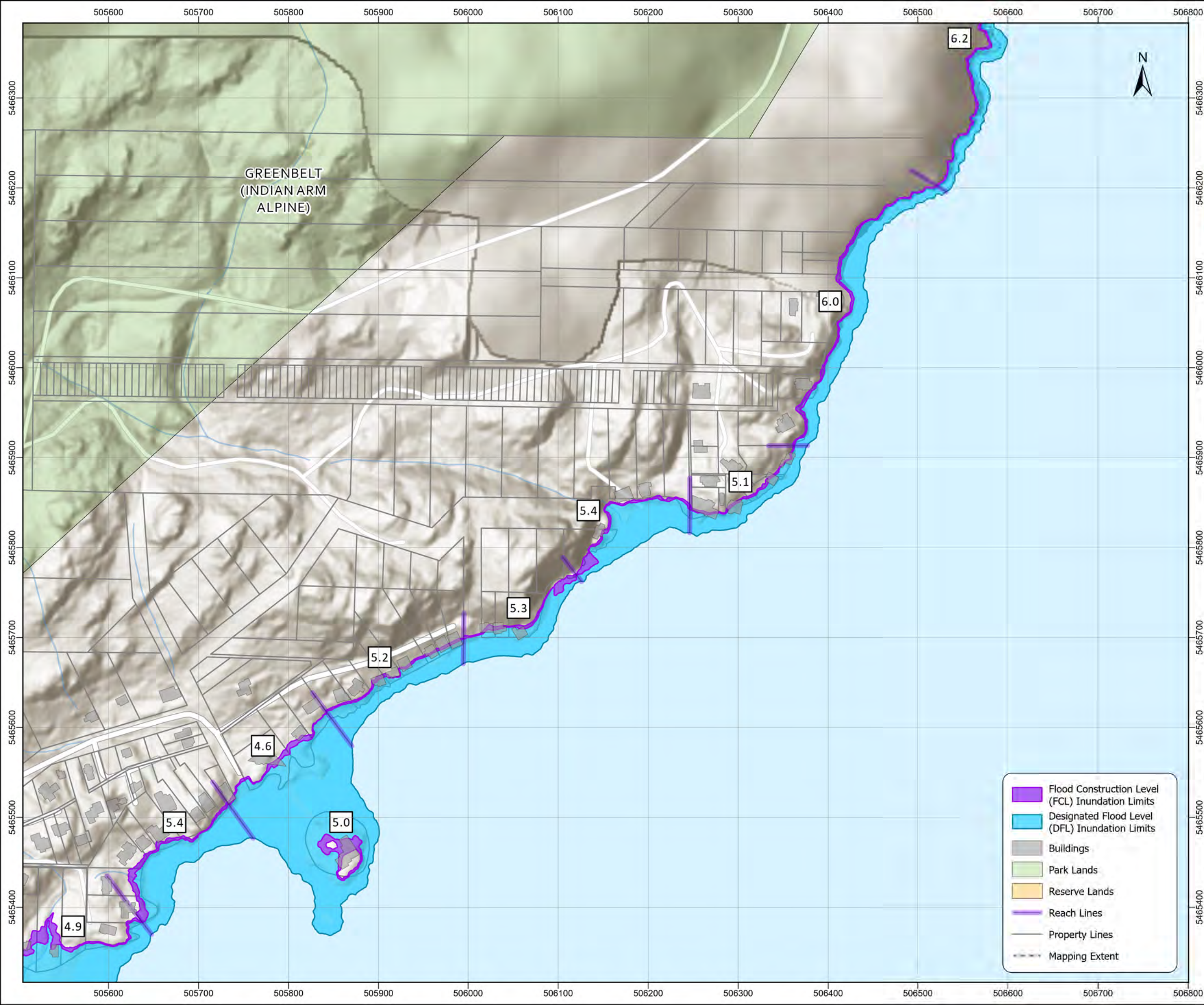
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DFL: Designated Flood Level
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SLR: Sea Level Rise

TITLE
District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise
Map 11 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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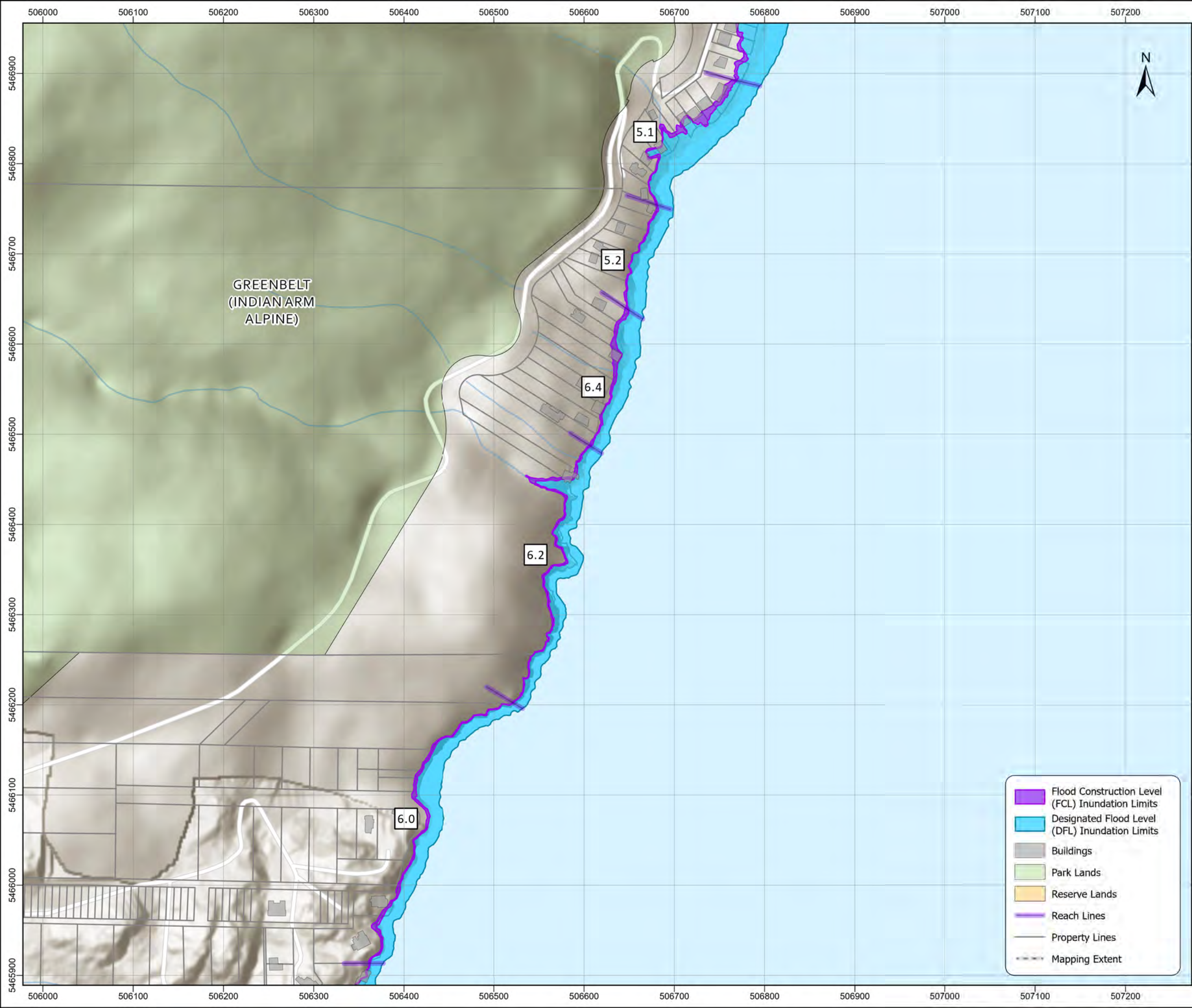
TITLE
District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise
Map 12 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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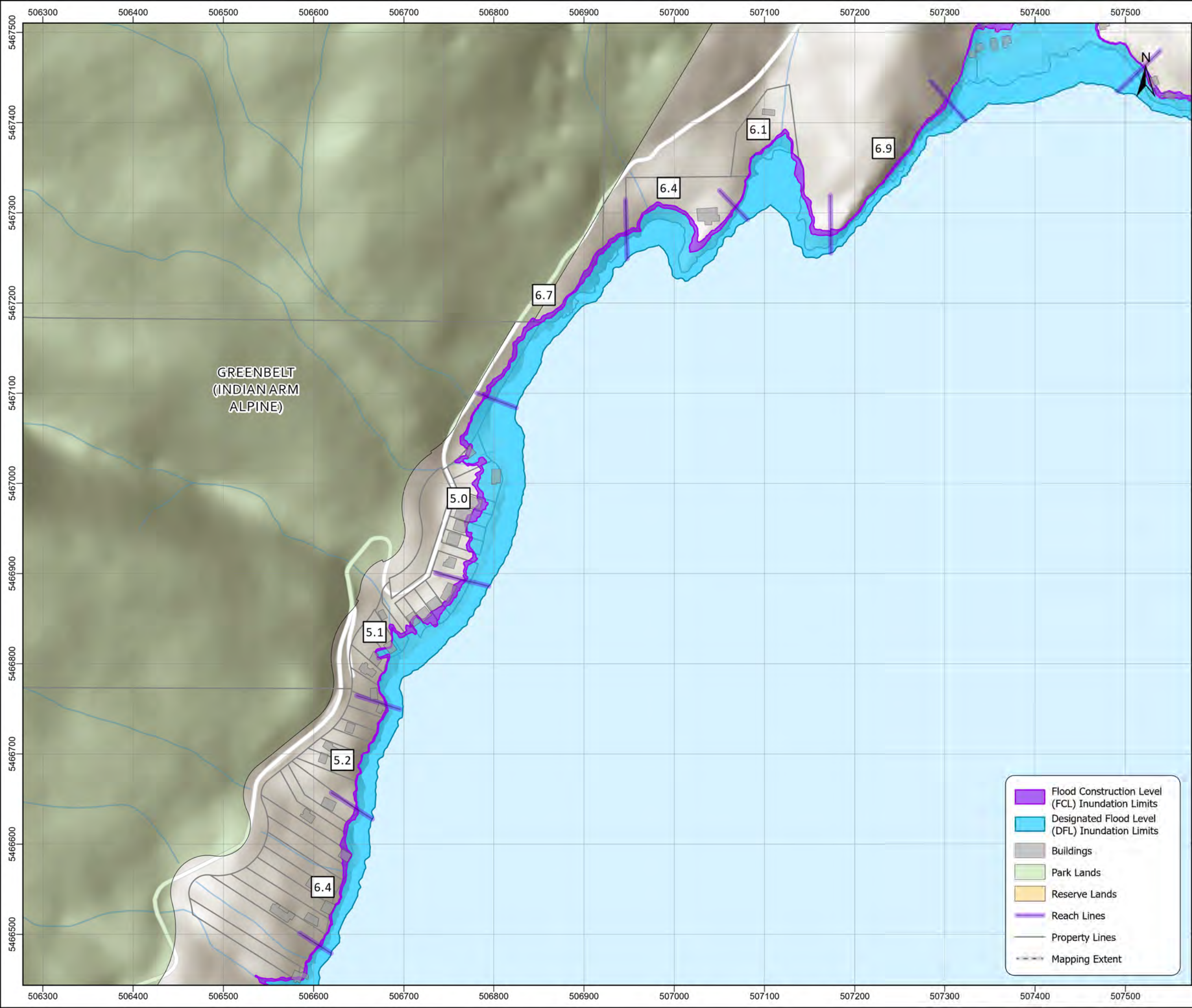
TITLE
District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise
Map 13 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
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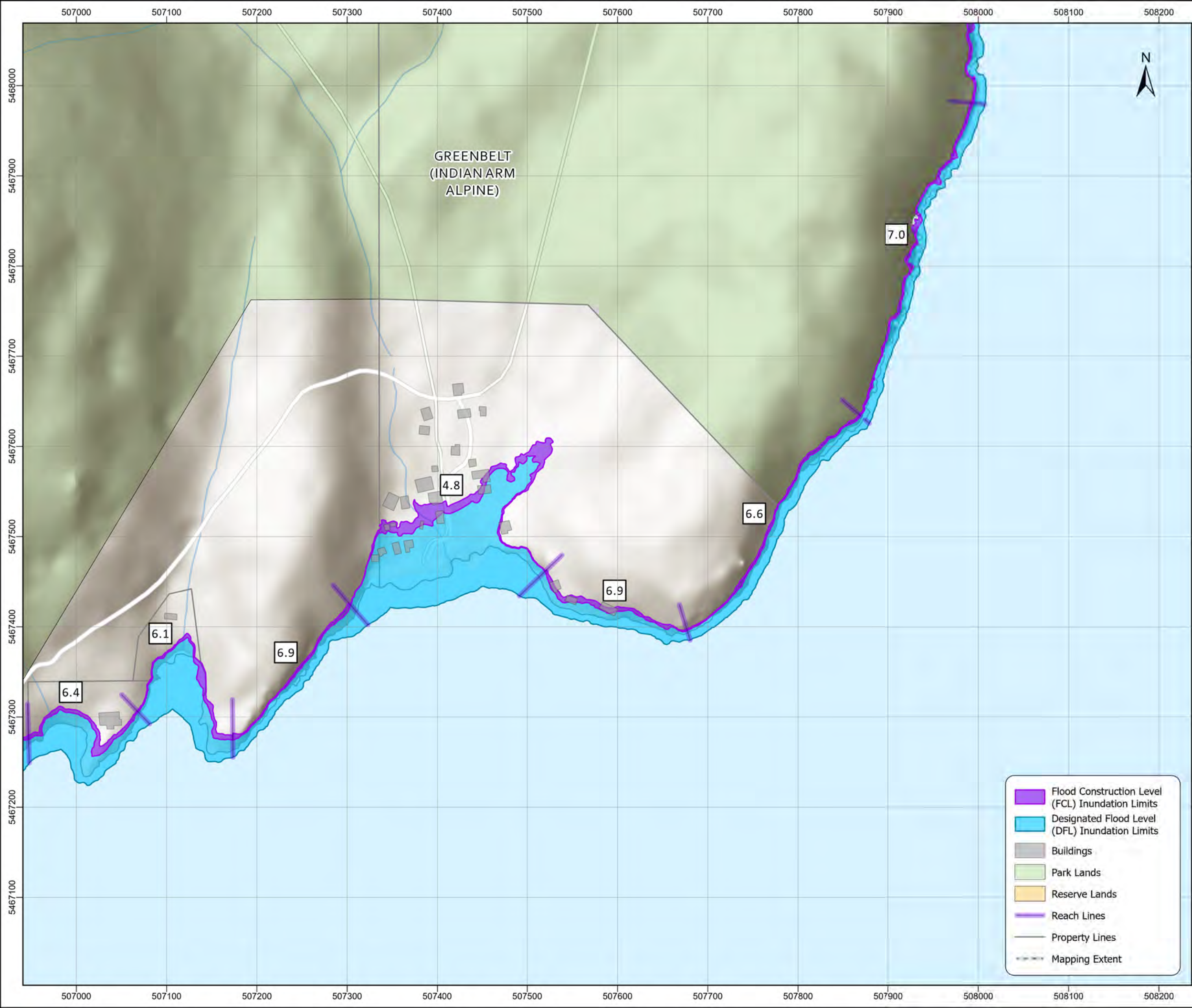
PCS: Projected Coordinate System
CGVD2013: Canadian Geodetic Vertical Datum of 2013
EPSG: European Petroleum Survey Group
CSRS: Canadian Spatial Reference System
DFL: Designated Flood Level
FCL: Flood Construction Level
SLR: Sea Level Rise

TITLE
District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise
Map 14 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



Overview:
These maps have been developed by DHI Water & Environment Inc. (DHI) for the District of North Vancouver to provide Flood Construction Reference Plane (FCRP) and Flood Construction Level (FCL) guidance. Notably, these mapping products incorporate wave effects.

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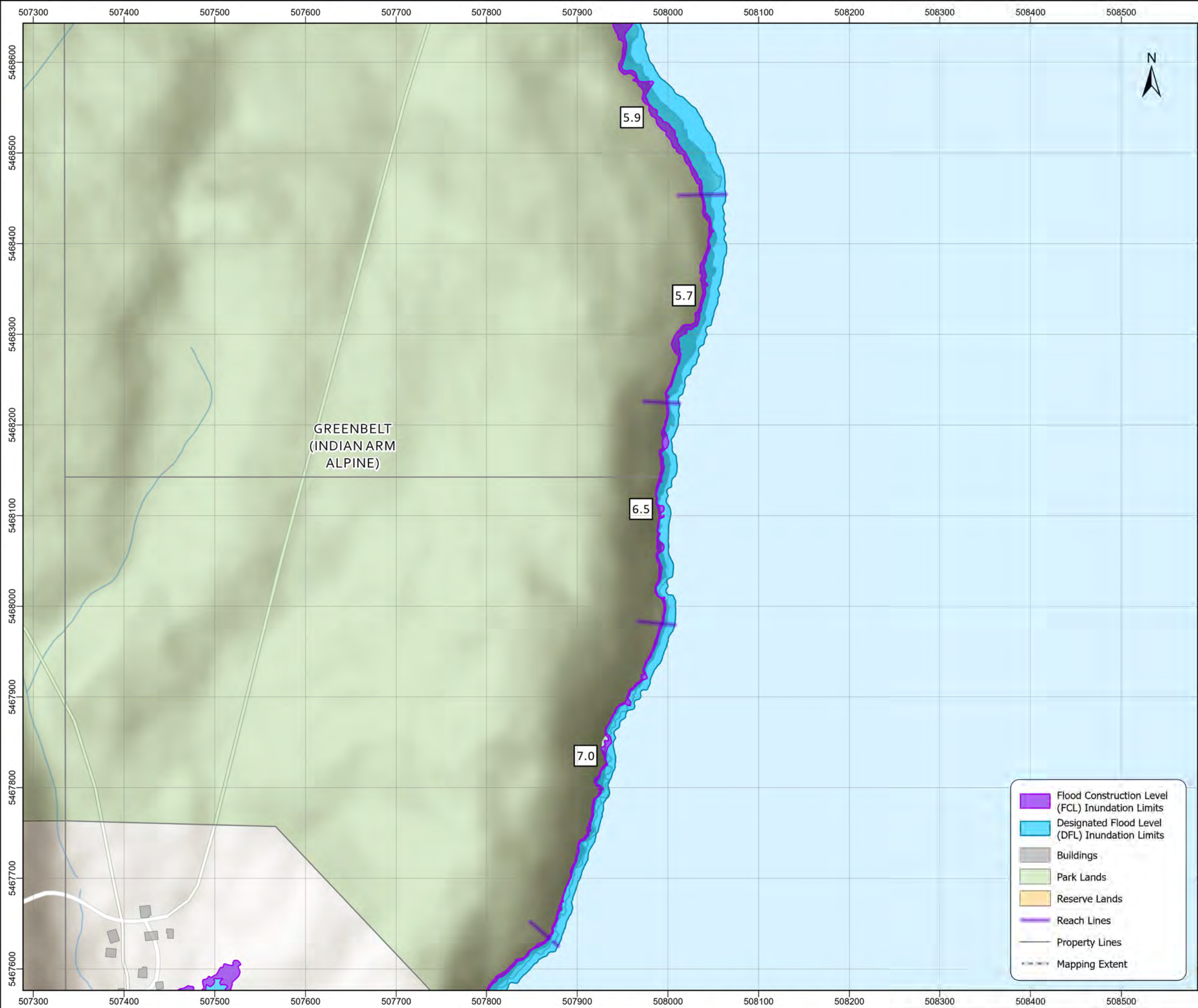
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CSRS: Canadian Spatial Reference System
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SLR: Sea Level Rise

TITLE
District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise
Map 15 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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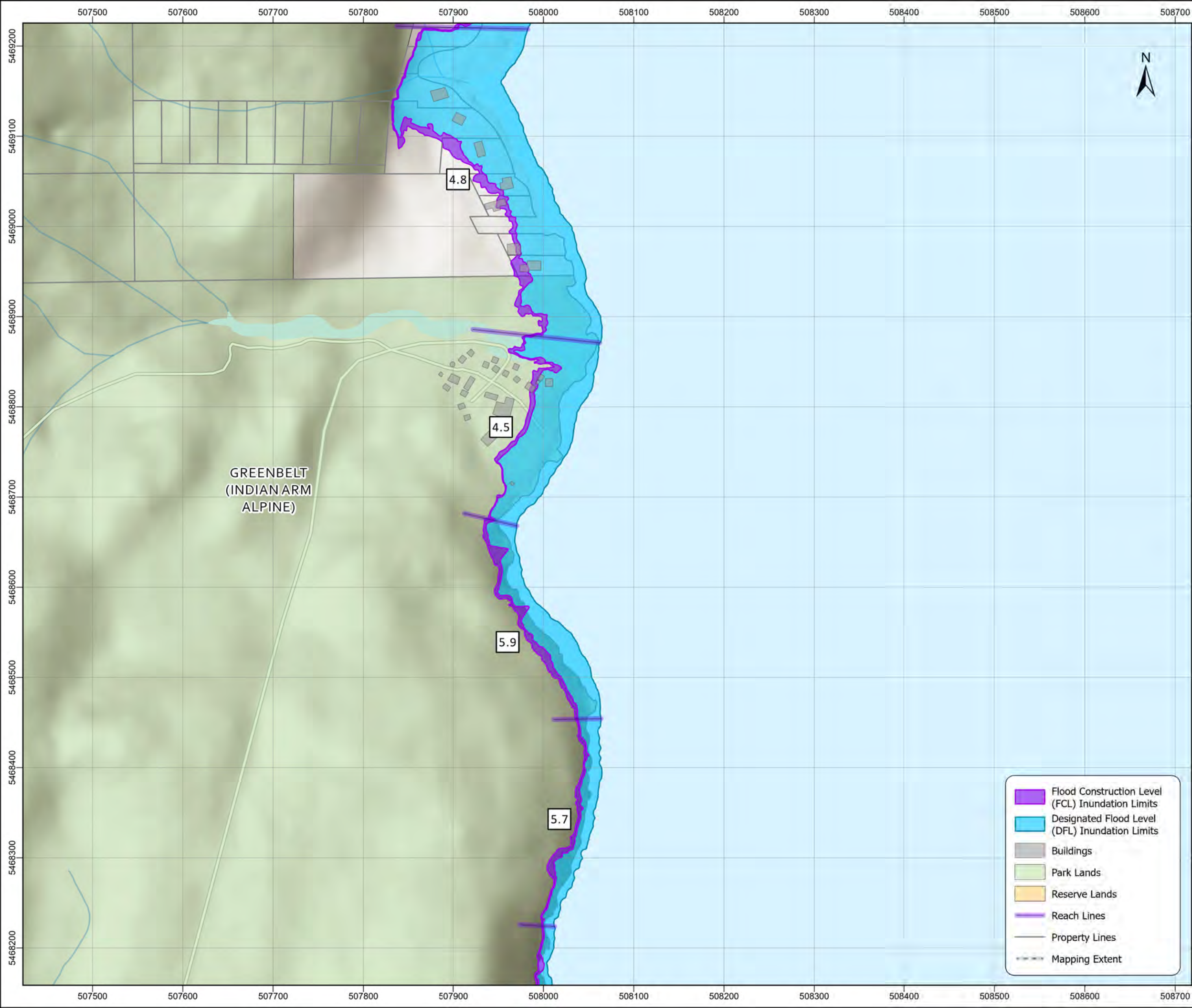
TITLE
District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise
Map 16 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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TITLE
District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise
Map 17 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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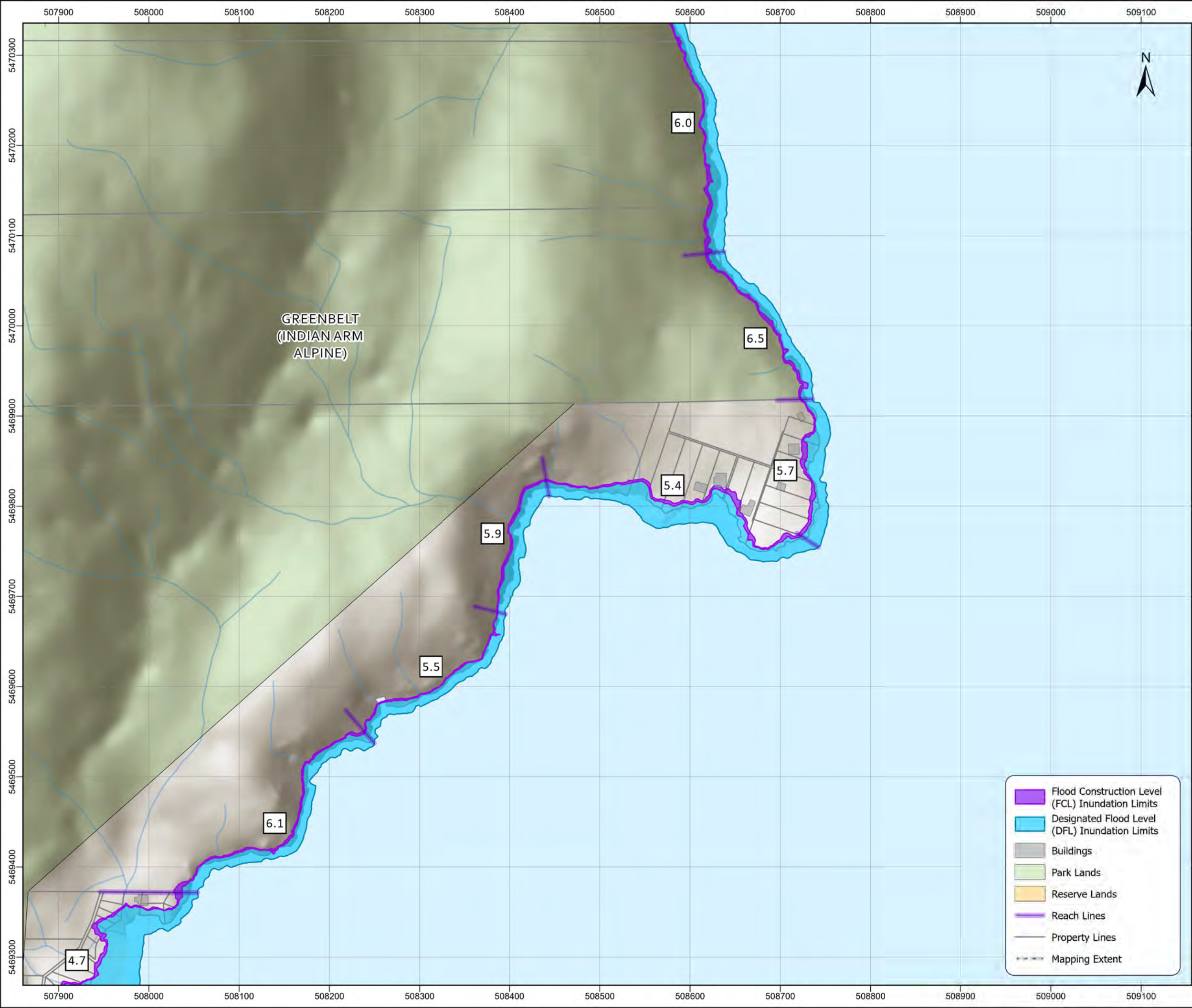
TITLE
District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise
Map 18 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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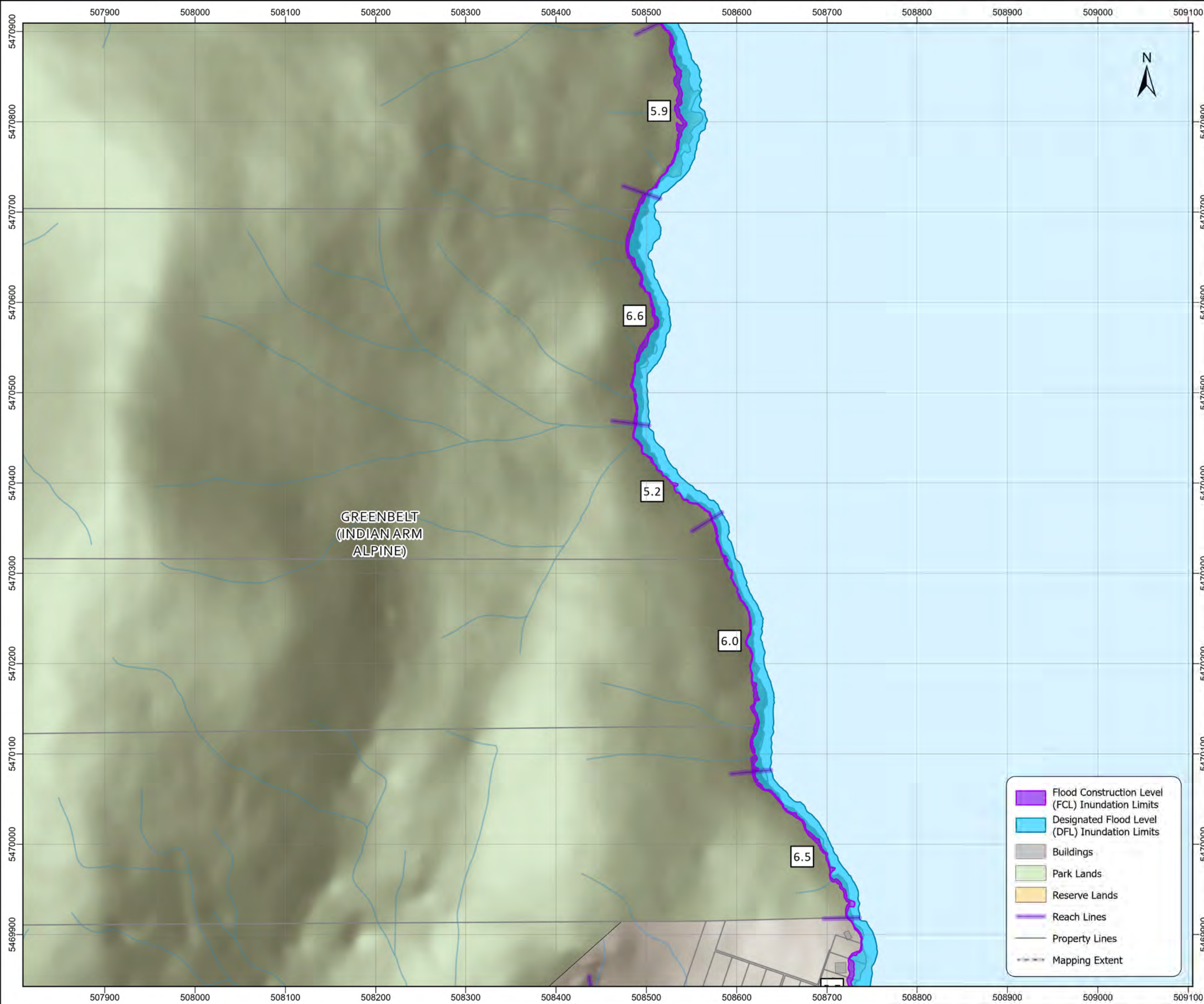
TITLE
District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise
Map 19 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

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SLR: Sea Level Rise

TITLE
District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise
Map 20 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



Overview:
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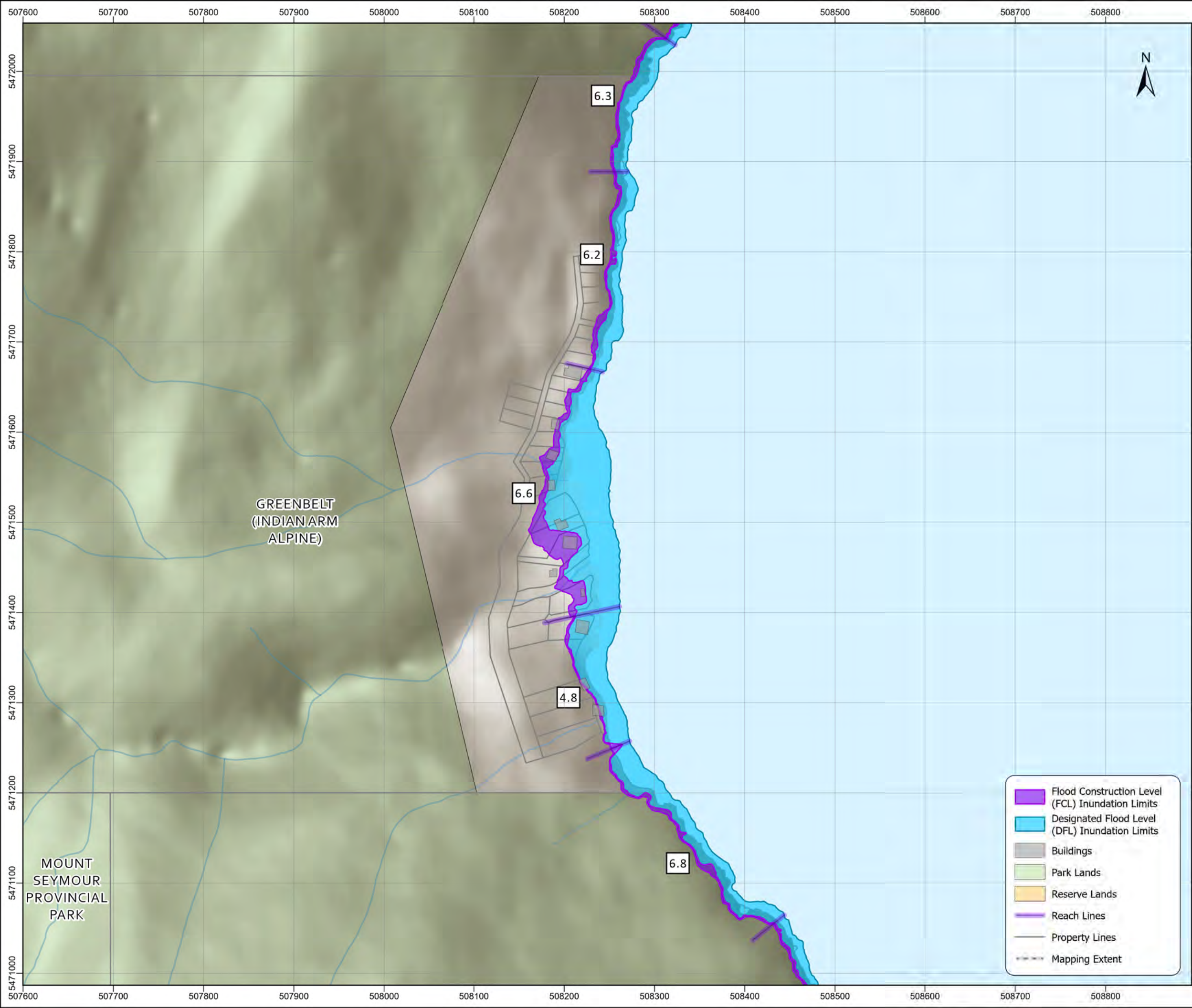
PCS: Projected Coordinate System
CGVD2013: Canadian Geodetic Vertical Datum of 2013
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CSRS: Canadian Spatial Reference System
DFL: Designated Flood Level
FCL: Flood Construction Level
SLR: Sea Level Rise

TITLE
District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise
Map 21 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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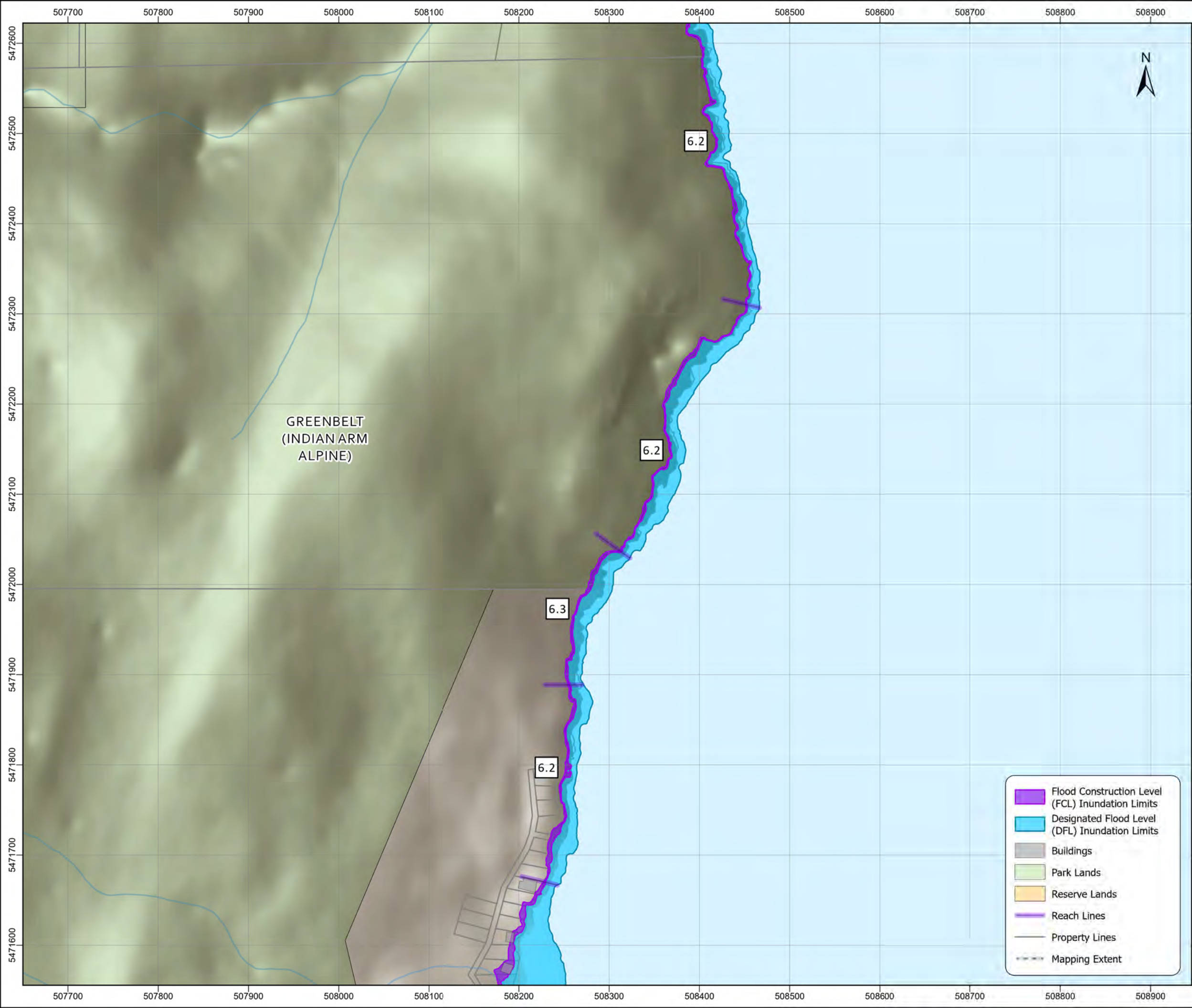
PCS: Projected Coordinate System
CGVD2013: Canadian Geodetic Vertical Datum of 2013
EPSG: European Petroleum Survey Group
CSRS: Canadian Spatial Reference System
DFL: Designated Flood Level
FCL: Flood Construction Level
SLR: Sea Level Rise

TITLE
District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise
Map 22 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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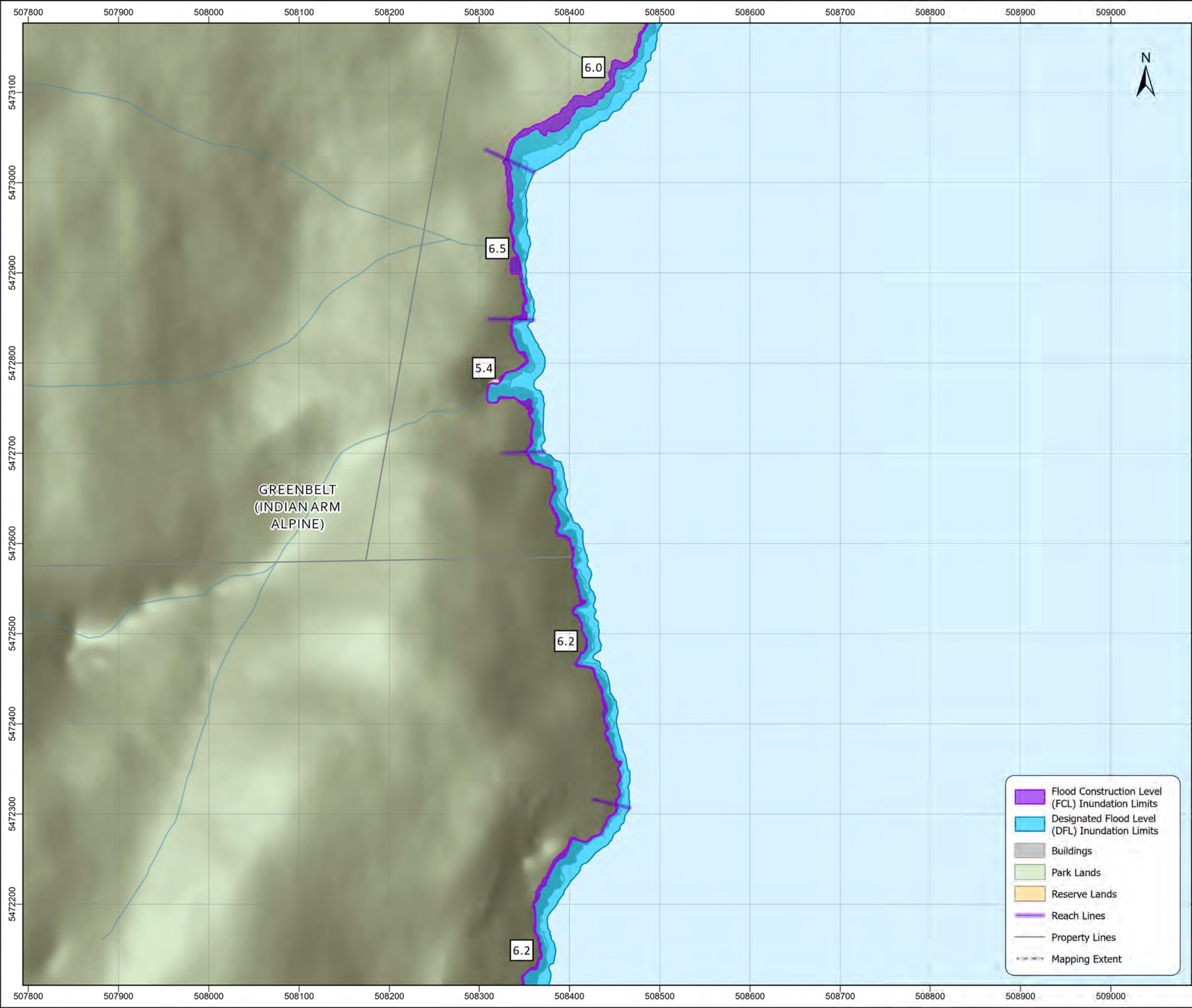
TITLE
District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise
Map 23 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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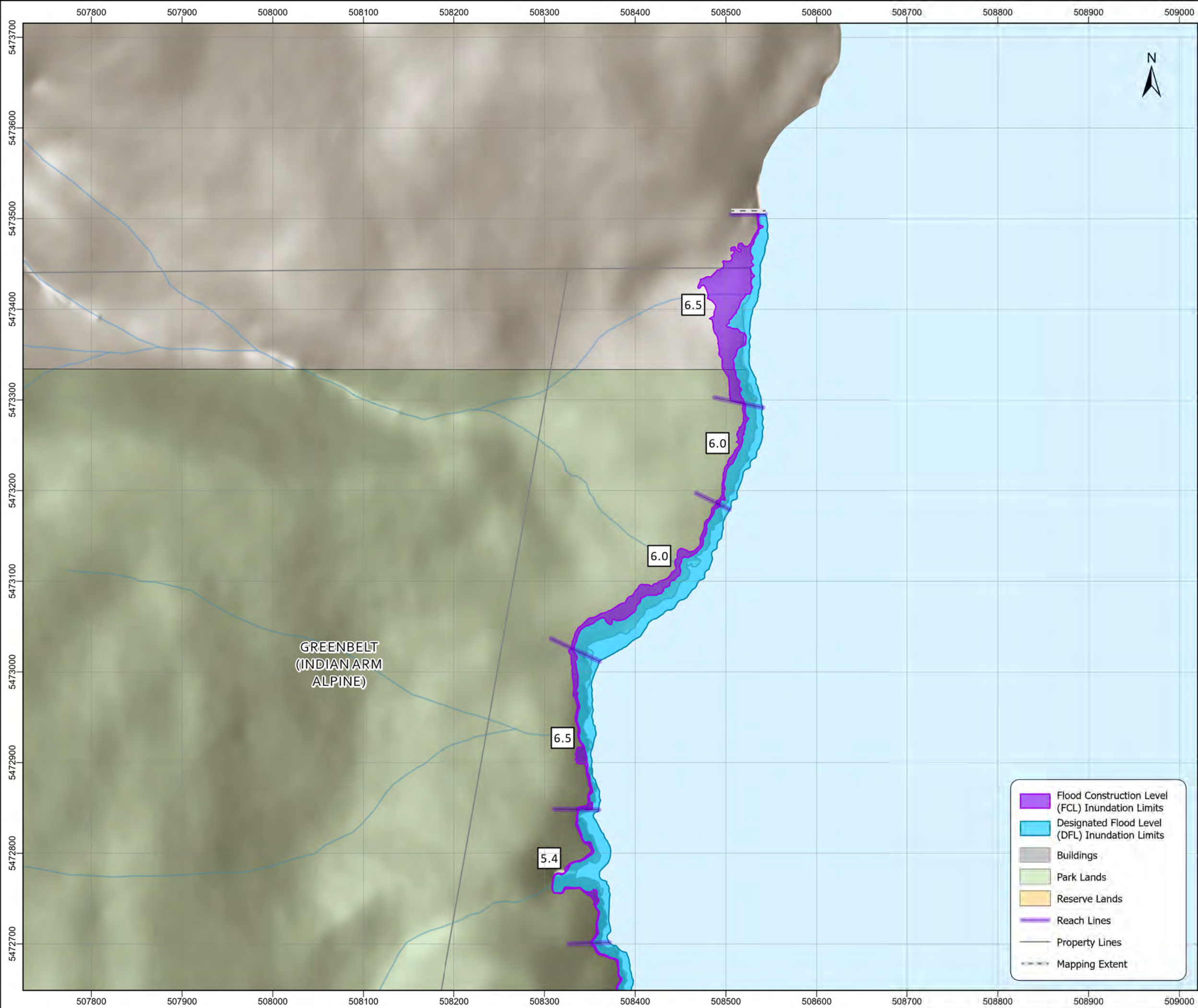
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SLR: Sea Level Rise

TITLE
District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise
Map 24 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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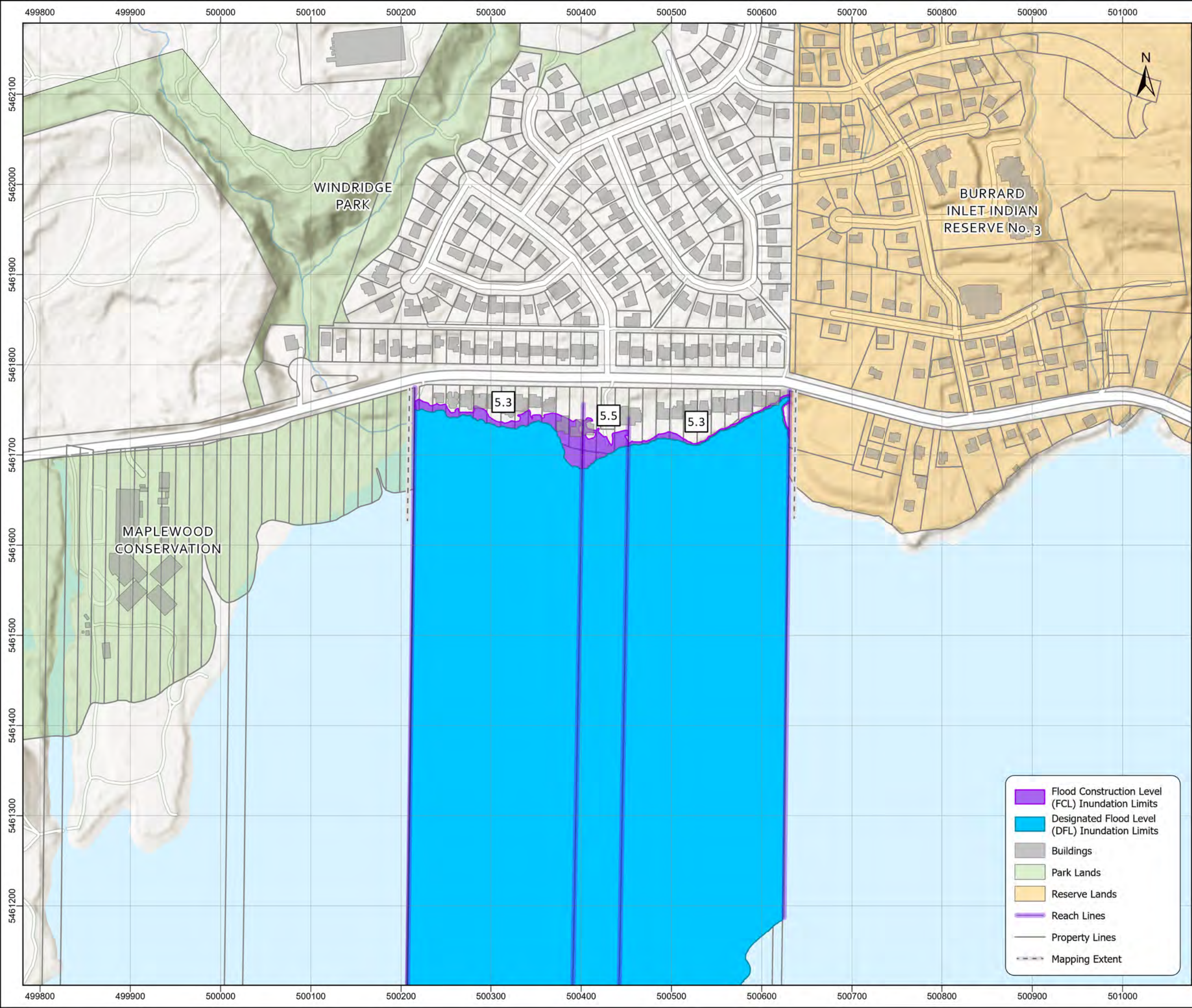
TITLE
District of North Vancouver - Flood Construction Level Maps for 0.5 m Sea Level Rise
Map 25 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121

Appendix F.4 Flood Construction Level with 1.0 m Sea Level Rise



Overview:
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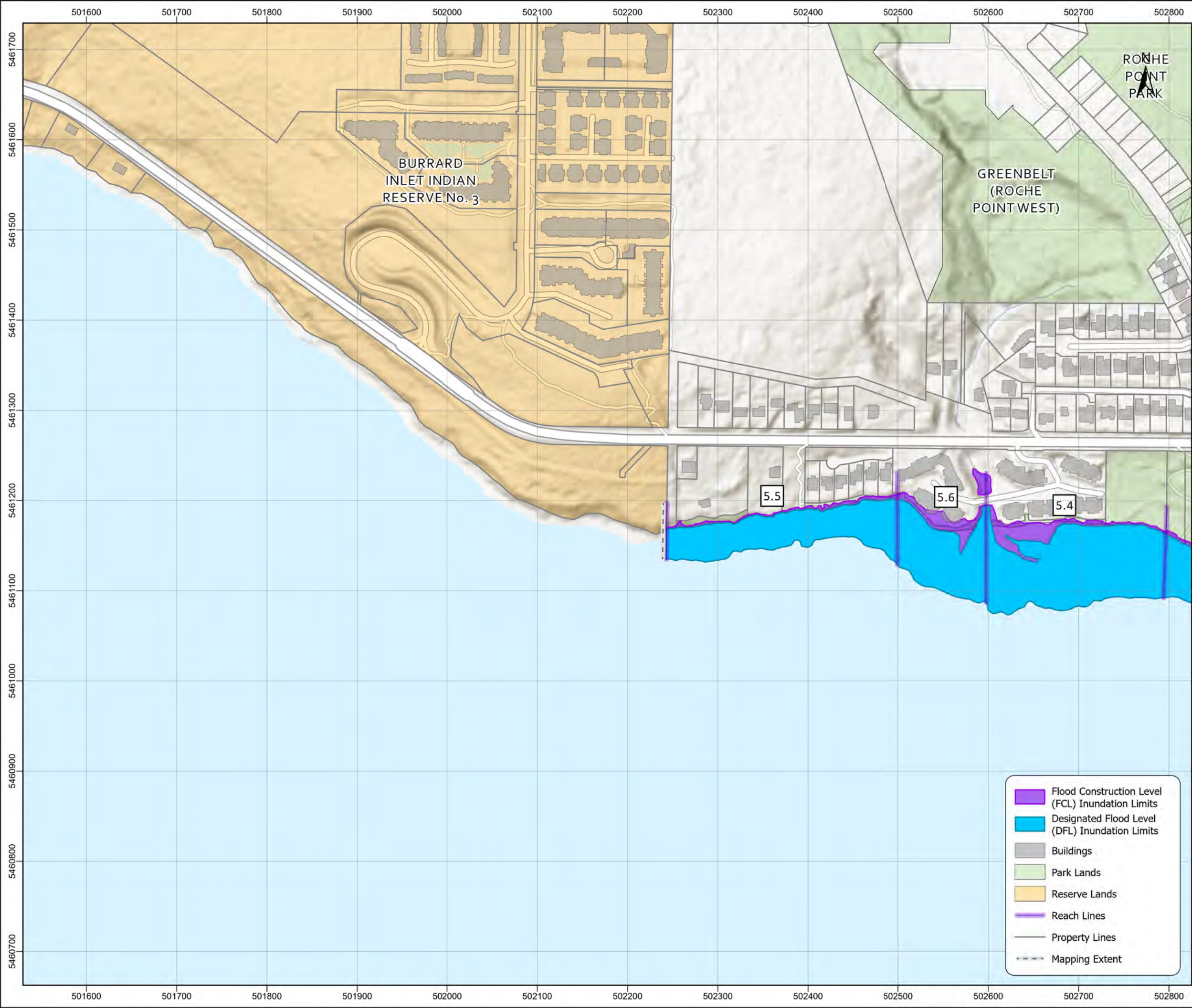
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SLR: Sea Level Rise

TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 1 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
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Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

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DFL: Designated Flood Level
FCL: Flood Construction Level
SLR: Sea Level Rise

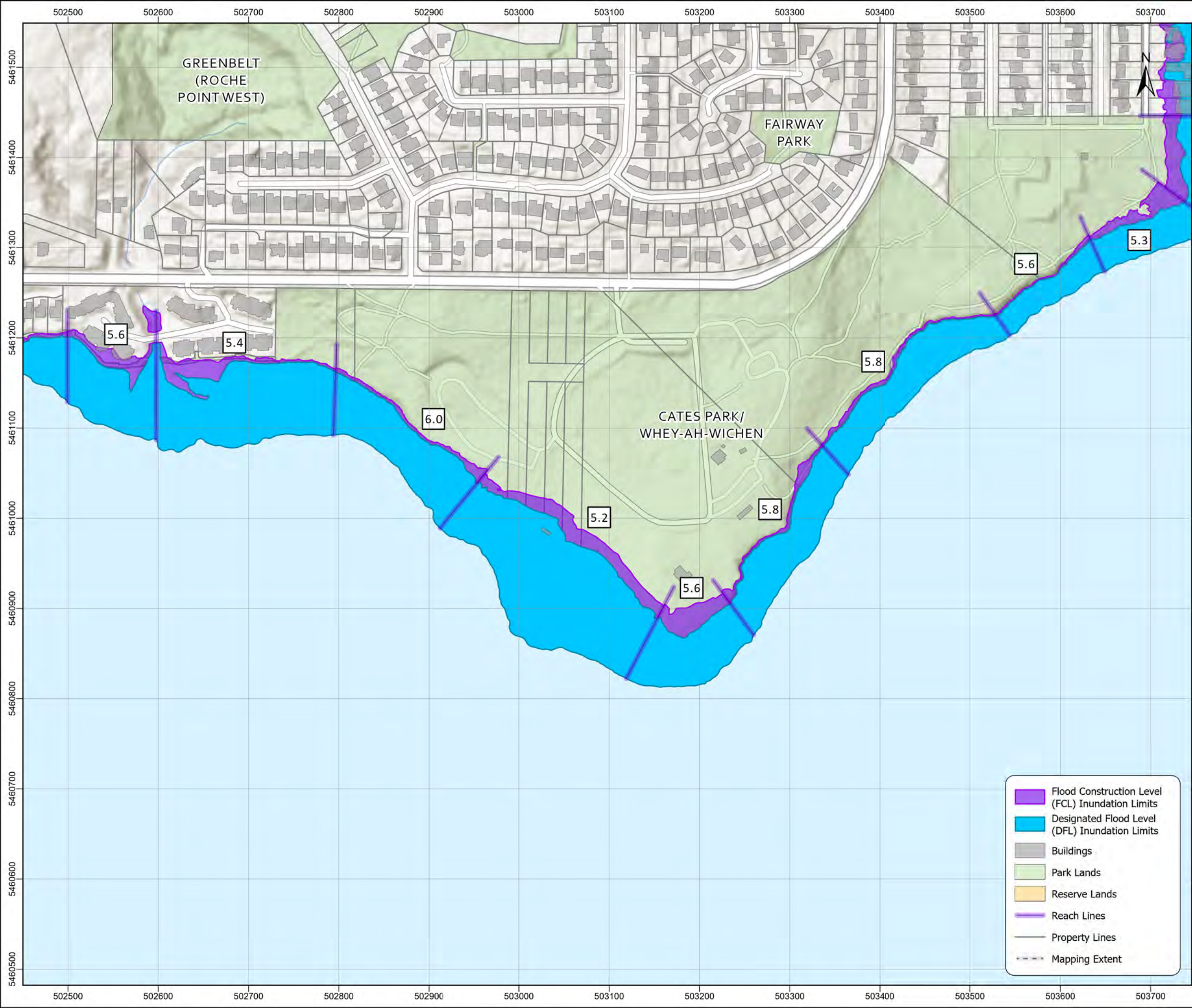
TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 2 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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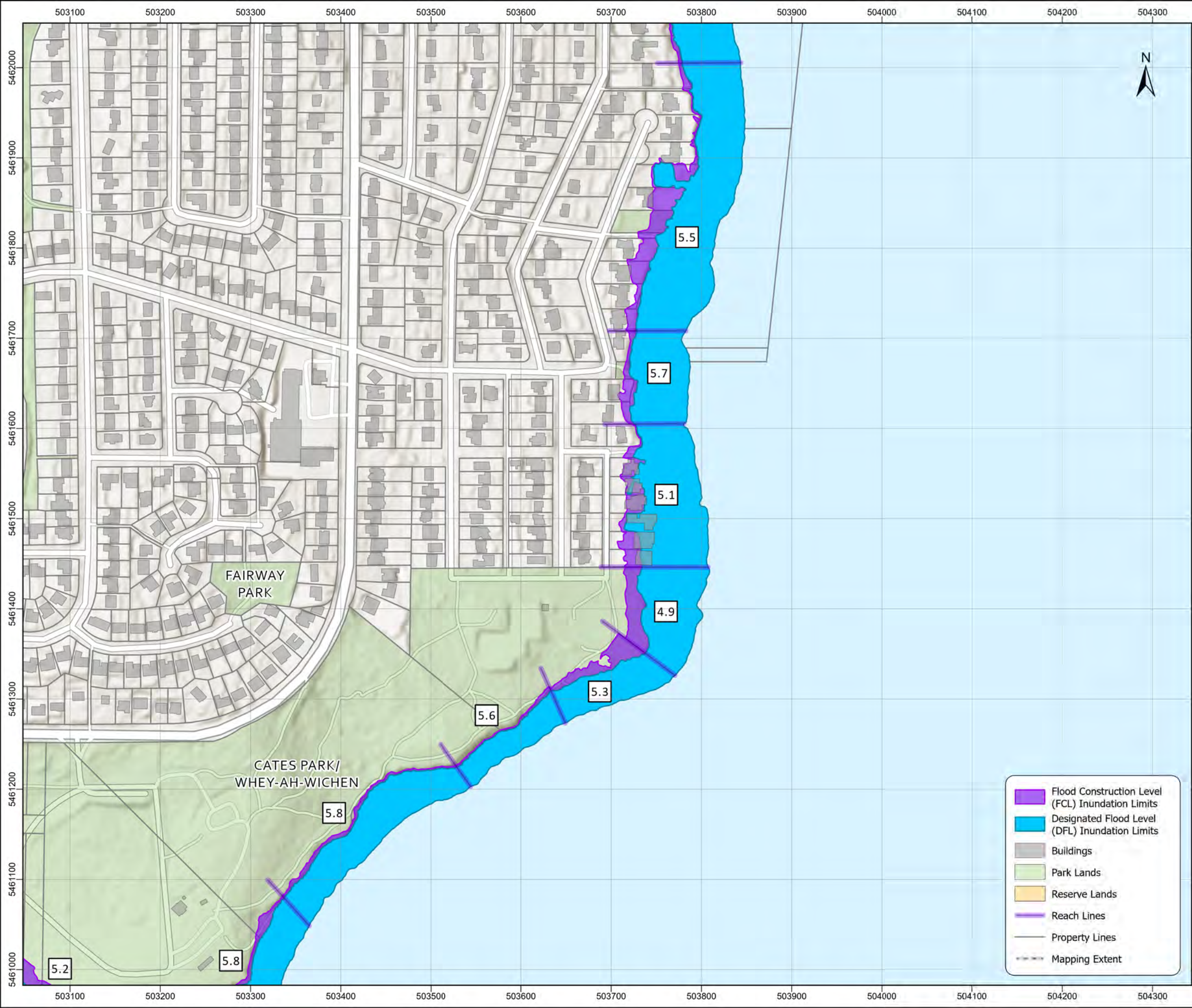
TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 3 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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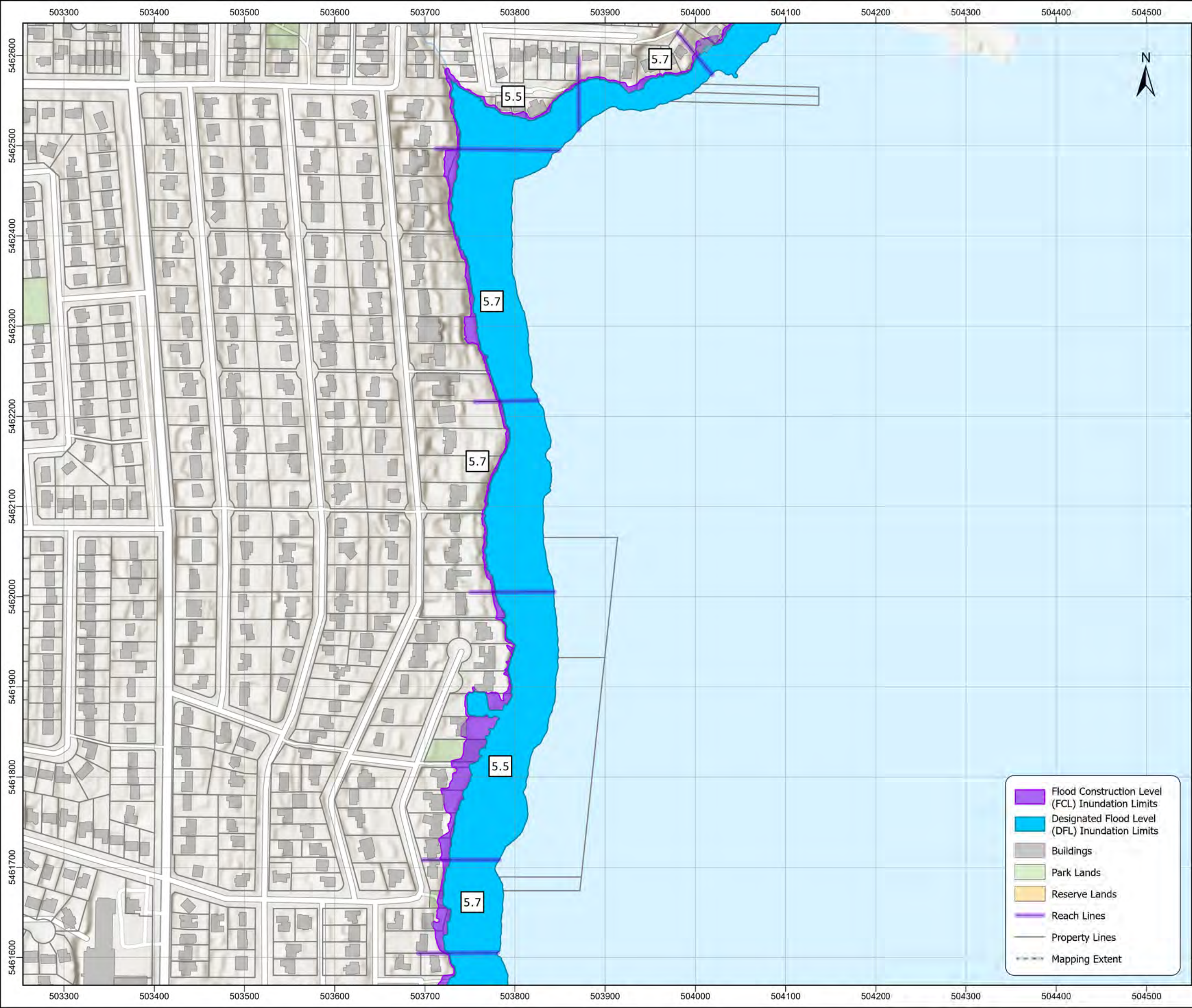
TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 4 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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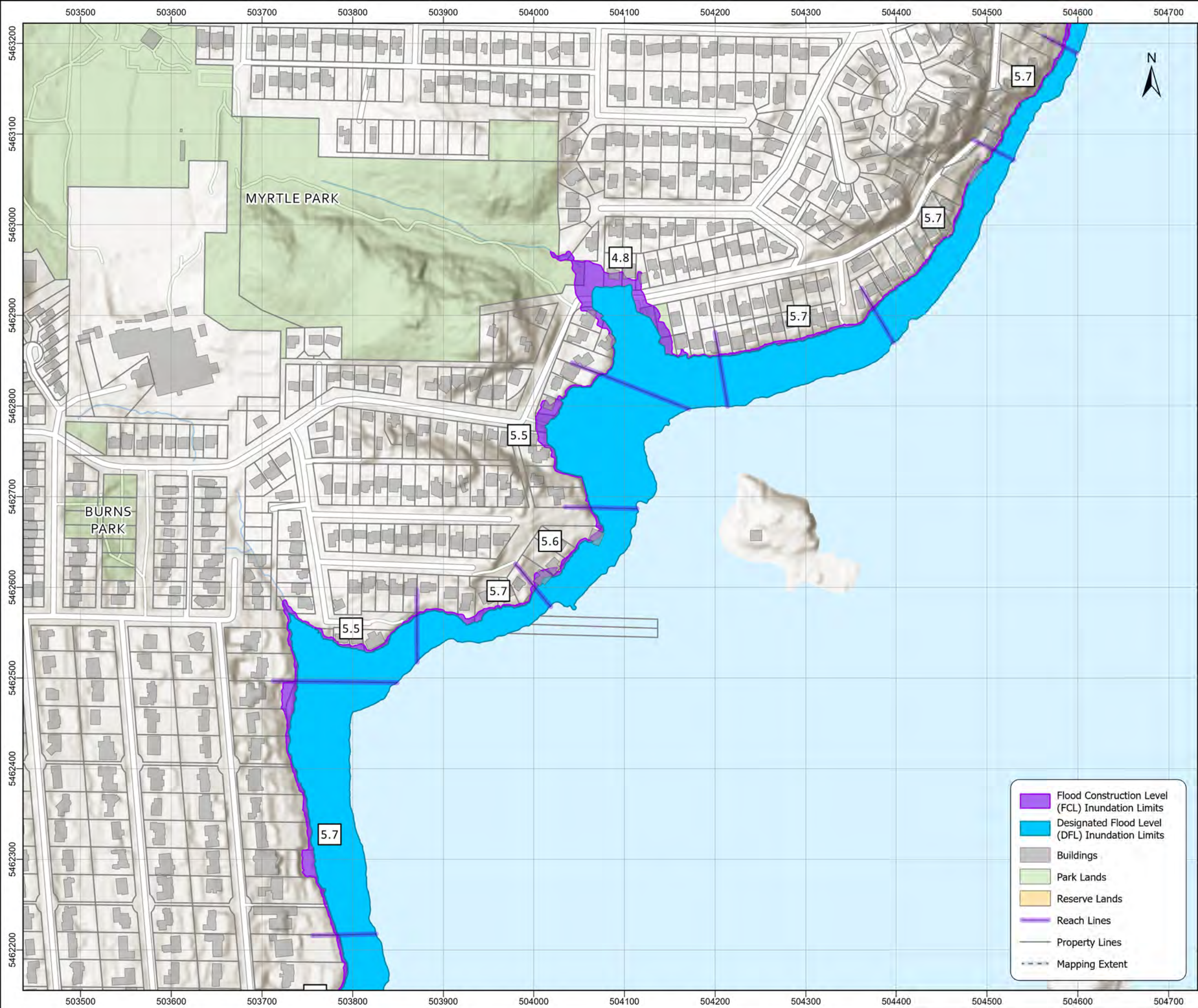
TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 5 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 6 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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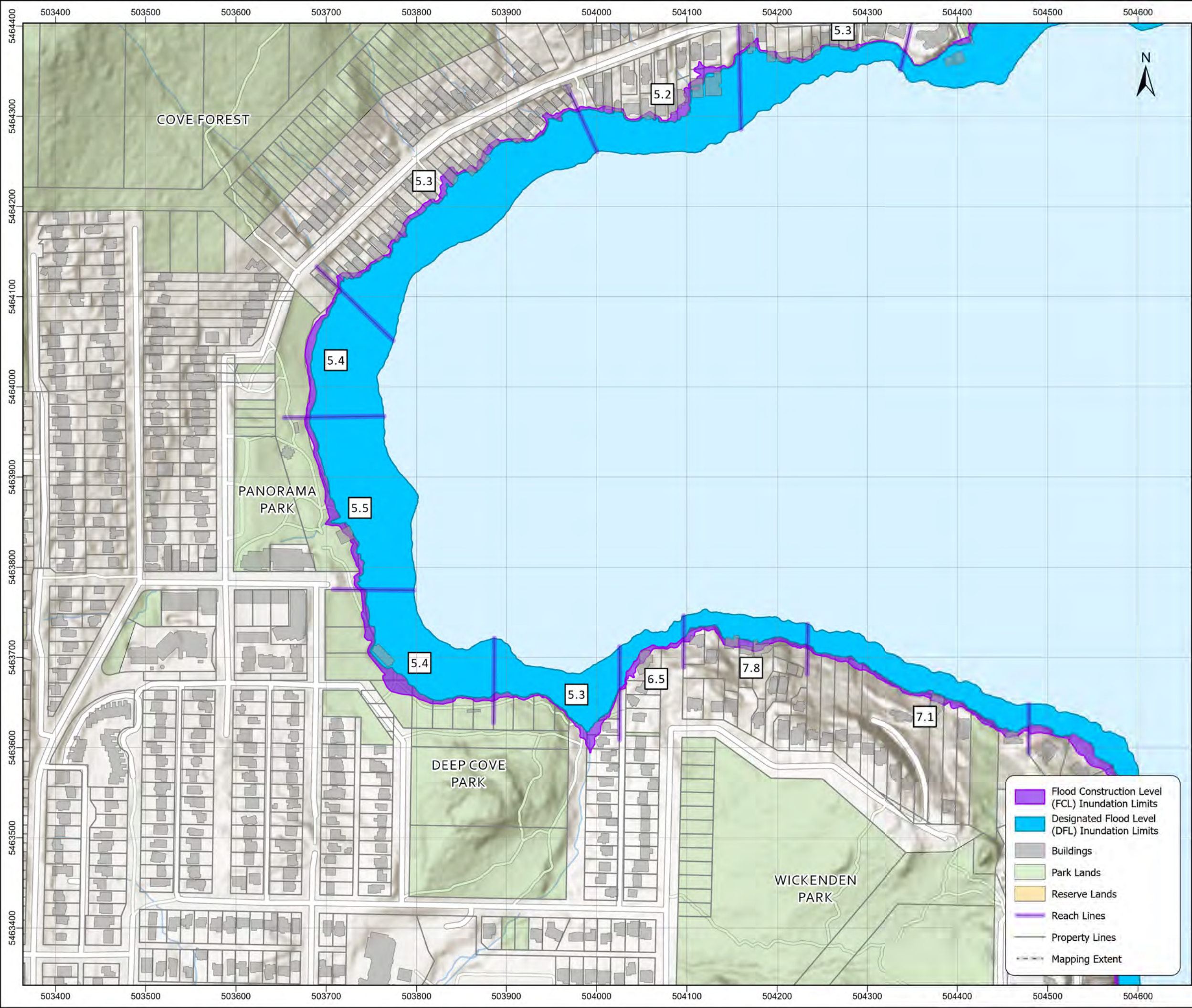
TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 7 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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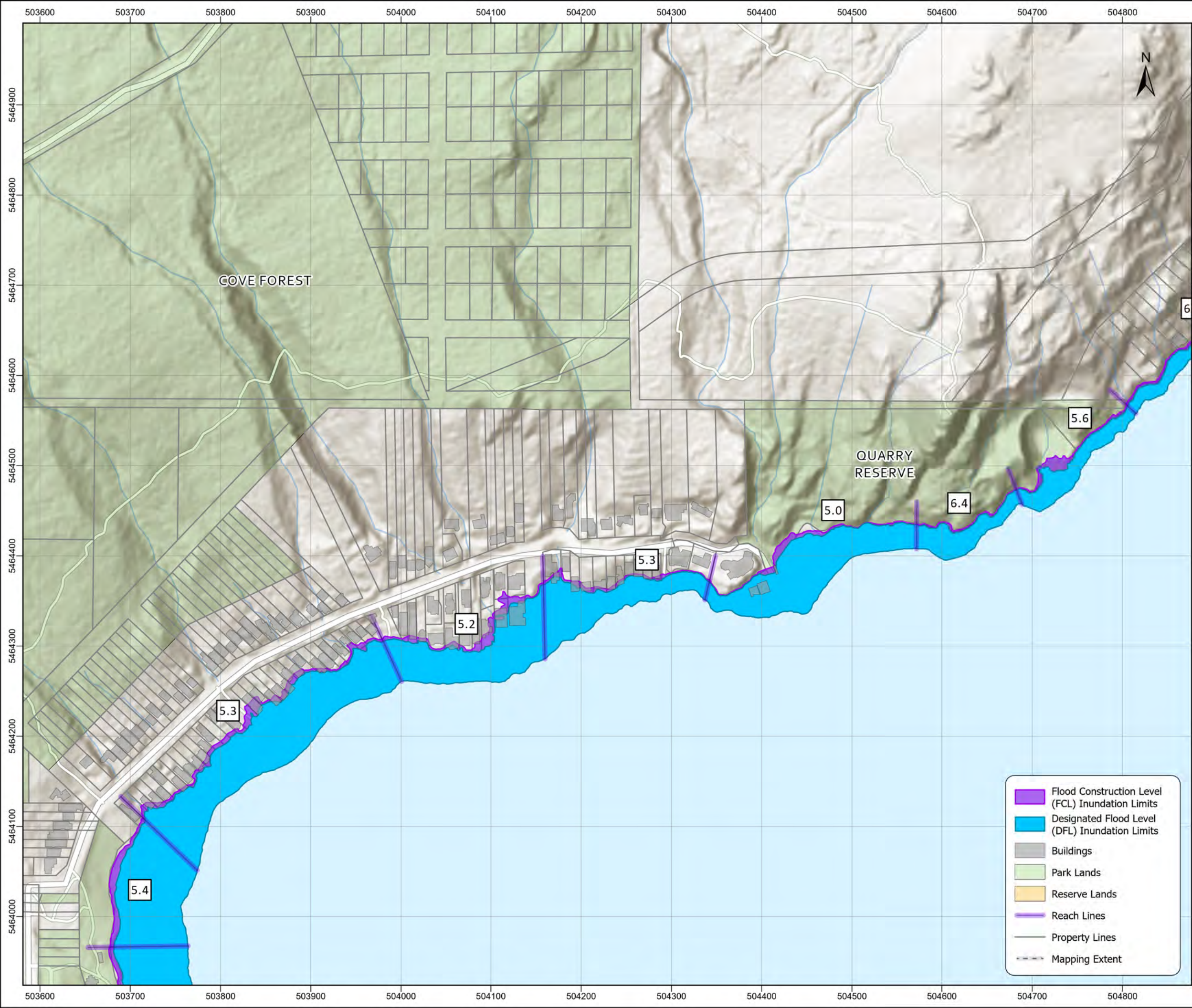
PCS: Projected Coordinate System
CGVD2013: Canadian Geodetic Vertical Datum of 2013
EPSG: European Petroleum Survey Group
CSRS: Canadian Spatial Reference System
DFL: Designated Flood Level
FCL: Flood Construction Level
SLR: Sea Level Rise

TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 8 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



Overview:
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FCL: Flood Construction Level
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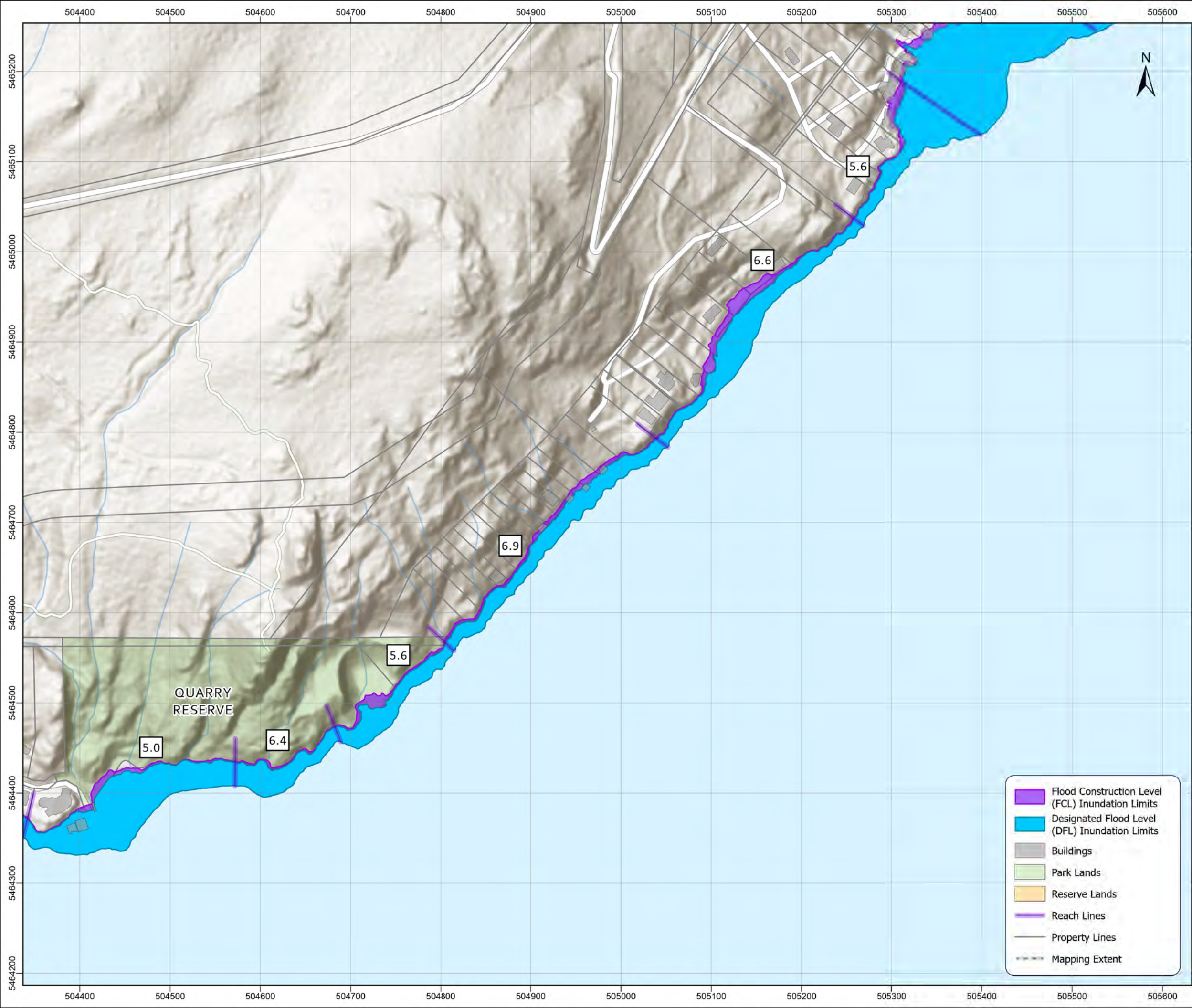
TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 9 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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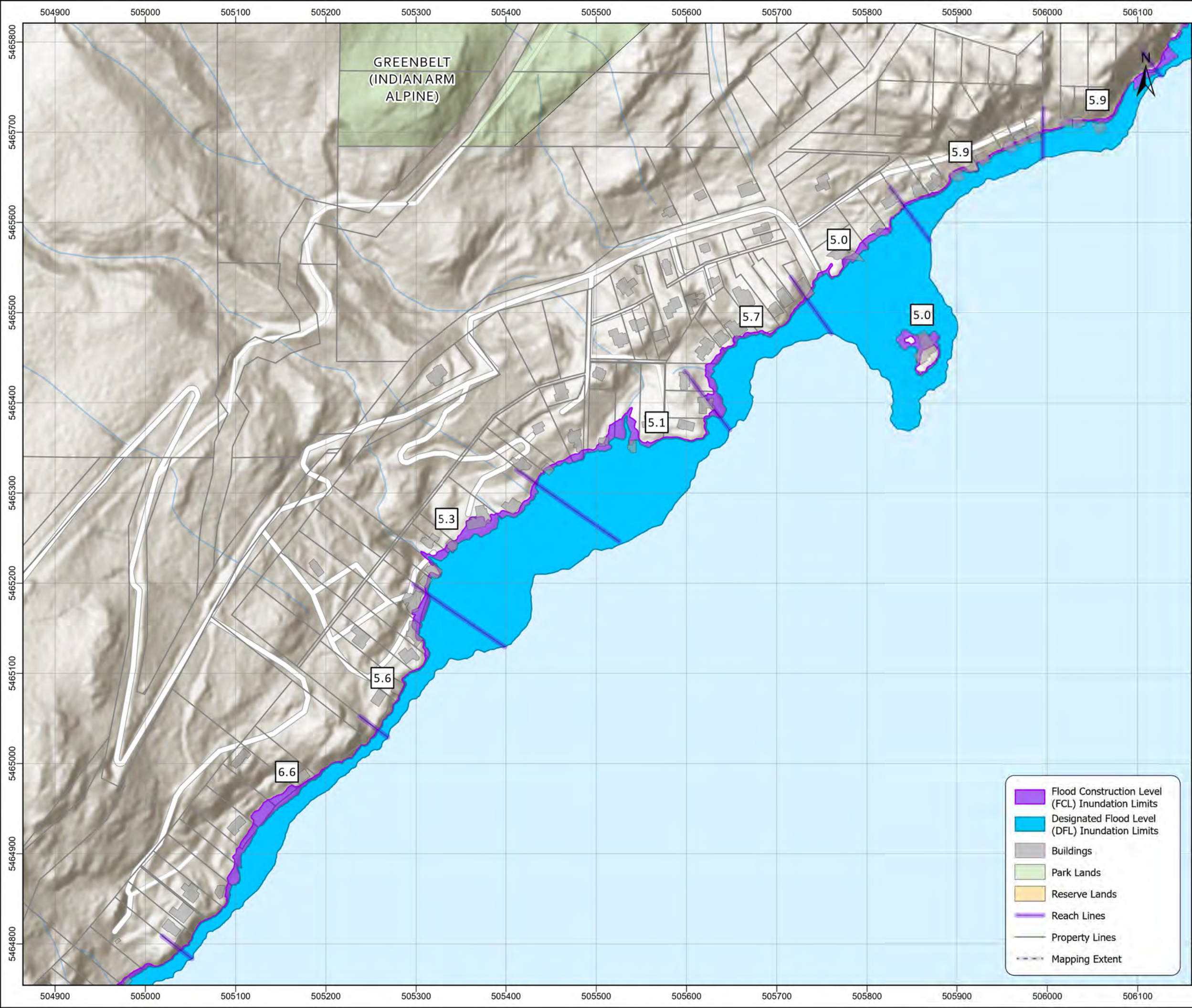
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EPSG: European Petroleum Survey Group
CSRS: Canadian Spatial Reference System
DFL: Designated Flood Level
FCL: Flood Construction Level
SLR: Sea Level Rise

TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 10 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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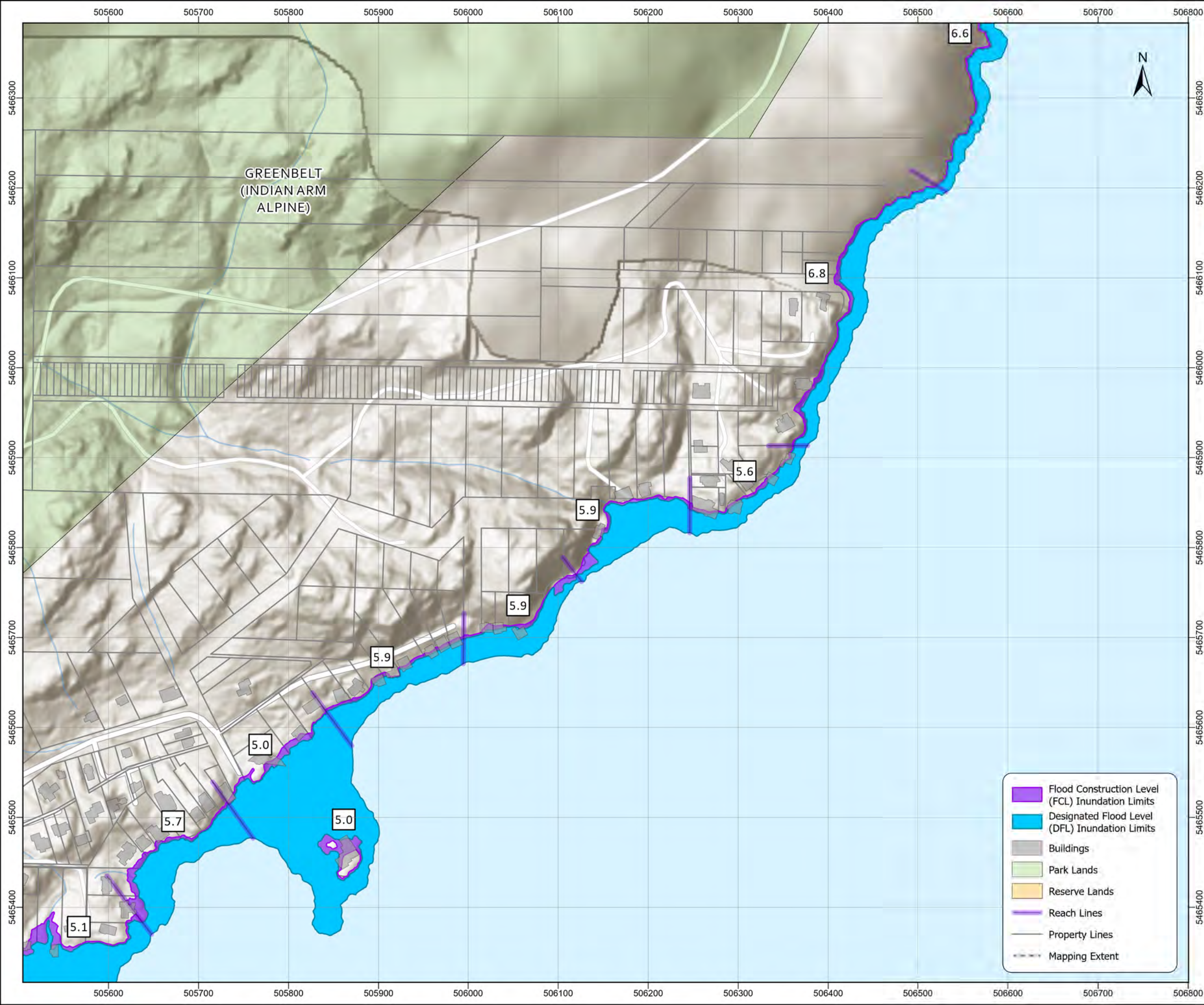
TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 11 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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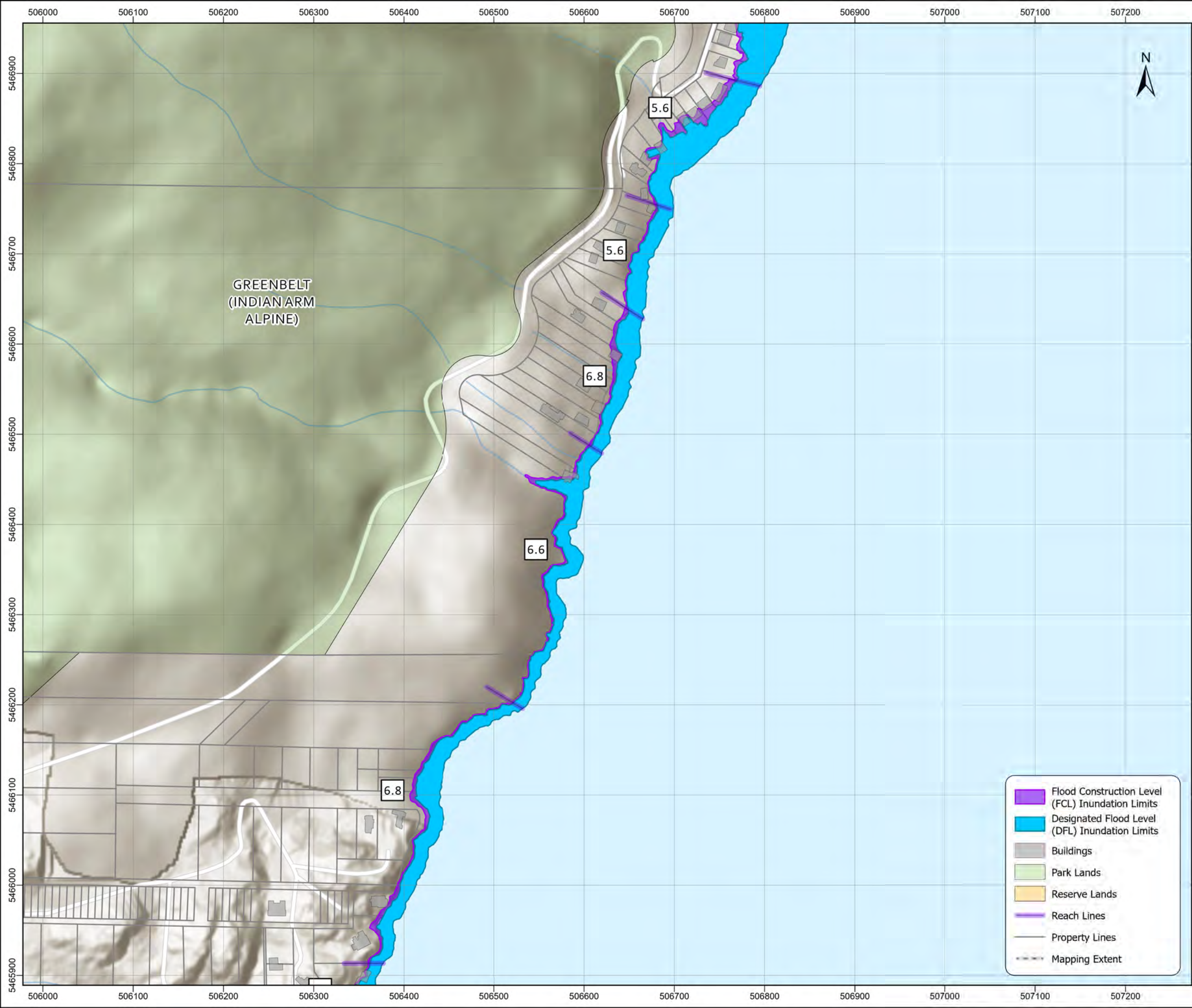
TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 12 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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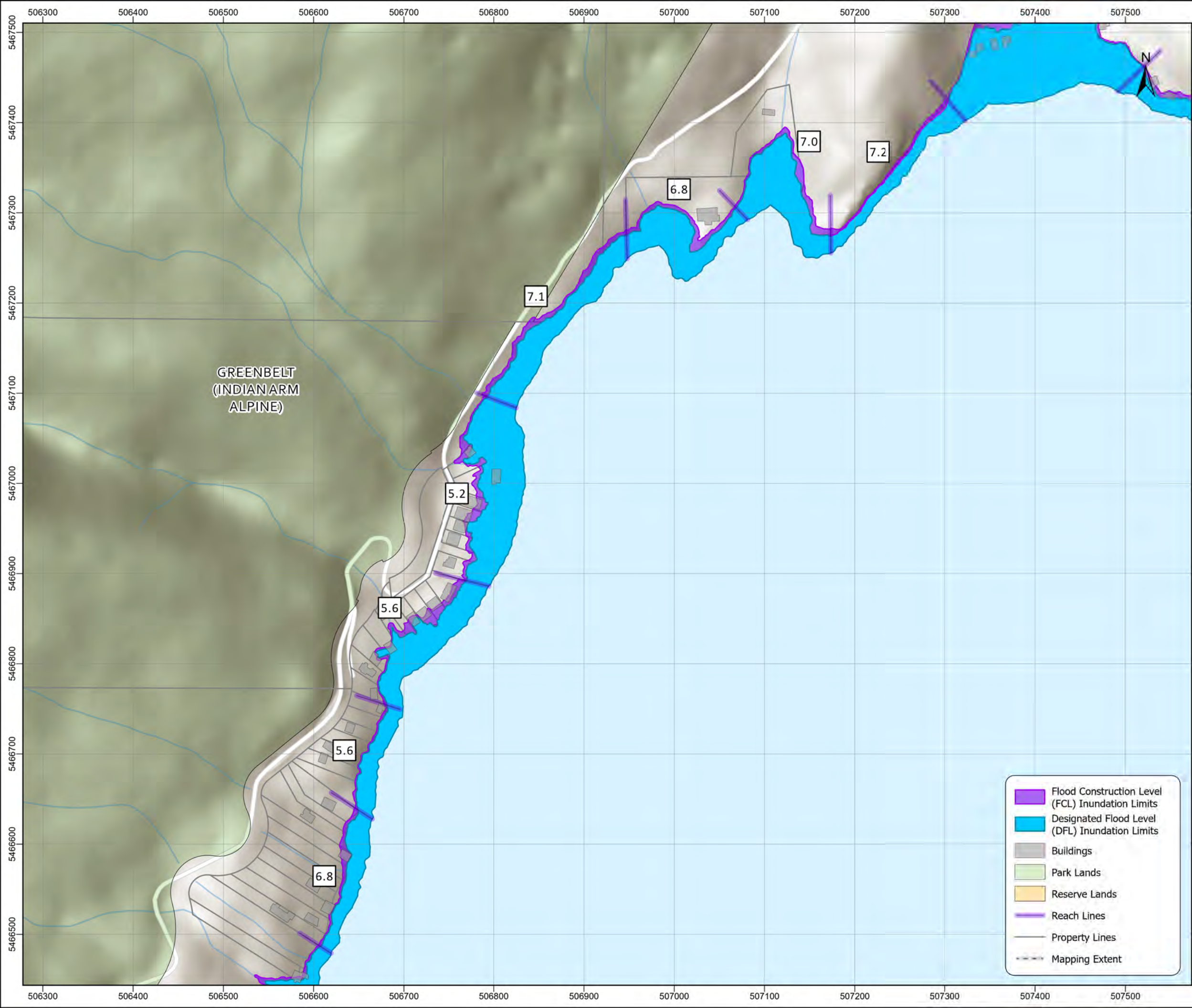
TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 13 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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Flood Construction Level (FCL) Inundation Limits

Designated Flood Level (DFL) Inundation Limits

Buildings

Park Lands

Reserve Lands

Reach Lines

Property Lines

Mapping Extent

TITLE

District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise

Map 14 of 25

PCS: NAD 1983 UTM Zone 10N

EPSG: 26910

Datum: CGVD2013

Map Units: Meter

Scale: 1:4,000

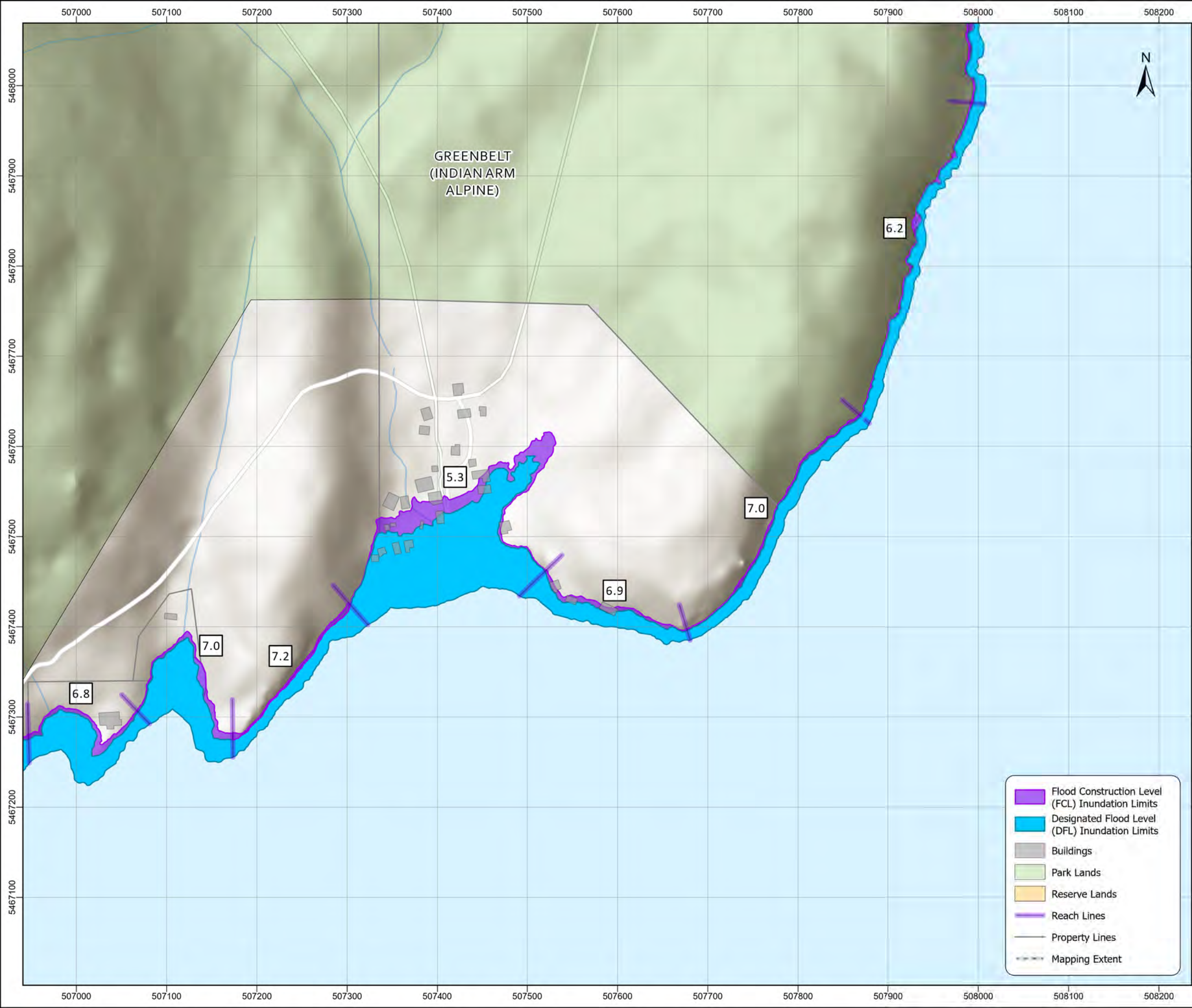
0 25 50 100

Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121

DISTRICT OF NORTH VANCOUVER

DHI



Overview:
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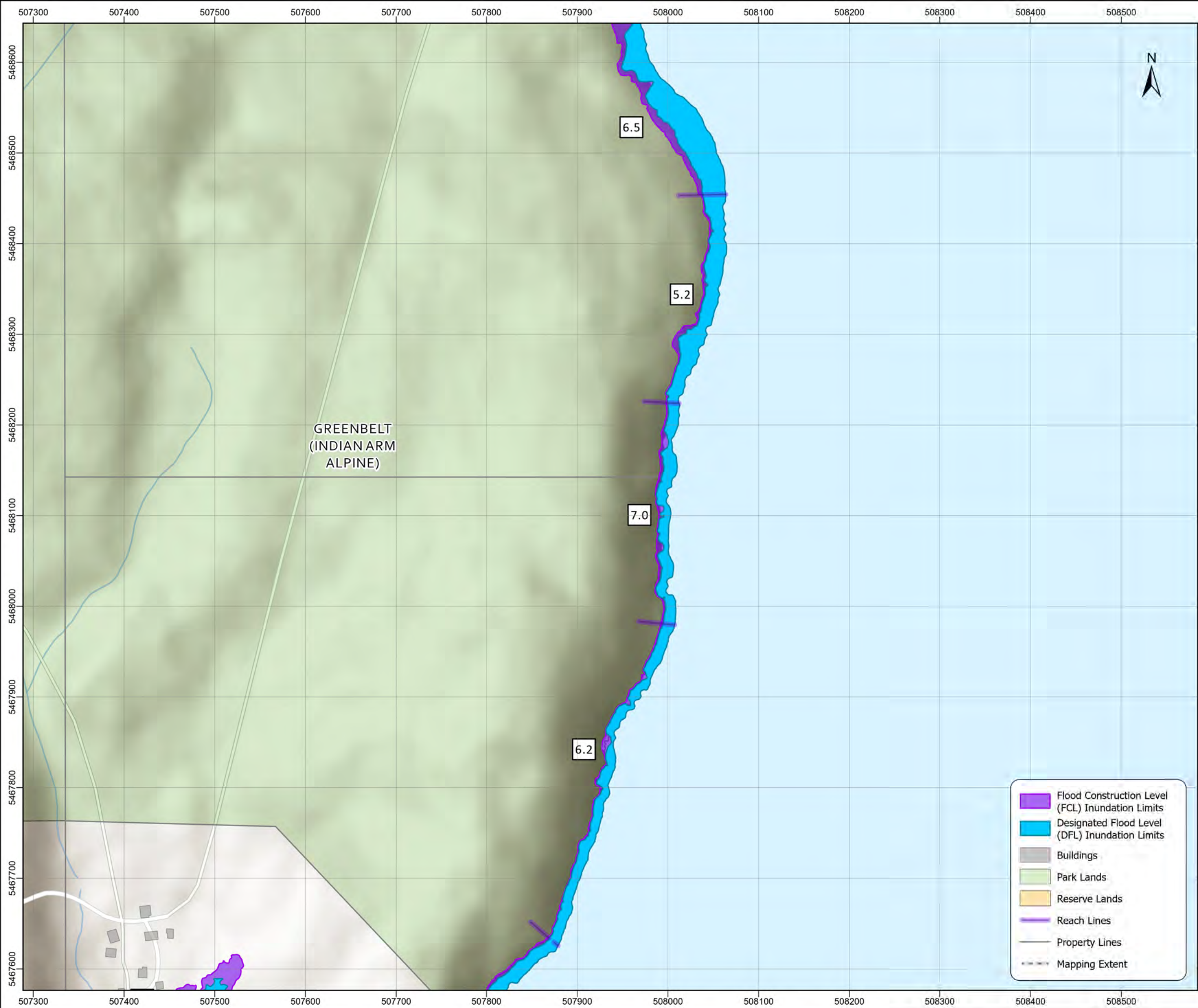
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TITLE District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise Map 15 of 25			
PCS: NAD 1983 UTM Zone 10N EPSG: 26910 Datum: CGVD2013 Map Units: Meter		Scale: 1:4,000 0 25 50 100 Meters	
DATE	2024-05-24	AUTHOR	SSIN
APPROVER	DANK	DHI PROJECT NUMBER	42804121
REVISION	1	REVIEWER	DANK





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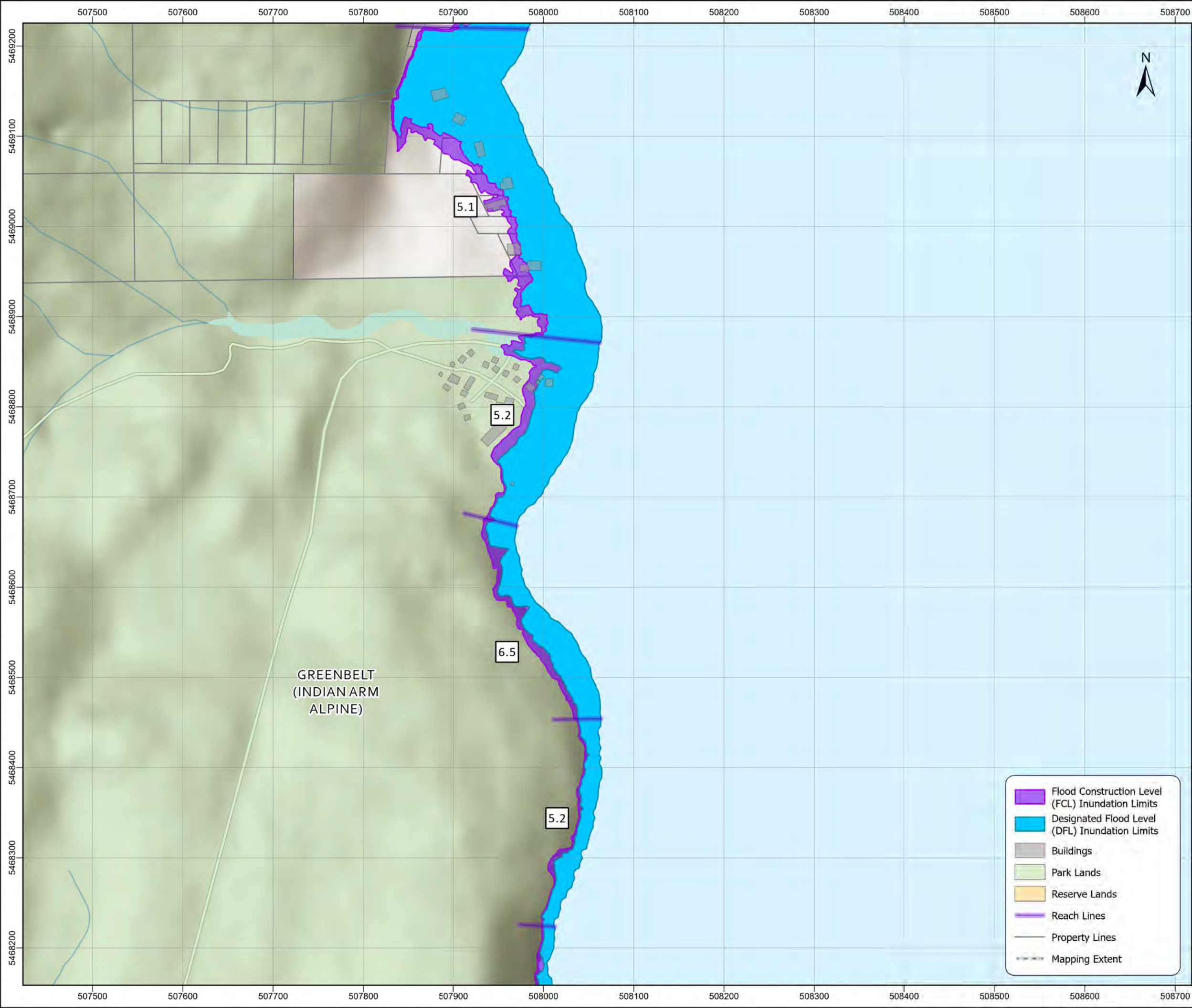
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TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 16 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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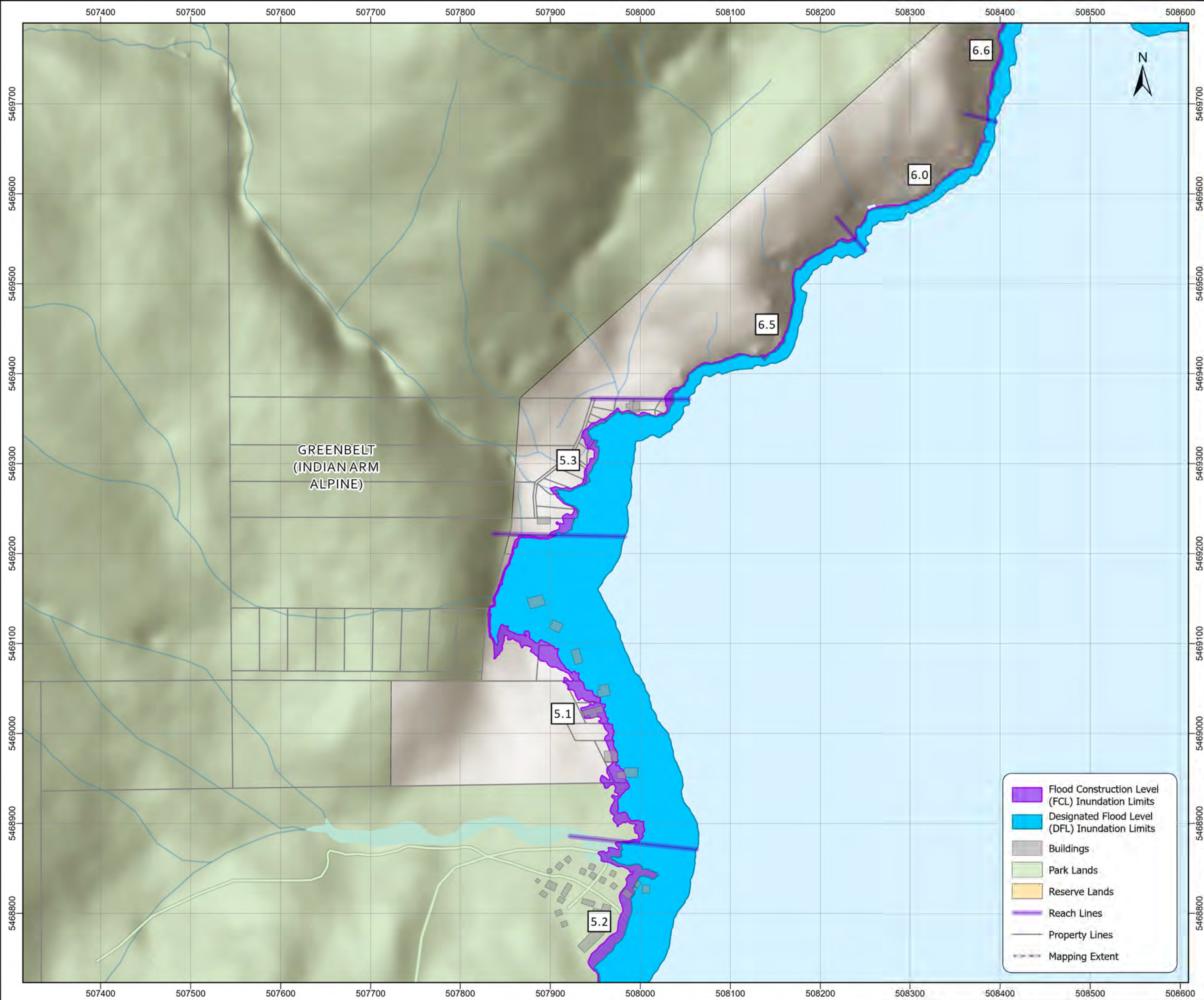
TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 17 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121





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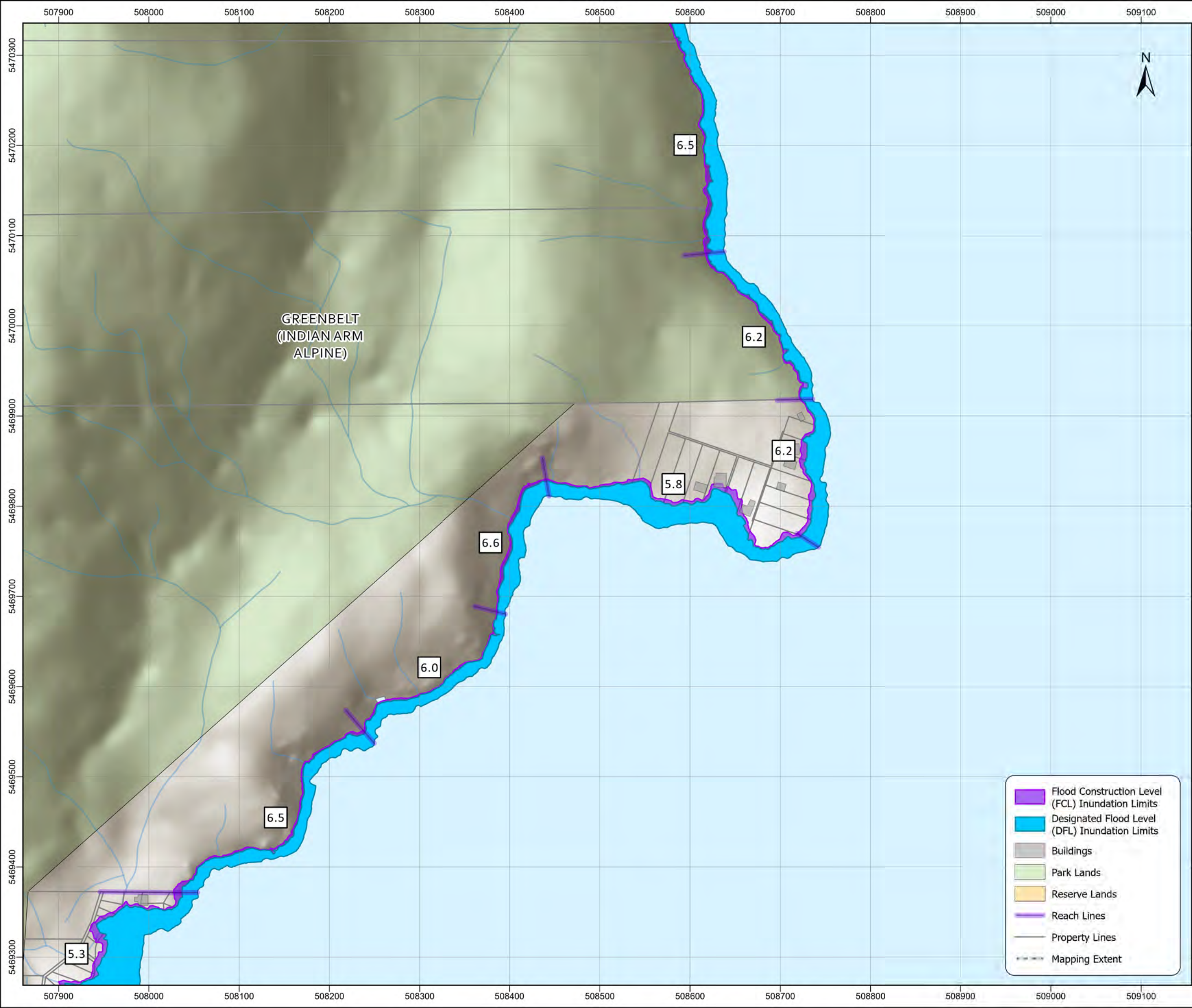
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TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 18 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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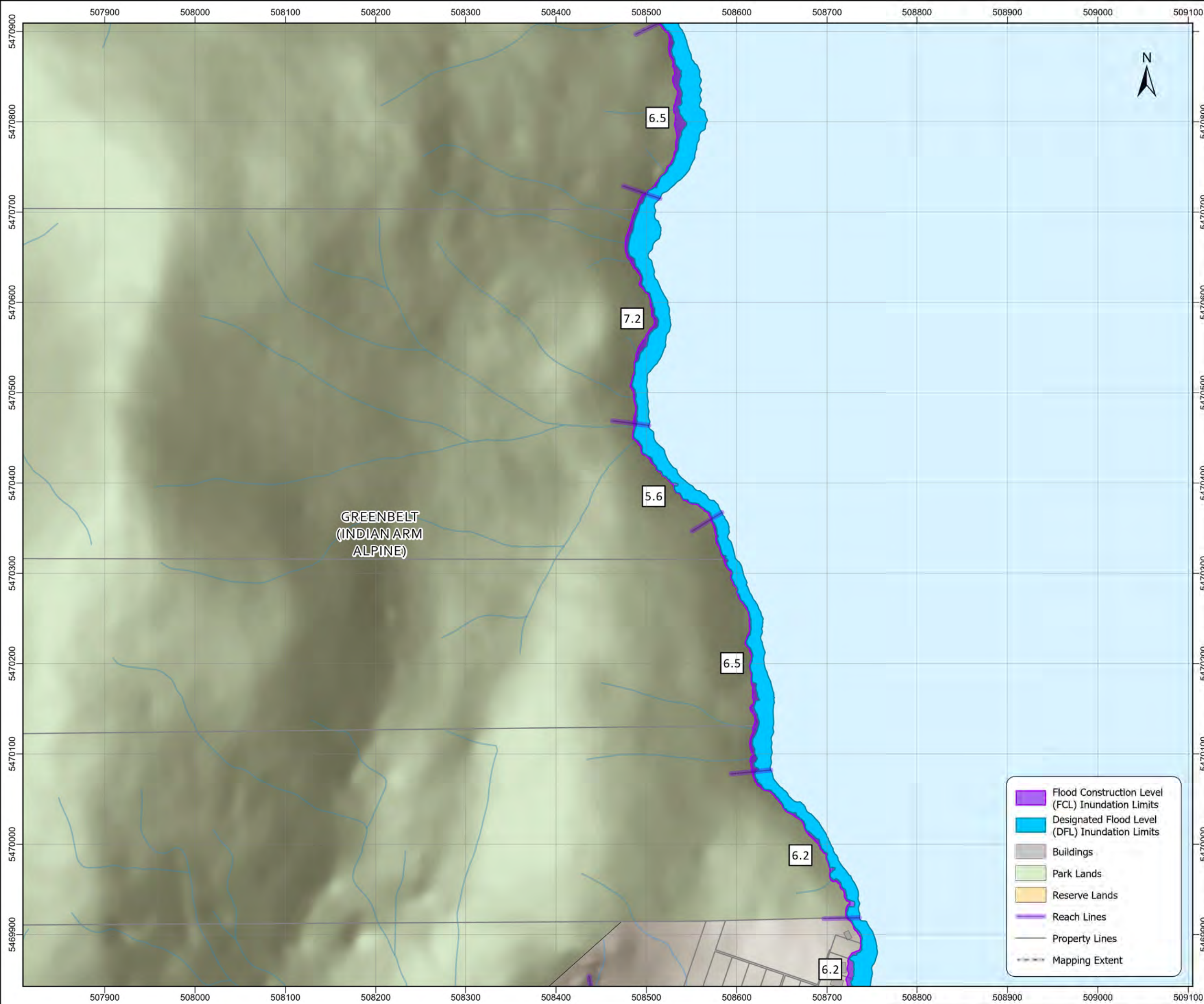
TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 19 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

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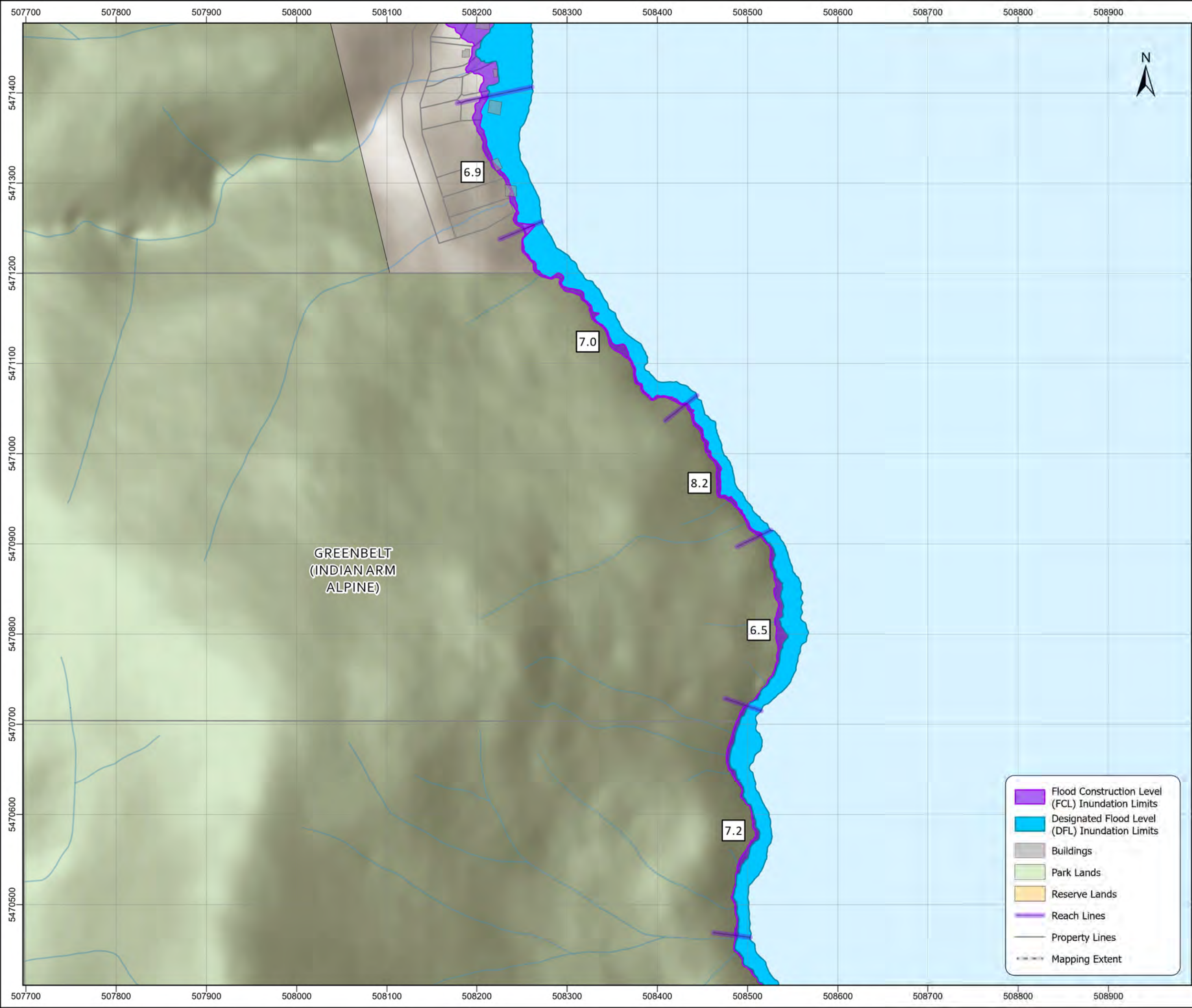
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CGVD2013: Canadian Geodetic Vertical Datum of 2013
EPSG: European Petroleum Survey Group
CSRS: Canadian Spatial Reference System
DFL: Designated Flood Level
FCL: Flood Construction Level
SLR: Sea Level Rise

TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 20 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



Overview:
These maps have been developed by DHI Water & Environment Inc. (DHI) for the District of North Vancouver to provide Flood Construction Reference Plane (FCRP) and Flood Construction Level (FCL) guidance. Notably, these mapping products incorporate wave effects.

Notes:

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Use and Limitations:

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CGVD2013: Canadian Geodetic Vertical Datum of 2013
EPSG: European Petroleum Survey Group
CSRS: Canadian Spatial Reference System
DFL: Designated Flood Level
FCL: Flood Construction Level
SLR: Sea Level Rise

TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 21 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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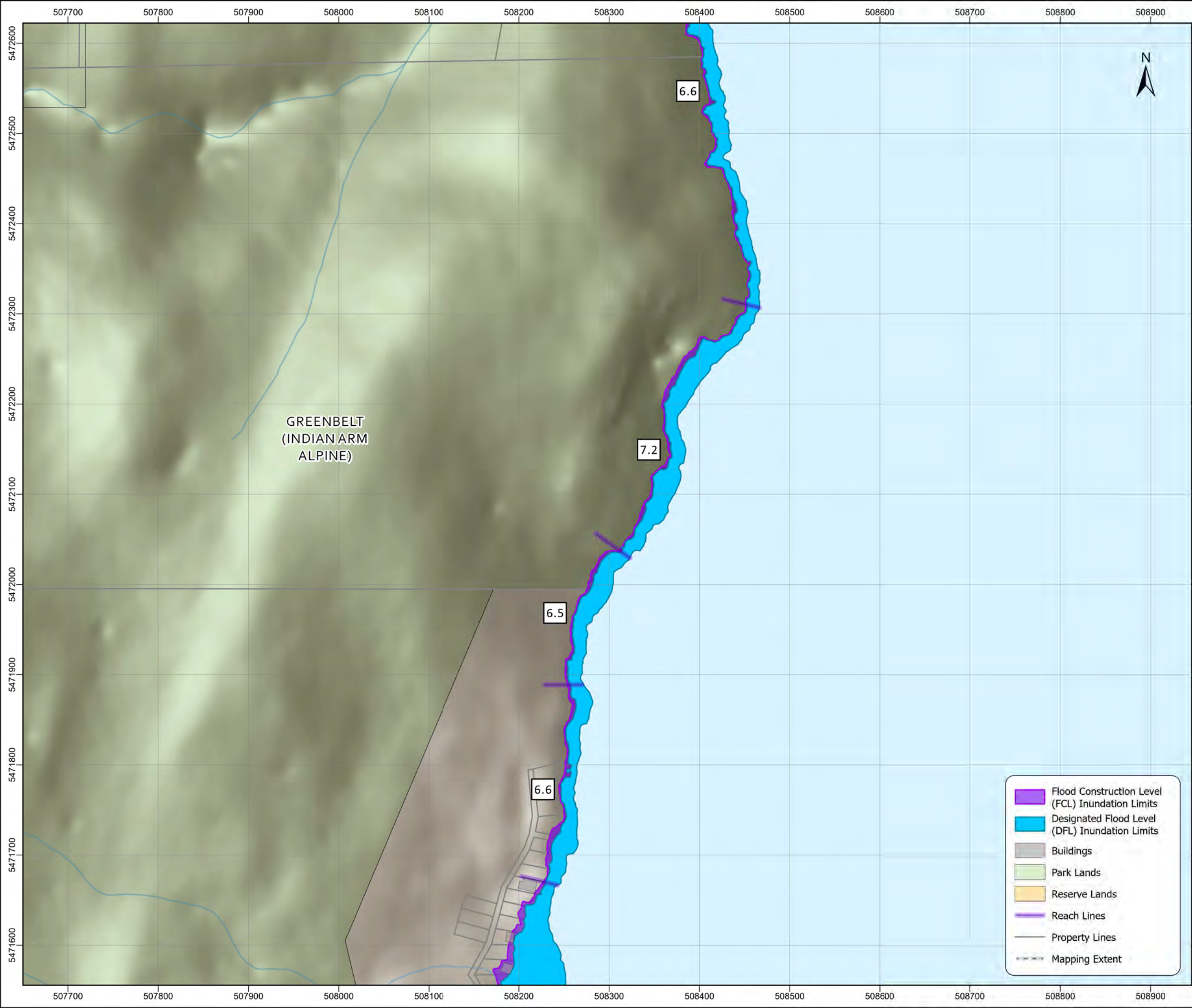
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EPSG: European Petroleum Survey Group
CSRS: Canadian Spatial Reference System
DFL: Designated Flood Level
FCL: Flood Construction Level
SLR: Sea Level Rise

TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 22 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



Overview:
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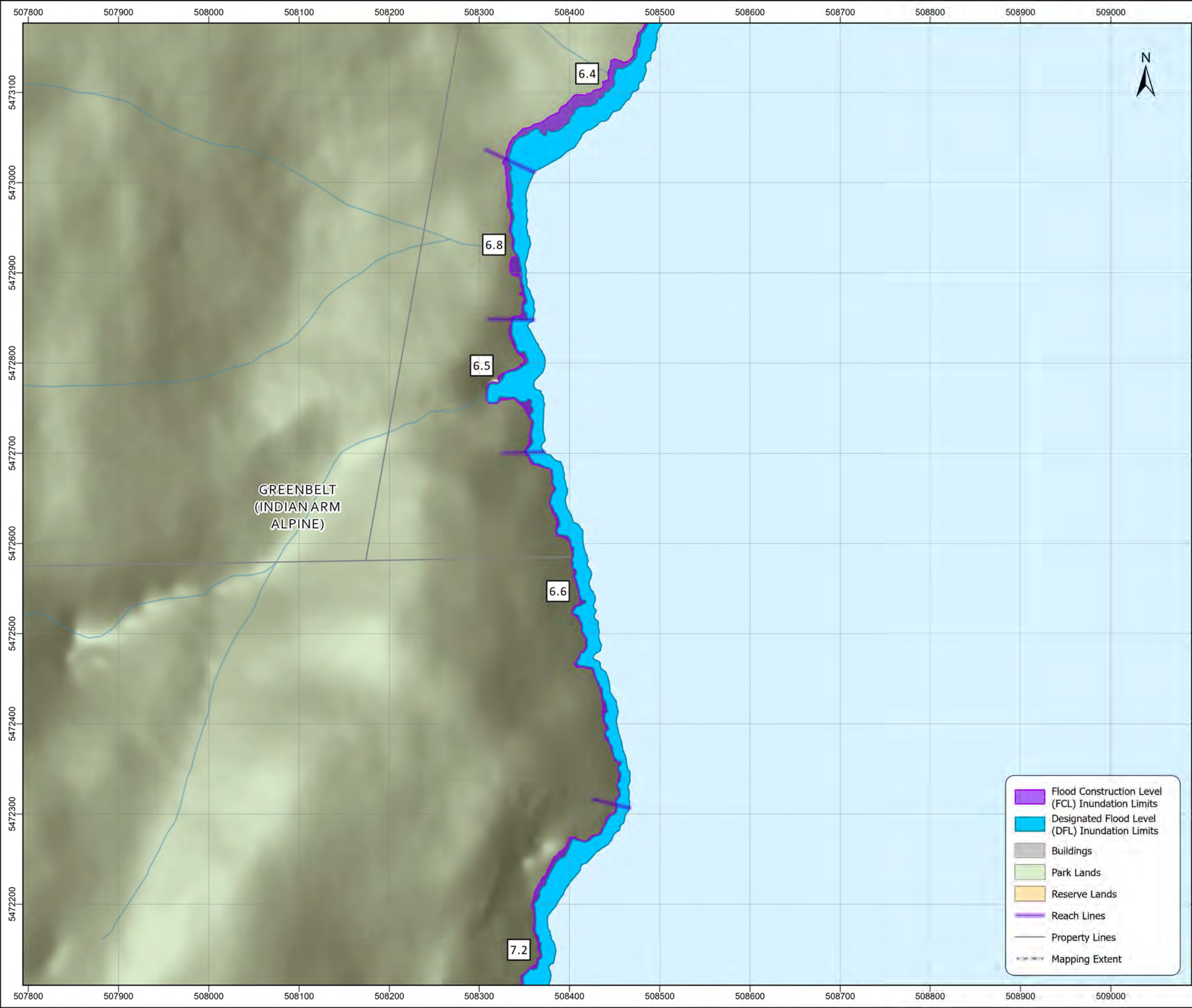
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CSRS: Canadian Spatial Reference System
DFL: Designated Flood Level
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SLR: Sea Level Rise

TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 23 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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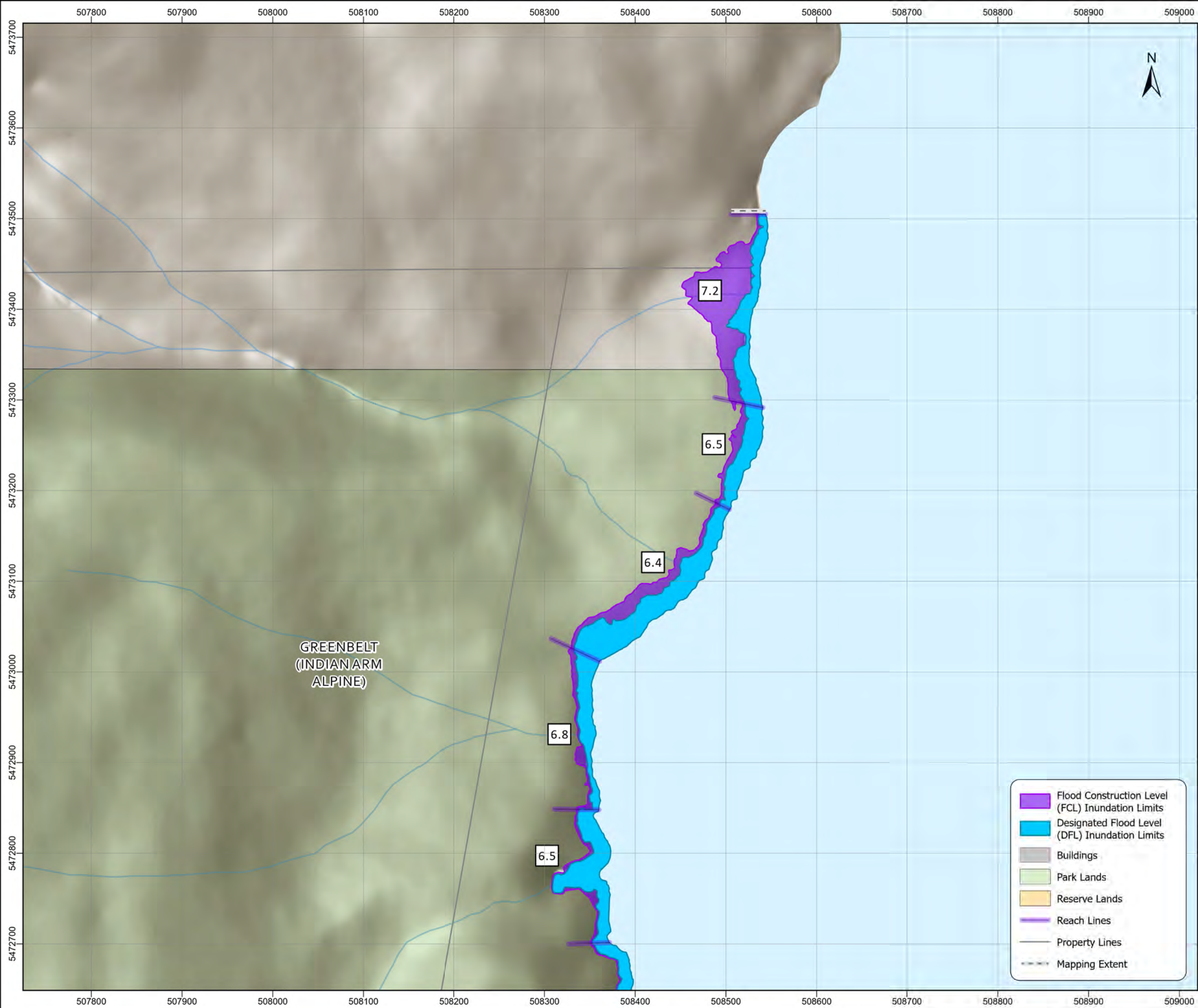
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FCL: Flood Construction Level
SLR: Sea Level Rise

TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 24 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
REVISION	1	REVIEWER	DANK	DHI PROJECT NUMBER	42804121



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SLR: Sea Level Rise

TITLE
District of North Vancouver - Flood Construction Level Maps for 1.0 m Sea Level Rise
Map 25 of 25

PCS: NAD 1983 UTM Zone 10N
EPSG: 26910
Datum: CGVD2013
Map Units: Meter

Scale: 1:4,000
0 25 50 100
Meters

DATE	2024-05-24	AUTHOR	SSIN	APPROVER	DANK
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