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Coquitlam/Fraser/Pitt Rivers Floodplain Mapping

Final Report
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Contents

Figures (at end of text)

Tables

Appendices

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Executive Summary

Executive Summary

The City of Coquitlam (City) engaged Kerr Wood Leidal Associates (KWL) to review current floodplain criteria, to update the City's floodplain mapping, and to review the City's floodplain development policies in light of evolving industry standards.

The study included utilizing flood level information for the Fraser River recently completed by the Ministry of Forest, Lands, and Natural Resource Operations (MFLNRO) and modelling of the Coquitlam River and its floodplain from the Coquitlam Lake Dam to the Fraser River confluence. A floodplain model was also needed for the Fraser River floodplain between the Coquitlam River and the Lower Brunette River to determine how the Fraser River water levels would spread northward given the variable topography and the river's sloping flood profile. Because the Pitt River is backwatered during high Fraser River water levels, no modelling was required.

The current design flood (Year 2014) and two climate change scenarios (Year 2100 Moderate and Year 2200 Intense) were utilized in this study. These scenarios were previously used in the MFLNRO Fraser River potential climate change assessment which looked at sea level rise and increasing flows due to precipitation changes.

The City's dike system crest elevations were assessed against the estimated Year 2014, Year 2100, and Year 2200 design flood levels. It was found that the City's Standard Dikes were in largely in conformance with the Year 2014 design flood profiles. The non-Standard Dikes protecting Colony Farm and those protecting the lowlands along the Pitt River upstream of the DeBoville Slough (including the DeBoville Slough north bank dike) are lower than the Year 2014 design flood profiles. The Pitt River non-Standard Dikes were assessed in a previous report which recommended that the dikes be kept at a non-Standard level. The Colony Farm non-Standard Dike, however, currently protects not only farmland but also institutional and industrial development. The City's preference is to build a dike or raise the ground along the east edge of the Mayfair Industrial Park to protect the non-agricultural land. The Forensic Psychiatric Institute is in the process of floodproofing their property and Metro Vancouver is responsible for the protection of the agricultural land (Colony Farm). For the Year 2100 and Year 2200 design flood profiles, most of the dikes will require raising. Cooperation with the City of Port Coquitlam will be required where the Coquitlam River and Pitt River dikes continue into that jurisdiction.

Floodplain mapping was produced for the City's Fraser River, Coquitlam River, and Pitt River floodplain areas showing the Year 2014, Year 2100, and Year 2200 potential flood extents and the Year 2100 Flood Construction Levels which included freeboard added to the peak water level values.

The City's floodplain development policies were reviewed and a number of changes were proposed for the City's consideration. The wording in the bylaw was revised to more accurately describe the Fraser River design flood and the figures showing the City's floodplain in the bylaw were updated with the flood extents determined in this study. The new flood extents are larger than those shown in the previous bylaw figures.

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Section 1

Introduction

1. Introduction

1.1 Background

The City of Coquitlam (City) engaged Kerr Wood Leidal Associates (KWL) to review current floodplain criteria, to update the City's floodplain mapping, and to review the City's floodplain development policies in light of evolving industry standards.

Focus was placed on the City's three major floodplain areas, the Coquitlam River floodplain, the Fraser River floodplain, and the Pitt River floodplain.

Coquitlam River

The Coquitlam River was previously modeled by Water Management Consultants (WMC) using the 1D-2D coupled MIKE Flood model to determine flood construction levels (FCLs) on the east side of the river floodplain (WMC, 2010). That study was completed for the City of Port Coquitlam and consisted of modelling different dike breach scenarios along the Coquitlam River and Pitt River to estimate the combined maximum flooding depths and to establish FCLs across the City of Port Coquitlam.

For the current study, the same modelling platform and approach were adopted to assess potential flooding in the City of Coquitlam floodplain. However, different climate change scenarios have been included in the current study to integrate climate change adaptation as per the newly developed provincial guidelines on flood assessment and floodplain mapping. Dike breach scenarios were modelled to define the floodplain water levels and flood construction levels in the areas protected by dikes on the Coquitlam River. More detailed information can be found in sections below.

Fraser River

The Fraser River flows and water levels govern the design flood levels along the City's southern boundary and also along the downstream end of the Coquitlam River. Therefore, it was important to select an appropriate downstream boundary condition at the Coquitlam River mouth to estimate the flood levels along the Coquitlam River and to map the floodplain extents.

Flooding on the Fraser River has been extensively studied over the past number of years. The following two key reports provided the information necessary to complete the floodplain mapping along the Fraser River:

- *Fraser River Hydraulic Model Update* - Final Report to the BC Ministry of Environment (NHC, March 2008).
- *Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios* - Final Report (BC Ministry of Forest, Lands and Natural Resource Operations, May 2014).

Both reports were used as the basis for design flood levels along the Fraser River, including the downstream boundary conditions for the Coquitlam River models.

Pitt River

The Pitt River design flood level profile along the Pitt River is horizontal and governed by the Fraser River freshet. The above two key reports provided the information necessary to complete the floodplain mapping along the Pitt River.

Lower Brunette River

The Lower Brunette River was not included in the scope of this study. The Brunette River design flood levels and floodplain mapping have been previously developed in the *Still Creek - Brunette River Floodplain Mapping Technical Report* (GVRD, Dec 1998). The 200-year flood levels including freeboard but not including climate change for the Lower Brunette River within the City of Coquitlam range from approximately 6.0 m at North Road (the municipal boundary) to 4.5 m near the CN Rail bridge and then are a constant 4.5 m to the Fraser River confluence. The 4.5 m elevation is governed by the Fraser River design flood level as it was defined at the time of the GVRD report. Since then, the Fraser River design flood level has been updated and two future climate change scenario design flood levels produced for Year 2100 and Year 2200. The Lower Brunette River floodplain mapping in the Fraser River dominated area downstream of the CN Rail bridge (east of Brunette Avenue) has been updated based on the new Fraser River flood levels, however, between North Road and the CN Rail, the GVRD flood levels are out of date and should be re-evaluated.

1.2 Floodplain Mapping Criteria

A review of the relevant provincial guidelines was undertaken to determine the most up-to-date criteria related to floodplain mapping. The three main documents outlining floodplain mapping procedures are:

- *Flood Hazard Area Land Use Management Guidelines* (Ministry of Water, Land, and Air Protection, May 2004 and updated in 2011). An amendment is currently being produced to incorporate current sea level rise information (Sea Level Rise Amendment)
- *Coastal Floodplain Mapping – Guidelines and Specifications* (MFLNRO, 2011)
- *Professional Practice Guidelines - Legislated Flood Assessments in a Changing Climate in BC* (APEGBC, 2012)

The following sections summarize the criteria from these documents and provide a brief explanation on how the criteria were accounted for in this study.

Return Period

The design return period for floodplain mapping and for establishing FCLs is 1 in 200 years (i.e. 200-year return period). An exception to this is the design flood on the Fraser River which is based on the 1894 flood which is estimated to be larger than 200-year.

Because peak flows on the Coquitlam River and Fraser River are not expected to occur simultaneously, two separate flood conditions representing both high Coquitlam River flows and high Fraser River flows/water levels need to be assessed. The following models were created to cover both conditions:

- 200-year flood on the Coquitlam River with a 200-year winter peak Fraser River water level downstream boundary.
- 2-year flood on the Coquitlam River and a design freshet (1894 design flood) water level profile on the Fraser River.

Freeboard

As per the City's Bylaws, freeboard means a vertical distance of 0.6 m added to a Designated 200-year Flood Level, used to establish an FCL. The Provincial standard for freeboard is the greater of 0.3 m added to the instantaneous 200-year peak water level or 0.6 m added to the daily 200-year peak water level. The two provincial freeboard values and associated peak water levels were used to establish the FCLs produced in this study.

Climate Change

Climate change can affect both the peak sea levels and the peak flows in the watercourses. Current predictions for sea level rise (SLR) into the future indicate a 1m rise by the Year 2100 and 2m rise by the Year 2200. Peak flow and water level changes due to climate change for the Fraser River were estimated in the MFLNRO May 2014 report cited above. The Coquitlam River flows are regulated by a dam on Coquitlam Lake operated by BC Hydro. The 200-year design flow has been estimated based on the flood buffers at the dam. Under climate change conditions, the flow may increase. Minor tributaries to the Coquitlam River downstream of the dam may also experience climate change related flow increases. The flows in the Coquitlam River were scaled up by 10% and 20% to correspond to the Year 2100 and Year 2200 scenarios.

Based on the SLR horizons, modelling and mapping was prepared for the current (2014), the Year 2100, and Year 2200 time horizons. The Fraser River sensitivity models corresponding to these time horizons are discussed in detail in Section 2.1.2.

The time horizons presented in this report provide an indication of the possible future conditions. When setting FCLs, the City should take into consideration the expected lifespan of the development and apply the appropriate time horizon results.

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Section 2

Hydraulic Modelling

2. Hydraulic Modelling

2.1 Model Structure

Modelling of the Coquitlam River was carried out using the MIKE FLOOD software created by the Danish Hydraulic Institute (DHI). This modelling package is capable of interfacing MIKE 11 (one-dimensional) and MIKE 21 (two-dimensional) hydrodynamic models to describe both the channel and floodplain flows and the interaction between the two. In this study, MIKE 11 was used to model the Coquitlam River channel, MIKE 21 used to model the floodplain, and MIKEFLOOD used to link the two in real-time.

The modelled area covers approximately 18 km of the Coquitlam River from downstream of the Coquitlam Dam to the Fraser River. Figure 1 shows the location plan of the model coverage area.

2.1.1 MIKE 11

The channel portion of the Coquitlam River was modelled in MIKE 11.

Cross Sections

The river geometry was modelled using a combination of surveyed data and Digital Terrain Model (DEM) data to obtain cross sections that extend to high ground or to the top of the dike, where present. The bathymetric data sources used in the MIKE 11 model are described as follows:

- River bathymetric survey performed in 2000 as part of the Coquitlam River Water Use Plan (WUP) developed by BC Hydro. From the data available, only six surveyed cross sections were used from downstream of the Coquitlam Dam to approximately the Coquitlam Watershed security gate, which is situated at the end of Pipeline Road.
- River bathymetric survey performed in year 2010 by BC Hydro. From the data available, thirty-five surveyed cross sections were used from the Coquitlam Watershed security gate to the Fraser River confluence.
- River bathymetric survey performed in year 2003 and 2004 for Northwest Hydraulic Consultants (NHC). From the data available, thirteen surveyed cross sections were considered to complement locations without more recent topographical information. These cross sections are located from upstream of Gallette Ave to the Mary Hill Bypass.

  The older cross sections were spot checked with a survey completed in 2013 by KWL to determine whether the river had changed in the last decade. No major differences were encountered between both sets of data and therefore the thirteen 2003/2004 cross sections were used in the model.

The floodplain area between the mouth of Scott Creek and the Pitt River Road Bridge was divided into two parallel branches, the main channel and the floodplain on the east side of a low embankment that runs north to south along the east bank of the river. The model was structured this way to better represent the river and floodplain dynamics occurring along this reach. The overtopping of the low embankment was simulated in the model.

Bridges

The following five major river crossings were modelled:

- **Lougheed Highway**: comprised of the original 75 m long free-span steel truss structure and a parallel concrete bridge immediately north of the original bridge

- **CPR Railway**: comprised of the original 61 m long free-span steel truss structure and a parallel steel bridge on two concrete piers to the north.

- **Kingsway Avenue**: a 61 m long concrete bridge on pile piers (adjacent to CPR bridge).

- **Pitt River Road**: a 90 m concrete bridge on pile piers.

- **Mary Hill Bypass**: a 116 m long concrete bridge on pile piers.

Roughness

Manning's roughness coefficients have been selected for the channel portion of the river in the range of 0.035 to 0.065 based on field observations of the channel roughness. The overbank roughness value of 0.100 was used in MIKE 11. In the absence of calibration data, KWL selected these values to provide a reasonable but conservative representation of the approximate channel characteristics. The delineation between channel and overbank was based on cross section shape which showed the top of bank locations and on the orthophotos which showed the treeline.

Dike Breach Locations, Extents and Timing

Two potential dike breach locations were strategically selected by KWL along the existing dike alignment. The locations of the two breaches are shown on Figure 1.

- **Breach No. 1** is at the east end of the Riverbend Drive subdivision near the Port Coquitlam municipal boundary, and;
- **Breach No. 2** is at the north end of the Colony Farm dike.

The width of a dike breach originated by floods on the Coquitlam River would probably range between 100 m and 120 m based on observations of several breaches that occurred during the Fraser River 1948 flood (WMC, 2010)

An empirical equation has been developed and is presented in the paper entitled *Time-dependent breach development in cohesive material* published in the proceedings of the 2nd IMPACT project workshop in Mo-i-Rana, Norway, WL / Delft Hydraulics (Verheij, 2002) to estimate a relationship between the maximum breach width "B" (m) and time to total breach t (seconds) for dikes built of cohesive soil.

$$\text{Sand: } \mathrm{B} = 67\ \log\frac{\mathrm{t}}{522}$$

Based on this equation, a 120 m wide breach will develop in approximate 10 hours; however, this research work was not specifically done for quickly eroded dikes as expected on the Coquitlam River. Considering the flashy nature of the inflow hydrograph, the Coquitlam River dikes would most likely fail by bank erosion and occur relatively quickly compared to other dike failure mechanisms such as overtopping or piping failure.

Therefore, a more conservative relationship between the dike width and time consists of having the dike breach initiating one hour before the Coquitlam River peaks and becoming fully developed to a maximum width of 120 meters at the time of the river peak.

The breach development on the Colony Farm dike is much less important because the much flatter Fraser River hydrograph peak governs the floodplain water levels at this location. There is sufficient time for the water levels on both sides of the dike to equalize, reaching the Fraser River peak water level. It should also be noted that the Colony Farm dike is not currently up to standard and would overtop along nearly its entire length during a Fraser River design freshet flood.

2.1.2 MIKE 21

The floodplain terrain was represented by a rectangular computational grid using 10 x 10 m cells. The following two data sources were compiled in GIS to create a combined DEM and ultimately generate the MIKE 21 model grid:

- 2012 LiDAR data provided by the City of Coquitlam.
- 2013 elevation contours maps provided by the City of Port Coquitlam.

The floodplain roughness selected in MIKE 21 was equivalent to a Manning's n of 0.10.

2.1.3 MIKE FLOOD

Dike breach scenarios were simulated using the coupled MIKE FLOOD model to allow transfer of the flow from the river channel into the floodplain area and vice versa.

The City of Port Coquitlam floodplain on the east side of the Coquitlam River east dike was excluded from the model to simulate the worst case condition that would occur if those dikes were raised. This assumption would result in the maximum amount of water flowing through the dike breach and thus would produce the highest floodplain water levels.

2.2 Fraser and Pitt Rivers (models by others)

2.2.1 1894 Design Flood

The Fraser and Pitt River design flood profiles were most recently updated in the 2008 NHC report and are based on the 1894 flood. The Fraser River Hydraulic Model uses the 1894 peak flow estimate of 17,000 m^3/s at Hope and 18,900 m^3/s at Mission, respectively. The 2008 design profiles do not include climate change or sea level rise.

2.2.2 Sensitivity and Climate Change Simulations

The 2014 MFLNRO report includes sensitivity analyses performed to estimate the Fraser and Pitt River water level variations with respect to:

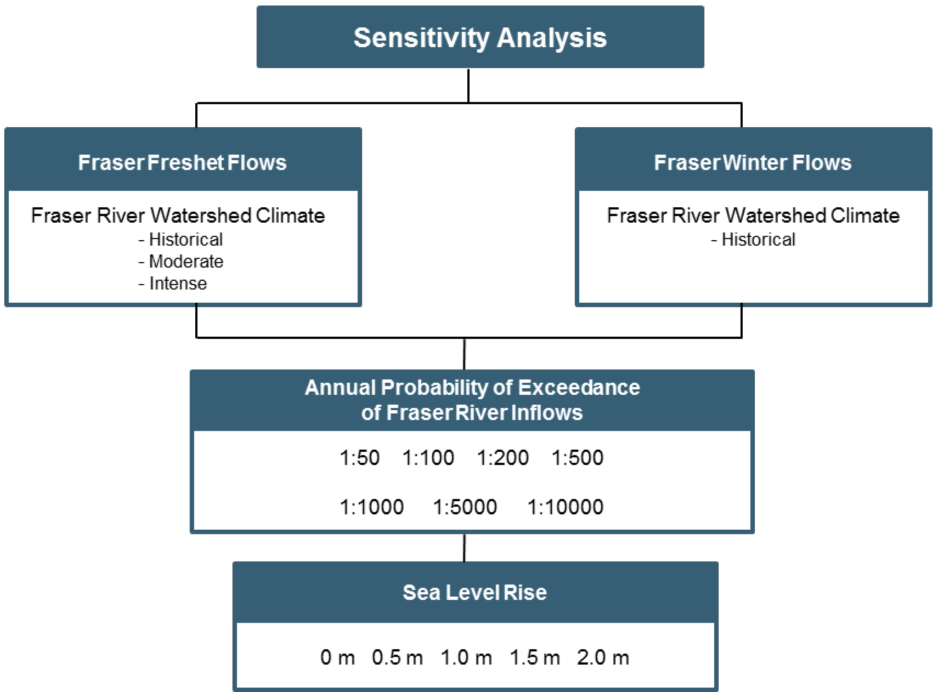
a) Historical freshet flow condition;

b) Historical winter flow condition;

c) Two freshet climate change conditions (moderate and intense); and

d) Five sea level rise scenarios.

Seven different return periods or annual exceedance probabilities (AEPs) were evaluated under the above conditions resulting in a total of 140 scenarios (105 for freshet and 35 for winter) depicted in the chart below:



Fraser River Climate and Sea Level Rise Scenarios

It was found that the 500-year flood with no sea level rise and no climate change freshet scenario nearly equalled the 1894 design flood profile. Therefore the climate change scenarios selected for this study are based on the 500-year flood. From the above sensitivity scenarios and from the 2008 NHC study, the following scenarios were used in this study:

- Scenario Year 2014: Fraser Freshet 1894 design flood profile (NHC, 2008).
- Scenario Year 2100: 500-year Fraser Freshet, Moderate Climate Change and SLR =1 m.
- Scenario Year 2200: 500-year Fraser Freshet, Intense Climate Change and SLR = 2 m.

The Intense Climate Change scenario was selected for the Year 2200 horizon to encompass an extreme flooding condition and provide a conservative upper bound to the floodplain mapping flood extent. Had the Moderate Climate Change scenario been used instead, the difference between the Year 2100 and Year 2200 flood extent would have been solely a result of the sea level rise which would have shown very little difference in the flood extents mapping.

2.3 Pitt River

The Pitt River design flood levels are governed by the Fraser River Freshet and are constant from Pitt Lake to the Fraser River. The Design Flood Water Levels along the Pitt River are:

- Scenario Year 2014: 4.92 m Geodetic.
- Scenario Year 2100: 5.84 m Geodetic.
- Scenario Year 2200: 7.15 m Geodetic.

Because the Fraser River freshet peak of the water level hydrograph is flatter, the daily peak plus 0.6 m freeboard governs. Therefore, a freeboard of 0.6 m is added to the above water levels to calculate the Design Flood Level and Flood Construction Level.

2.4 Coquitlam River

2.4.1 Scenarios

As noted in Section 1, the two main design events that were evaluated to obtain the Coquitlam River design flood profile are the 200-Year and 2-Year return period Coquitlam River flows. The corresponding Coquitlam River downstream boundaries are the 200-year Winter and 1894-based/500-year Freshet condition Fraser River water levels, respectively. The maximum of these two scenario water level profiles (with dike breaches to define the diked floodplain maximum water levels and without to define the maximum river water levels) plus freeboard defines the design flood level.

Table 2-1 summarizes the combined Coquitlam and Fraser River conditions used for each time horizon scenario considered in this study.

Table 2-1: Coquitlam River Scenario Summary

Time Horizon	Fraser River Peak Water Levels	
	200-Year Coquitlam River Flood	2-Year Coquitlam River Flood
2014	200-year Winter W.L	Design Flood W.L[1]
2100	200-year Winter W.L	500-year Freshet W.L[2]
2200	200-year Winter W.L	500-year Freshet W.L[3]

1. Based on the 1894 Design Flood (NHC, 2008)
2. Based on the Moderate Climate Change Scenario (MFLNRO, 2014)
3. Based on the Intense Climate Change Scenario (MFLNRO, 2014)

2.4.2 Boundary Conditions

Inflows

The Coquitlam Dam is operated with a series of flood buffers (keeping water levels below the spillway elevation) to reduce downstream flooding. The Cities of Coquitlam and Port Coquitlam and BC Hydro have entered into an agreement to operate the reservoir this way with the Cities financially compensating BC Hydro for lowered reservoir levels. With the flood buffer operation, a 200-year inflow to the reservoir and 200-year downstream flow from the unregulated catchment area downstream of the dam results in a 200-year flow at the CP Rail Bridge of 371 m^3/s. (WMC, 2010)

The flows in the Coquitlam River for smaller return period events were estimated by performing a frequency analysis on the Water Survey of Canada (WSC) 08MH002 Coquitlam River at Port Coquitlam data. This gauge covers all catchments upstream of the CP Railway Bridge. The catchments downstream of the WSC gauge are Scott Creek and local inflows on the right and left bank of the river (Ungauged Downstream Catchment). The Scott Creek peak flows were derived from the *Drainage System Study - Scott Creek Basin* (KWL, 2006).

All of the inflows have been adjusted for future climate change for the Year 2100 and Year 2200 scenarios. The current (Year 2014) flows were scaled up by 10% for the Year 2100 and by 20% for the Year 2200 scenarios.

The inflow boundary conditions used in the model include the above three inflow sources (Coquitlam River, Scott Creek and "Ungauged Downstream Catchment"). Table 2-2 shows the discharge values for all six flow scenarios analyzed in this study.

Table 2-2: Summary of Inflows

Catchment Area	Peak Flow (m^3/s)					
	200-Year Coquitlam River with 200-Year Fraser River Winter Flow			2-Year Coquitlam River with Design Fraser River Freshet		
	2014	2100[1]	2200[2]	2014	2100[1]	2200[2]
Coquitlam River	371	409	446	19.0	20.9	22.8
Scott Creek	19.6	21.5	23.5	4.3	4.7	5.1
Ungauged D/S Catchment	15.0	16.5	18.0	3.3	3.6	3.9

1. Factored up by 10% *Coastal Floodplain Mapping – Guidelines and Specifications* (MFLNRO, 2011)
2. Factored up by 20% *Coastal Floodplain Mapping – Guidelines and Specifications* (MFLNRO, 2011)

Downstream Water Levels

The boundary condition at the downstream end of the Coquitlam River is the Fraser River water level defined by the scenarios in Table 2-3.

Table 2-3: Summary of Water Level Boundary Conditions

Time Horizon	Fraser River Peak Water Levels (m)	
	200-Year Coquitlam River Flood with 200-Year Fraser River Winter Flow	2-Year Coquitlam River Flood with Design Fraser River Freshet
2014	3.04	4.65
2100	3.98	5.80
2200	4.83	7.13

Values from the Fraser River model reports (NHC, 2008 and MFLNRO, 2014)

2.5 Extended 2D Model

During the course of the mapping, it became apparent that the Coquitlam River floodplain flows (namely in the Colony Farm area) would not be contained by existing topography and could travel southwest towards the Fraser River. To allow this exchange of floodplain flows, the Coquitlam River 2D MIKE 21 models were extended to include the Fraser River floodplain from the Coquitlam River mouth to the New Westminster municipal boundary. The Fraser River flood profiles (as described in Section 2.2) were used as spatially-varying water level boundary conditions along the Fraser River in the 2D model.

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Section 3

Dike Design Profiles

3. Dike Design Profiles

Existing dike profiles along the Coquitlam River and along the DeBoville Slough were assessed relative to predicted flood levels for a variety of modelling scenarios.

3.1 Coquitlam River

3.1.1 Existing Coquitlam River Dikes

The Coquitlam River has nearly 14 km of dikes along its banks. The river acts as a natural divide between the Cities of Coquitlam and Port Coquitlam downstream of the Riverbend Drive / Wilson Avenue alignments, near the location of Breach No. 1. Approximately 2.3 km of right bank dike (looking downstream) is in the City of Port Coquitlam and 2.5 km of right bank dike is in the City of Coquitlam. The 9.2 km of left bank dike is all in the City of Port Coquitlam. The City of Coquitlam also has almost 750 m of dike on the left bank of Scott Creek that ties into the Coquitlam River right bank dike.

The City's right bank Coquitlam River dike is composed of two sections, the Upper Dike and the Lower Dike which are assessed with the modelling. The Upper Dike extends from Riverbend Drive at the Coquitlam/Port Coquitlam municipal boundary to the Scott Creek confluence. The Scott Creek left bank dike which extends north to Shiloh Place is also an integral part of the Upper Dike, however it has not been assessed in this assignment. The Upper Dike also extends upstream along the Coquitlam River into Port Coquitlam. This portion of dike was included in the assessment for convenience. The Lower Dike extends from the north end of Colony Farm to the Mary Hill Bypass near the Fraser River confluence where it ties into the Fraser River dike.

As part of the survey carried out by BC Hydro in 2010, top of the dike elevations were measured at a few locations along the Upper Dike. These survey elevations were used to validate the dike elevations extracted from the LiDAR DEM. Both dike elevation data sources were generally found to be within 0.7 m of each other in the City of Coquitlam as shown in Figure 2a. In the City of Port Coquitlam, the differences were significantly larger.

3.1.2 Predicted Design Flood Profile

The MIKE 11 model was run to determine the 'Design Flood Profile' for each time horizon. The Design Flood Profile was created by taking the maximum of a number of profiles, without breaches which resulted in higher river levels, and for the two flow scenarios, adding 0.3m of freeboard to the instantaneous peak level (generally the Coquitlam River dominated portion where the hydrograph is peaky) and 0.6m of freeboard to the daily peak level (generally the Fraser River dominated portion where the peak of the water level hydrograph is flatter).

The maximum water level profiles from the two scenarios (2-year and 200-year Coquitlam River flow, with and without breaches), the Design Flood Level with freeboard, and existing dike elevation profiles (Upper Dike and Lower Dike) are shown in Figures 2a and 2b, 3a and 3b; and 4a and 4b for the Year 2014, 2100 and 2200 scenarios, respectively. Figures 5a and 5b show how the design flood profile may change from Year 2014 to Year 2200 due to climate change.

3.1.3 Model Results

In general, the design flood profiles show that the Lower Dike and the floodplain behind it are governed by the Fraser River Freshet design flood levels. The Upper Dike is governed by the Coquitlam River

200-year flow in Year 2014 and Year 2100, but would be governed by the Fraser River Freshet under the Intense Climate Change scenario used for Year 2200.

The Lower Dike (photo to right) is currently classified as a Non-Standard Dike as it does not meet the Standard Dike design parameters (defined in “Dike Design and Construction Guide: Best Management Practices for British Columbia”, 2011). It is currently intended to mainly protect the agricultural land (Colony Farm) however, the modelling showed that flooding would extend past the agricultural areas into the Mayfair Industrial Park and into the Forensic Psychiatric Institute should this dike overtop and/or breach.

The Upper Dike is currently classified as a Standard Dike protecting residential areas. The protection of the residential areas relies on the integrity of both portions, the one within the City of Coquitlam and the one within the City of Port Coquitlam.

Modelling results indicate that there are dike height deficiencies in the following sections along the Coquitlam River (refer to Figure 5a and 5b):

Year 2014 Scenario

- Approximately 270 m of the Upper Dike from 50 m downstream of Lougheed Hwy to 90 m upstream of the CP Railway (north bridge). – Port Coquitlam
- Approximately 140 m of the Upper Dike from immediately upstream of the CP Railway (north bridge) to 100 m downstream of the Kingsway Bridge. – Port Coquitlam
- Approximately 280 m of the Upper Dike from 140 m downstream of the McAllister Foot Bridge to 260 m upstream of the Maple Creek floodbox. – Port Coquitlam
- Most of the Lower Dike, except approximately 30 m of dike ending 120 m upstream of the Mary Hill Bypass. – Coquitlam

Year 2100 Scenario

- Approximately 290 m of the Upper Dike from 40 m downstream of Lougheed Hwy to 90 m upstream of the CP Railway (north bridge). – Port Coquitlam
- Approximately 170 m of the Upper Dike from 30 m upstream of the CP Railway (north bridge) to 100 m downstream of the Kingsway Bridge. – Port Coquitlam
- Approximately 510 m of the Upper Dike from 30 m upstream of the McAllister Foot Bridge to 150 m upstream the Maple Creek floodbox. – Port Coquitlam
- The entire Lower Dike. – Coquitlam

Year 2200 Scenario

- Approximately 290 m of the Upper Dike from 40 m downstream of Lougheed Hwy to 90 m upstream of the CP Railway. – Port Coquitlam

- Approximately 170 m of the Upper Dike from 30 m upstream of the CP Railway (north bridge) to 110 m upstream of the McAllister Foot Bridge. – Port Coquitlam
- Approximately 550 m of the Upper Dike from 30 m upstream of the McAllister Foot Bridge to 150 m upstream of the Maple Creek floodbox. – Port Coquitlam
- Approximately 50 m of the Upper Dike near Scott Creek. – Coquitlam
- The entire Lower Dike. – Coquitlam

3.2 Pitt River

The Pitt River acts as a natural divide between the Cities of Coquitlam and Pitt Meadows. The river has nearly 7 km of dikes along its right (west) bank in the City of Coquitlam. In addition to this, there are 4 km of dikes along both banks of the DeBoville Slough, a tributary to the Pitt River.

The City's dike along the right bank of the Pitt River is located upstream of the DeBoville Slough confluence. The DeBoville Slough dikes are also an integral part of the City's Pitt River dike system as is the City of Port Coquitlam dike along the west bank of the Pitt River, downstream of DeBoville Slough.

The dike crest elevations presented in Figure 6 were obtained from the 2012 LiDAR DEM.

The Design Flood Profile for each time horizon was created by adding 0.6m of freeboard to the peak water levels shown in Section 2.3.

Dike Standards

The City's Pitt River dike, and the floodplain behind it, is governed by the Fraser River Freshet design flood levels. The Pitt River dike and the DeBoville Slough north dike are currently classified as non-Standard Dikes as they do not meet the Standard Dike design parameters. They are currently intended to mainly protect agricultural land. The DeBoville Slough south dike, on the other hand, is classified as a Standard Dike and protects the City of Port Coquitlam and City of Coquitlam floodplain area south of DeBoville Slough.

A recent study by the Ministry of Forests, Lands, and Natural Resource Operations entitled "Coquitlam River Dyking District Dike Assessment 2012" (KWL, 2013) was conducted to examine the Pitt River and DeBoville Slough north dikes. This study recommended that the non-Standard Dike be kept at an agricultural standard and therefore a comparison of the existing dike profile and the design flood levels was not performed.

3.2.1 Elevation Comparison Results

A comparison of the dike crest elevations and the design flood profiles was conducted for the DeBoville Slough south dike. The City of Port Coquitlam Pitt River dike crest elevation was not checked due to insufficient LiDAR coverage. The DeBoville Slough south dike comparison is shown in Figure 6 and indicates that there are dike height deficiencies in the following sections:

Year 2014 Scenario

- The DeBoville Slough south dike is adequate along most of its length with only minor dips appearing to be no more than 0.1 m below the design profile.
- The upstream end of the dike appears to need raising as well as extending to tie into high ground which would require raising of the intersection of Lower Victoria Drive and Cedar Drive.

Year 2100 Scenario

- The entire south dike is inadequate for the Year 2100 design profile and would need to be raised by 0.7 to 0.9 m.

Year 2200 Scenario

- The entire south dike is inadequate for the Year 2200 design profile and would need to be raised by 2.0 to 2.2 m.

3.3 Recommended Dike Upgrades

Based on the above observations, the following planning works and upgrades are recommended:

3.3.1 Short Term Upgrades

- Raise the upstream end of the DeBoville Slough south dike to the Year 2014 Design Profile and extend to high ground by raising the intersection of Lower Victoria Drive and Cedar Drive.
- Encourage the City of Port Coquitlam to upgrade their portion of the Coquitlam River Upper Dike to the Year 2014 Design Profile.
- Encourage the City of Port Coquitlam to assess, and if needed upgrade, their portion of the Pitt River dike to the Year 2014 Design Profile (El. 5.52 m).

3.3.2 Long Term Upgrades

- Build a dike or raise the ground along the east edge of the Mayfair Industrial Park. The Forensic Psychiatric Institute is currently in the process of flood-proofing their property and protection of the agricultural land (Colony Farm) is the responsibility of Metro Vancouver.
- Upgrade the DeBoville Slough south dike to the Year 2100 Design Profile, including the tie in to high ground.
- Encourage the City of Port Coquitlam to upgrade their portions of the Coquitlam River Upper Dike and Pitt River dike to the Year 2100 Design Profiles.

3.3.3 Long Term Planning

- In the future, if climate change results in greatly increased Coquitlam River peak flows and Fraser River Freshet flows and water levels as simulated by the Intense Climate Change scenario used for the Year 2200 models:
  - Raise the Coquitlam River Lower Dike a further 1.3 m and the downstream portion of the Upper Dike a further 1 m above the Year 2100 profile.
  - Raise the DeBoville Slough south dike and the City of Port Coquitlam Pitt River dike a further 1.3 m above the Year 2100 profile.
- the Cities' (Coquitlam and Port Coquitlam) long term planning should allow for such future raising by keeping the land adjacent to the dikes free of impediments to future filling and raising.

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Section 4

Floodplain Mapping

4. Floodplain Mapping

Floodplain mapping was developed for the Coquitlam, Fraser, and Pitt Rivers floodplain areas by examining the maximum water levels of simulations with and without dike breaches along the Coquitlam River and assuming overtopping of the non-Standard Dike along the Pitt River and breach of the Standard Dike along the south side of the DeBoville Slough. The approach taken for the diked Coquitlam River floodplain was to simulate worst case dike breaches. This approach results in higher floodplain water levels than simply extrapolating the river water levels out into the floodplain. The reason for this is because a dike breach can occur farther upstream on the Coquitlam River where water levels are higher and can flood the areas that are adjacent to a point farther downstream on the river. This is the case for the floodplain area near Scott Creek on the Coquitlam River. In floodplain areas that are not diked or where the dike is non-standard, the river flood levels are directly extrapolated into the floodplain as is the case along the Fraser River and the Pitt River. The flood levels in the Lower Brunette River downstream of the CN Rail bridge (east of Brunette Avenue) are governed by the Fraser River design flood levels and mapping includes this portion of the Brunette River. The portion of the Lower Brunette River upstream of the CN Rail bridge should be reassessed using updated Brunette River flows for Years 2014, 2100, and 2200 to complete the floodplain mapping of that area.

4.1 Effect of Dike Breaches

The floodplain limits for each time horizon (2014, 2100, and 2200) were determined based on the maximum water elevation from the Coquitlam River models and Fraser River water level boundary conditions. As two breaches and two Coquitlam River flows were evaluated, four different outputs were used to obtain the maximum flood elevations for each of the three time horizons.

4.1.1 Breach 1 – Upper Dike

Model results for breaching the Upper Dike at the “Breach No.1” location show that the Year 2014, Year 2100, and Year 2200 time horizons exhibit similar flood extents and peak flood levels in the floodplain protected by the Upper Dike. The maximum estimated water elevations for this area for the three time horizons are 7.40 m, 7.60 m and 7.80 m, respectively. The model results indicate that breaching the dike at this location would result in water flowing northwest, first overtopping Chine Drive and then inundating the area between Westwood St. and Firbrook Place. The flooding would reach the Scott Creek dike and inundate the lowland area up to Bouthot Court. It was assumed that the dike near the Scott Creek mouth would not be intentionally breached to allow the accumulated floodplain water to drain out. The result of this assumption would be a conservative worst case condition for defining the floodplain extent.

4.1.2 Breach 2 – Lower Dike

Unlike the Upper Dike, the model results for the Lower Dike breach (Breach No. 2) show larger differences between the three time horizons.

Year 2014

The Year 2014 model results show that the flooding in the floodplain protected by the Lower Dike is governed by the Fraser River Freshet. Once the dike breaches, the Colony Farm area floods and the flow continues west into the Mayfair Industrial Park. As the Fraser River water level rises, nearly the entire dike is overtopped and the water levels on both sides of the dike equalize. At the peak of the flooding, a majority of the area bounded by Lougheed Highway to the northwest, Highway 1 to the southwest, the Mary Hill Bypass to the south, and the Lower Dike to the east becomes inundated as shown in the Floodplain Maps in Appendix A. The Forensic Psychiatric Institute area, which has been raised, is above modelled flood levels.

Year 2100

The Year 2100 Breach No.2 model results show a similar flood pattern to the Year 2014 results, however with greater flood depths and a larger flood extent. In the Year 2100 scenario, most of the area bounded by Lougheed Highway to the northwest, Highway 1 to the southwest, the Mary Hill Bypass to the south, and the Lower Dike to the east becomes inundated, including flooding of the Forensic Psychiatric Hospital, Lougheed Highway, and United Boulevard. Flow is able to travel via United Boulevard under Highway 1 and to the south where flood waters meet the flood waters that travel north from the Fraser River (see Floodplain Maps in Appendix A).

Year 2200

Model results for the Year 2200 scenario are also shown in the Floodplain Maps in Appendix A. The flood extents and depths are even greater than the Year 2100 scenario with all but the highest portions of roads under water (portions of Highway 1 and of the Mary Hill Bypass). The peak flood levels result from a complex exchange of floodwater from the breach, the Lower Dike overtopping, and from the Fraser River floodplain flows.

4.1.3 Fraser River Floodplain

The floodplain along the north side of the Fraser River, downstream of the Coquitlam River, is not currently diked. The flood extents were mapped for the three time horizons. The results are presented on Floodplain Maps in Appendix A.

Year 2014

Model results for the Year 2014 time horizon show that much of the floodplain area between Highway 1 and the river has been raised. Flooding is concentrated near the river shore, along the railway area on the south side of Highway 1, and two main locations south of United Boulevard, near King Edward Street and to the west and around Leeder Street. The area north of Highway 1 and west of Coleman Avenue is protected from flooding by the highway. However, land lower than elevation 4.2 m Geodetic is flooded by the northward flow of water through the Nelson Creek and Como Creek culverts under the highway. The Como Creek stoplogs at United Boulevard may prevent the northward flow of water if they are higher than 4.4 m Geodetic. However, the Nelson Creek stoplogs would not be enough to prevent northward flooding as the ground levels in the area would allow overland flow to skirt the stoplogs. Flood water can also skirt the stoplogs by flow traveling north of United Boulevard at the west municipal boundary where the Fraser River flood can travel up the Lower Brunette River and spill into the floodplain immediately south of the CN Railway northwest of the Eaglequest Golf Course. The Brunette River east dike or the low ground adjacent to the dike would need to be raised to above elevation 4.1m to prevent flooding.

Year 2100

In the Year 2100 time horizon scenario, greater flooding than the Year 2014 scenario is expected along the Fraser River floodplain. The flooded area near Leeder Street would extend east to Highway 1 / Mary Hill Bypass. Highway 1 near Como Creek and Nelson Creek would not be high enough to prevent overtopping and flooding into the area north of the highway. The flood waters would reach the northernmost extent approximately 200 m north of Seguin Drive but would exclude commercial areas such as the Zone Bowling, the Superstore, and the Silvercity Theater sites. The Como Creek stoplogs at United Boulevard may prevent the northward flow of water if they are higher than 5.4 m Geodetic. However, the Nelson Creek stoplogs would not be enough to prevent northward flooding as the ground levels in the area would allow overland flow to skirt the stoplogs. Flood water can also skirt the stoplogs by flow traveling north of United Boulevard at the west municipal boundary where the Fraser River flood can travel up the Lower Brunette River and spill into the floodplain around the CN Railway northwest of the Eaglequest Golf Course. The Brunette River east dike or the low ground adjacent to the dike, including the railway bridges, would need to be raised to above elevation 5.4 m to prevent flooding.

Year 2200

The Year 2200 model results show that most of the Fraser River floodplain would be inundated nearly to Booth Avenue to the north, with the exception of high areas south of Highway 1 (Braid Street Fill Site / Eaglequest Golf course and the industrial areas around Clipper Street, Hartley Avenue and Fawcett Road). The Como Creek stoplogs at United Boulevard may prevent the northward flow of water if they are higher than 6.7 m Geodetic. However, the Nelson Creek stoplogs would not be enough to prevent northward flooding as the ground levels in the area would allow overland flow to skirt the stoplogs. Flood water can also skirt the stoplogs by flow traveling north of United Boulevard at the west municipal boundary where the Fraser River flood can travel up the Lower Brunette River and spill into the floodplain around the CN Railway northwest of the Eaglequest Golf Course. The Brunette River east dike or the low ground adjacent to the dike, including the railway bridges, would need to be raised to above elevation 6.6 m to prevent flooding.

4.1.4 Pitt River Floodplain

The floodplain along the west side of the Pitt River, upstream of the DeBoville Slough, is protected by a non-standard dike that is lower than the design flood levels. The floodplain was mapped for the three time horizons assuming overtopping of this dike. South of the DeBoville Slough, the floodplain was mapped assuming that the DeBoville Slough south dike or the City of Port Coquitlam Pitt River dike would be breached allowing the water levels in the floodplain and in the river to equalize. The results are presented on Floodplain Maps in Appendix A.

Year 2014

Model results for the Year 2014 time horizon show that much of the floodplain area between the DeBoville Slough and Pitt Lake (the City's south and north boundaries along the Pitt River) is inundated. Flooding extends into the City of Port Coquitlam on the south side of DeBoville Slough. North of DeBoville Slough, flooding is contained by high ground. Land lower than elevation 4.92 m Geodetic would be flooded.

Year 2100

In the Year 2100 time horizon scenario, greater flooding than the Year 2014 scenario is expected following a similar flooding pattern. Land lower than elevation 5.84 m Geodetic would be flooded.

Year 2200

In the Year 2200 time horizon scenario, greater flooding than the Year 2100 scenario is expected following a similar flooding pattern. Land lower than elevation 7.15 m Geodetic would be flooded.

4.1.5 Lower Brunette River Floodplain

The flood levels along the Lower Brunette River within the City of Coquitlam downstream of the CN Rail bridge (east of Brunette Avenue) are governed by the Fraser River flood levels as described below. The results are presented on Floodplain Maps in Appendix A.

Year 2014

Model results for the Year 2014 time horizon show flooding along the Lower Brunette River is contained by high ground at the Eaglequest Golf Course. North of the golf course, floodwaters spread eastward along the south side of Highway 1. Land lower than elevation 4.1 m Geodetic would be flooded.

Year 2100

In the Year 2100 time horizon scenario, greater flooding than the Year 2014 scenario is expected following a similar flooding pattern. Land lower than elevation 5.4 m Geodetic, including Highway 1, would be flooded.

Year 2200

In the Year 2200 time horizon scenario, greater flooding than the Year 2100 scenario is expected following a similar flooding pattern. Land lower than elevation 6.6 m Geodetic, including Highway 1, would be flooded.

The Lower Brunette River between North Road and the CN Rail bridge, which may or may not be governed by the Fraser River flood levels, should be reassessed using updated river flows and flows that include climate change for Years 2100 and 2200 to complete the floodplain mapping in this area.

4.2 Floodplain Maps

Floodplain maps were produced at a 1:5000 scale to be consistent with the previous Coquitlam River floodplain mapping completed in 1996 by the Province. Seven map sheets were produced to cover the Coquitlam River and the Fraser River floodplain areas and three to cover the Pitt River floodplain areas.

The floodplain maps are included in Appendix A and show the following:

- Year 2014 flood extent (no freeboard)
- Year 2100 flood extent (no freeboard)
- Year 2200 flood extent (no freeboard)
- Year 2014 flood contours (with and without freeboard)

The freeboard applied to the Year 2014 flood contours (or flood levels) is 0.6m along the Fraser River including in the backwater dominated portion of the Coquitlam River downstream of river chainage 13+967 and the backwatered entire length of the Pitt River. Upstream of chainage 13+967 on the Coquitlam River, 0.3m of freeboard has been added to the peak instantaneous water levels to produce the Year 2014 flood contours.

A table of design flood levels (including freeboard) along the Coquitlam, Fraser, and Pitt Rivers for Year 2014, Year 2100, and Year 2200 is included in Appendix B.

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Section 5

Floodplain Development Policy

5. Floodplain Development Policy

5.1 City's Existing Policies

The City's existing Zoning Bylaw 3000, as amended by Bylaw 3923, includes flood protection measures for floodplain development. The bylaw covers the following topics:

1. Floodplain Mapping (dated July 21, 2005);
2. Flood Construction Level, including freeboard amounts;
3. Setbacks from natural boundaries of watercourses; and
4. Exemptions to flood construction level requirements (renovations, small additions, non-habitable uses, and total building replacement).

The requirements in the existing bylaw are consistent with those in the *Flood Hazard Area Land Use Management Guidelines* (Ministry of Water, Land, and Air Protection, May 2004 and updated in 2011).

5.2 Federal, Provincial, and Local Guidelines

A number of documents have been released since the City's Zoning Bylaw was published. These documents should be taken into consideration when updating the City's bylaws and performing future floodplain assessments.

Flood Hazard Area Land Use Management Guidelines – Sea Level Rise Amendment

The Ministry of Forests, Lands, and Natural Resource Operations is in the process of finalizing an amendment to the *Flood Hazard Area Land Use Management Guidelines*. This amendment includes incorporating sea level rise into determination of watercourse setbacks and Flood Construction Levels.

It will improve alignment with the APEGBC *Professional Practice Guidelines for Legislated Flood Assessments in a Changing Climate in BC*. The purpose of this change is to explicitly acknowledge the professional practice guidelines as a key component of the professional reliance model and ensure consistency with Provincial guidance.

APEGBC 2012

In June 2012, APEGBC released the document *Professional Practice Guidelines - Legislated Flood Assessments in a Changing Climate in BC*. These guidelines provide direction for professional practice by a Qualified Professional (QP) undertaking flood assessments, guidance on anticipating climate change and land surface change, flood assessment procedures and a comparison of standard-based and risk-based approaches. Appendix G of the document specifies considerations for flood assessments for development approvals and is intended to be consistent with the *Flood Hazard Area Land Use Management Guidelines* (MWLAP 2004).

In summary the APEGBC document encourages:

- considering the use of standard dikes for protection of development in the floodplain,
- the use of restrictive covenants to inform potential buyers of the flood assessment reports,

- locating structures in lower hazard areas on a property if possible,
- maintaining watercourse setbacks,
- no variances for multi-family, industrial, commercial, and institutional land uses from the floodplain development standards,
- assessment of future climate change based on current best climate projections and historical trend analyses, and
- allowing development in unprotected floodplain only if the municipality has a bylaw or land use regulation that provides for building construction with knowledge of the flood hazard or the QP concludes that the site is suitable for the intended use.

These guidelines will influence the City's development standards in the floodplain that is currently not protected by a dike. Furthermore, the climate change considerations were accounted-for in the dike breach and floodplain inundation modelling undertaken in this study.

Fraser Basin Council 2013

The Fraser Basin Council published a report entitled *A Business Plan – Advancing a Collaborative, Regional Approach to Flood Management in British Columbia's Lower Mainland* in August 2013. This document presents a list of 10 technical projects that could be undertaken over the next several years. It is envisioned that this would lead toward a more comprehensive understanding of flood hazards, risks and recommended management options. Collaborating organizations ranked the 10 projects in order of importance; the top seven projects receiving support are as follows:

1. Projected water levels for multiple flood scenarios (i.e., different peak flows / return frequencies, sea level rise, storm surge events). This task was recently completed and summarized in the MFLNRO May 2014 report entitled Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios.
2. Region-wide analysis of current and future risk and vulnerability to flood hazards (i.e., what is vulnerable and what are the impacts, consequences and costs of a catastrophic flood in the Lower Mainland) at a coarse resolution.
3. Region-wide assessment of current conditions of flood protection works and effectiveness of floodproofing, bylaws, and floodplain management.
4. Regional-scale benefit cost analysis to review current and possible future flood risk / management scenarios.
5. Regional-scale joint probability analysis focused on coastal communities.
6. Pilot projects / case studies / feasibility studies to evaluate and/or select potential management options (e.g. green shores, barrier islands, floodproofing in coastal flood zones, alternative dike alignments, other).
7. Regional-scale assessment of seismic vulnerability of flood protection works.

This preliminary prioritization will form the basis for continued dialogue, further refinement of priority projects, as well as budget planning and fund development.

The findings in this report may influence the City's bylaws and policies. The first project has already been accounted-for in this study. The second and third projects in the above list, when completed, will be valuable in informing the City on further refinement to floodplain development standards and flood protection works.

Public Safety Canada 2014

As part of Public Safety Canada's mandate to mitigate losses resulting from natural events, a *National Floodplain Management Framework* (NFMF) has been prepared as an initial step in reducing flood risk across Canada. The NFMF specifically presents the standards and guidelines that will be applied to the updating of Flood Hazard Maps and the development of a National Flood Risk Database. The National Floodplain Management Framework builds upon the Emergency Management Framework, the National Disaster Mitigation Strategy and the original Flood Damage Reduction Program.

The NFMF report (*National Floodplain Mapping Assessment* by MMM Group, dated June 2014) concludes that existing floodplain mapping across Canada does not meet the majority of the standards proposed as part of the NFMF. This conclusion does not infer that existing mapping is inadequate, but rather that the proposed standards represent a step forward in defining how floodplains should be mapped and how flood risk should be documented. Appendix B of the report summarizes the proposed performance standards and the proposed technical standards for floodplain for survey, base mapping, hydrological and hydraulic modelling, floodplain development policy framework, and mapping.

The proposed NFMF exceeds the requirements in the BC *Flood Hazard Area Land Use Management Guidelines* (MWLAP 2004). It defines a 50-year floodway floodplain area where development is prohibited, increases the design standard of flood protection works in the flood fringe to 350-year return period, and defines safe access/egress depths and velocities for pedestrians and vehicles.

5.3 Floodplain Bylaw Changes

The City's current floodplain requirements are incorporated into the Zoning Bylaw 3000, by an amendment contained in Bylaw 3923-2008. Both bylaws require some revisions based on the work completed in this study. The changes consist of wording changes to better describe the Fraser River design flood and return period, and an update of the floodplain maps in Schedule G of the bylaw.

The suggested wording changes for the relevant sections of the bylaw are contained in Appendix C.

The updated floodplain extents were submitted digitally to the City so that their mapping staff could update the Schedule G figures.

5.4 Options for Other Policy Changes

In light of the information presented in the previous section and the work undertaken in this study, the City should consider the following policy changes:

1. Consider updating the design Flood Construction Levels based on the results of this study as shown on the maps in Appendix A.
2. Consider filling the floodplain along the Fraser River to the FCL to protect the development.
3. Consider raising the ground adjacent to dikes to form a more solid band of protection.
4. Consider requiring restrictive covenants at time of development to be placed on properties in the floodplain to inform potential buyers of the flood assessment reports.
5. Consider future refinement of floodplain development standards once the Fraser Basin Council region-wide assessments are complete.

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Section 6

Recommendations

6. Recommendations

6.1 Dike Upgrades

- Upgrade the City of Coquitlam portion of the Upper Dike to the Year 2100 Design Profile.
- Build a dike or raise the ground along the east edge of the Mayfair Industrial Park. The Forensic Psychiatric Institute is currently in the process of flood-proofing their property and protection of the agricultural land (Colony Farm) is the responsibility of Metro Vancouver.
- Upgrade the DeBoville Slough south side Standard Dike to the Year 2100 Design Profile (crest elevation = 6.44 m Geodetic).
- Plan the City's development keeping the land adjacent to the dike free of impediments to allow upgrading of the Upper and Lower Dike to the Year 2200 Design Profile in the future as needed.

The Pitt River and DeBoville Slough north side non-Standard Dikes were recently reviewed and the recommendation was to maintain them at an agricultural level.

6.2 Como Creek and Nelson Creek Stoplogs

Raise the existing stop-log structures (Como Creek and Nelson Creek) to the Year 2100 FCL. Low portions of United Boulevard would need to be raised to prevent overland flow near Nelson Creek.

6.3 Brunette River Dike

To prevent flood waters from skirting the United Boulevard stoplogs and flows traveling north into the low floodplain area north of Highway 1, the Brunette River dike or the land adjacent to the dike near the CN Railway northwest of the Eaglequest Golf Course would need to be raised. This raising is complicated by the presence of the CN Rail bridges which would also require raising under the Year 2100 and Year 2200 climate change scenario water levels.

In the short term, an Emergency Flood Response Strategy should be developed for this area until such time as the above raisings are completed.

The Lower Brunette River between North Road and the CN Rail bridge, which may or may not be governed by the Fraser River flood levels, should be reassessed using updated river flows and flows that include climate change for Year 2100 and Year 2200 to complete the floodplain mapping in this area.

6.4 Floodplain Bylaw Changes

The recommended Floodplain Bylaw wording changes are presented in Appendix C. It is recommended that the City revise its bylaw in accordance with the proposed text changes and update the Schedule G maps using the flood extents shapefiles provided digitally.

6.5 Report Submission

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Statement of Limitations

This document has been prepared by Kerr Wood Leidal Associates Ltd. (KWL) for the exclusive use and benefit of CITY OF COQUITLAM for the Coquitlam/Fraser/Pitt Rivers Floodplain Mapping. No other party is entitled to rely on any of the conclusions, data, opinions, or any other information contained in this document.

This document represents KWL's best professional judgement based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practising under similar conditions. No warranty, express or implied, is made.

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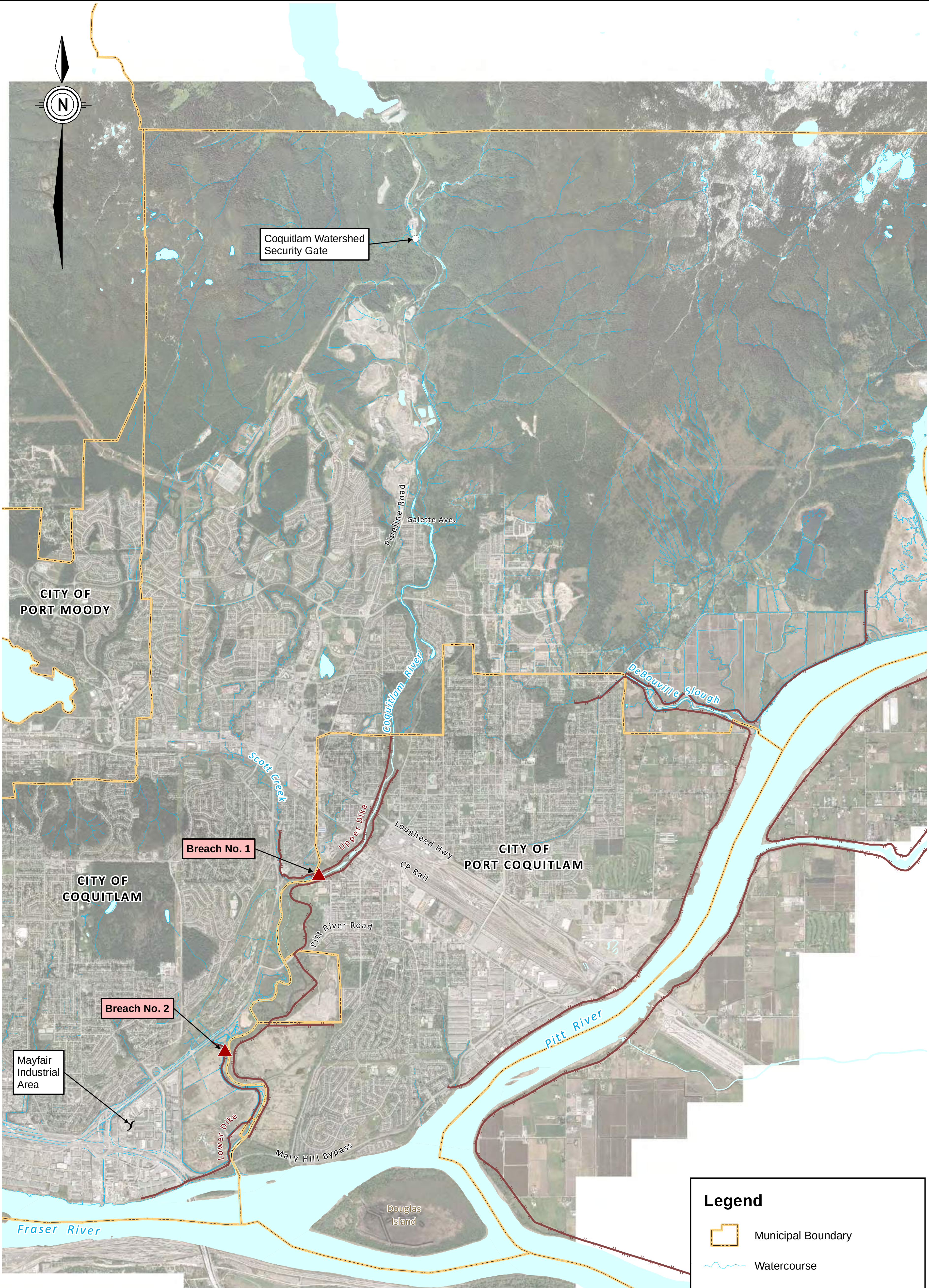
Revision History

Revision #	Date	Status	Revision	Author
A	Aug 28, 2014	Draft	Draft for Technical Reviewer	ABS/DZ
B	Sept 18, 2014	Draft	Submission to City	ABS/DZ
C	Oct 17, 2014	Draft	Second draft addressing City comments	ABS/DZ
D	May 20, 2015	Draft Final	Added Pitt River assessment	ABS/DZ
E	Oct 15, 2015	Draft Final	Added Lower Brunette River comments	ABS/DZ
F	Aug 17, 2017	Final	Update flood maps. Added reference to FLNRO Sea Level Rise Amendment	DZ

Path: O:\0400-0499\456-092\430-GIS\MXD-Rp\Figure 1 - Coquitlam River Location Plan.mxd Date Saved: 5/5/2015 8:06:49 AM
Author: DZabil



Reference: 2012 Orthophoto from the City of Coquitlam.

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City of Coquitlam
Coquitlam and Fraser Rivers Floodplain Mapping

Project No. 456-092

Date May, 2015

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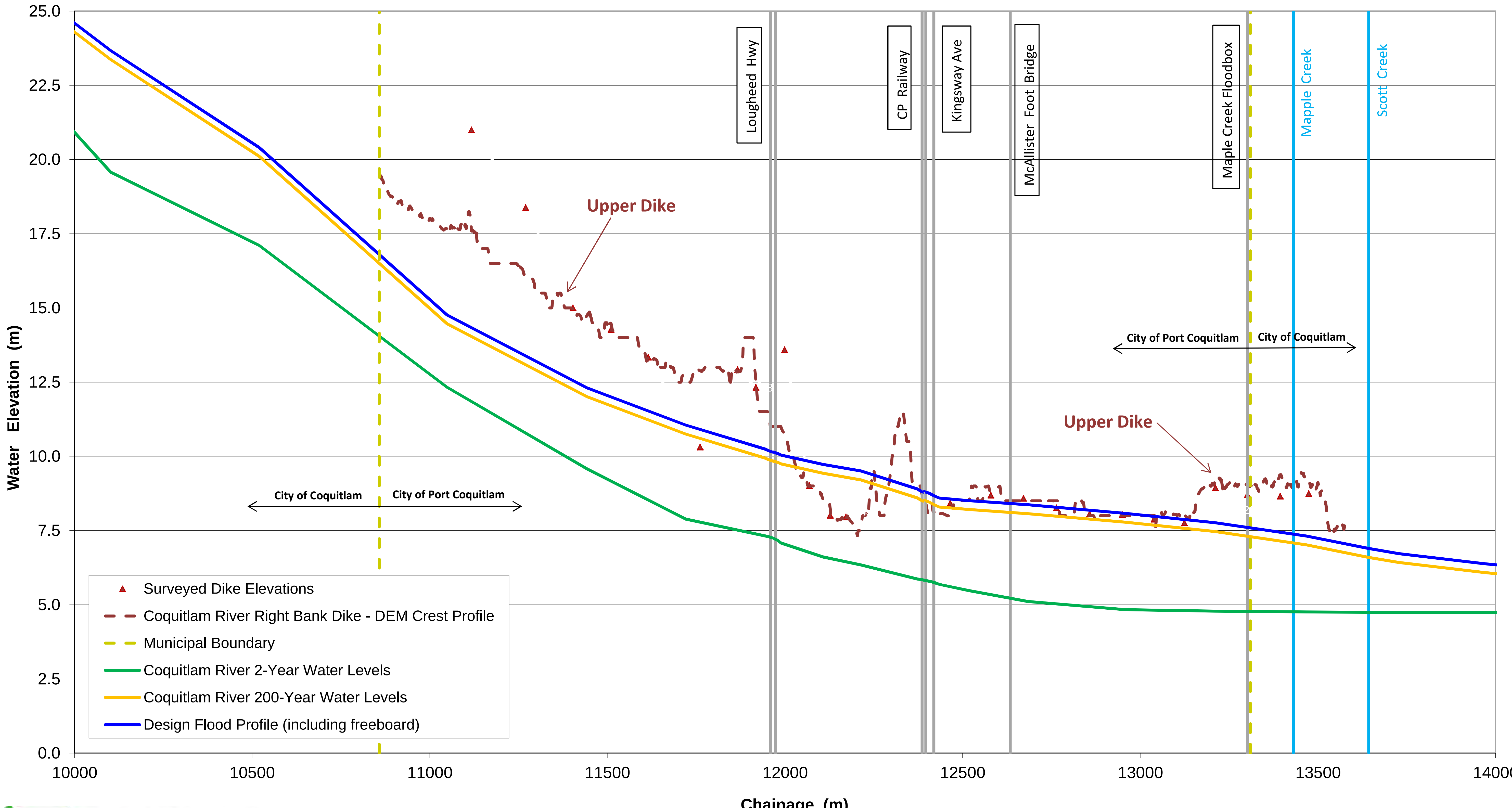
Coquitlam River Location Plan

Figure 1



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Coquitlam River Profiles - Upper Dike
Scenario 1 - Year 2014
FIGURE 2a

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Coquitlam River Profiles - Lower Dike
Scenario 1 - Year 2014
FIGURE 2b

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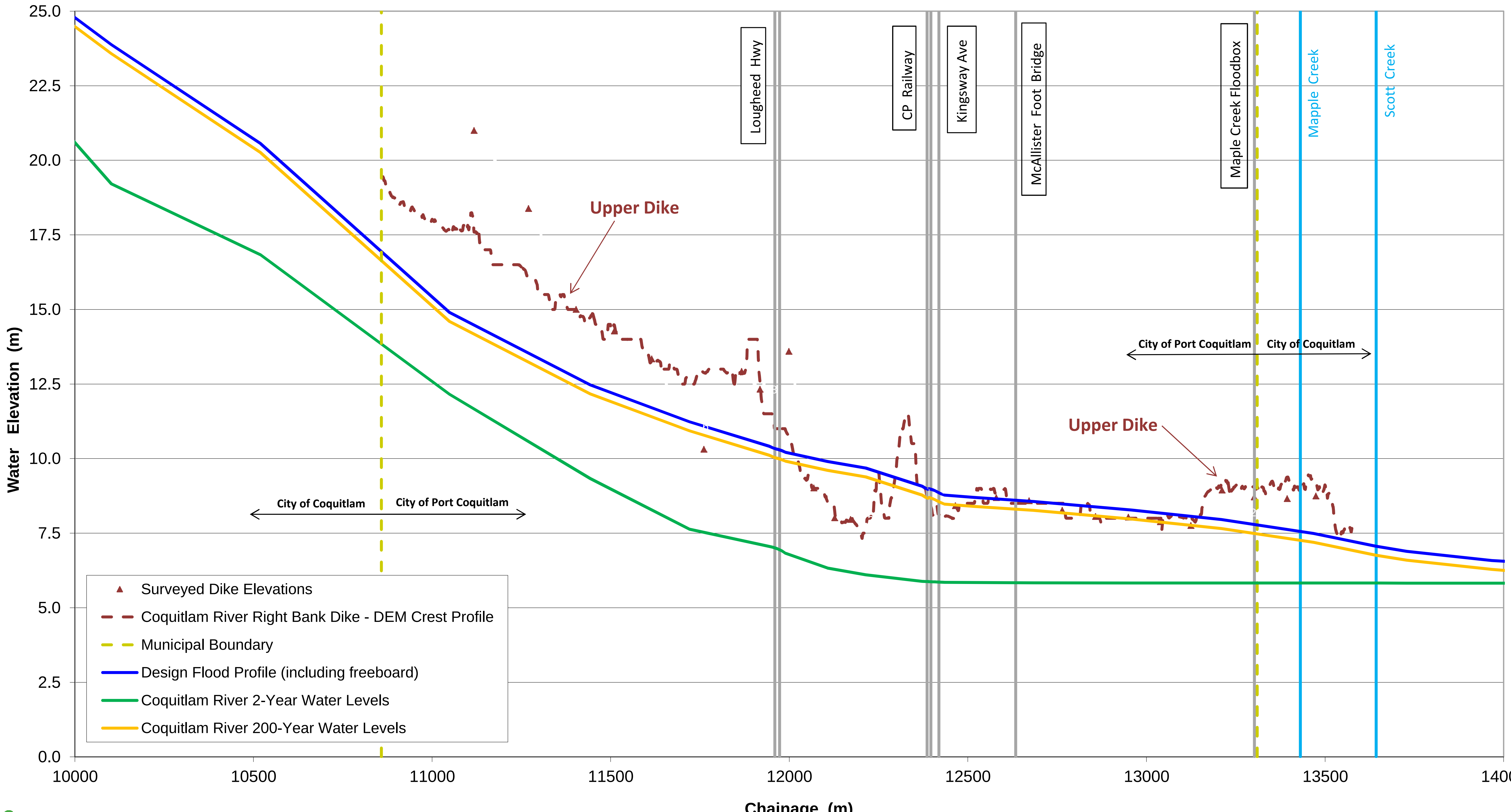

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Coquitlam River Profiles - Upper Dike
Scenario 2 - Year 2100
FIGURE 3a

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Coquitlam River Profiles - Lower Dike
Scenario 2 - Year 2100
FIGURE 3b

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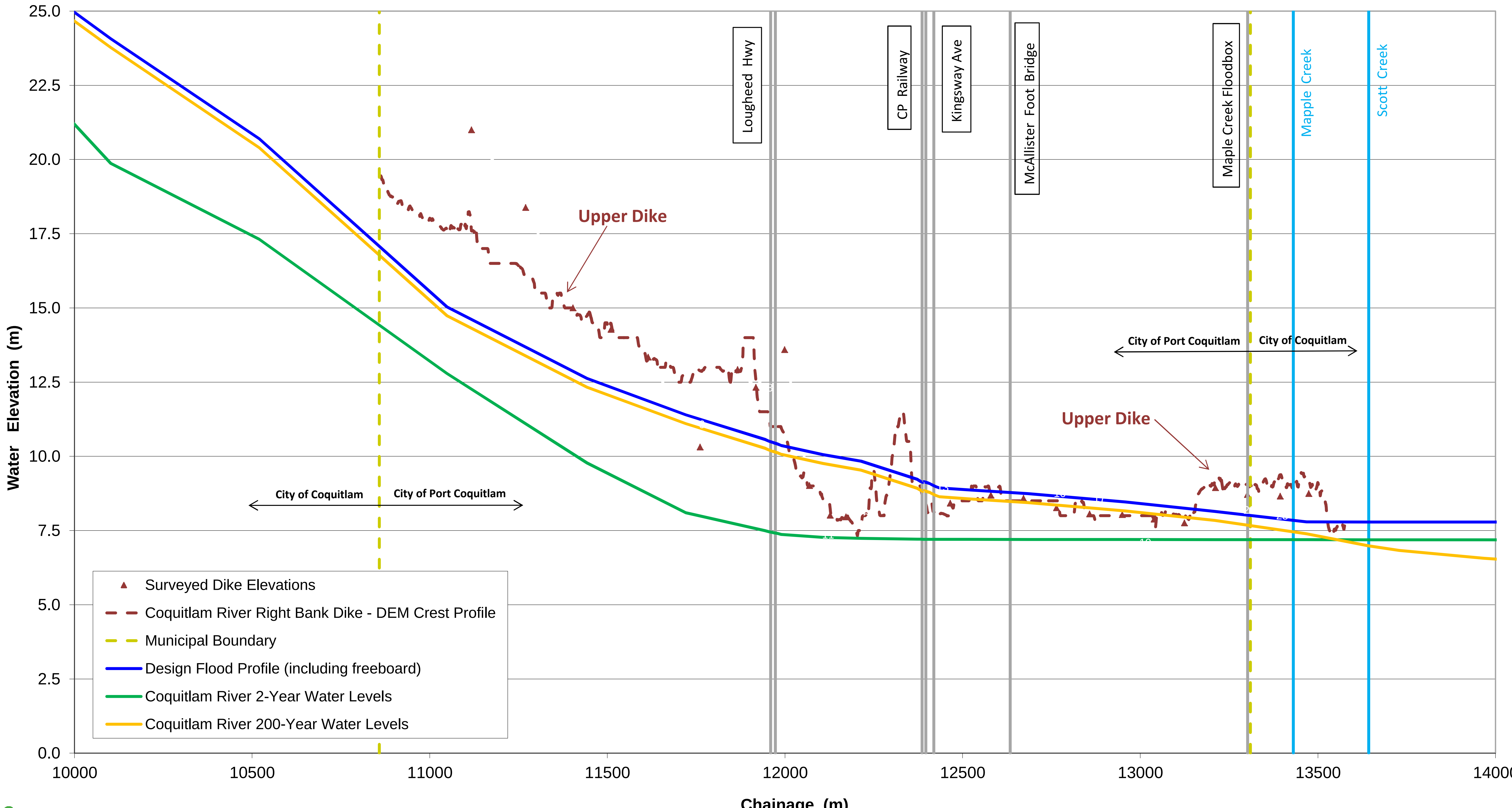

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Coquitlam River Profiles - Upper Dike
Scenario 3 - Year 2200
FIGURE 4a

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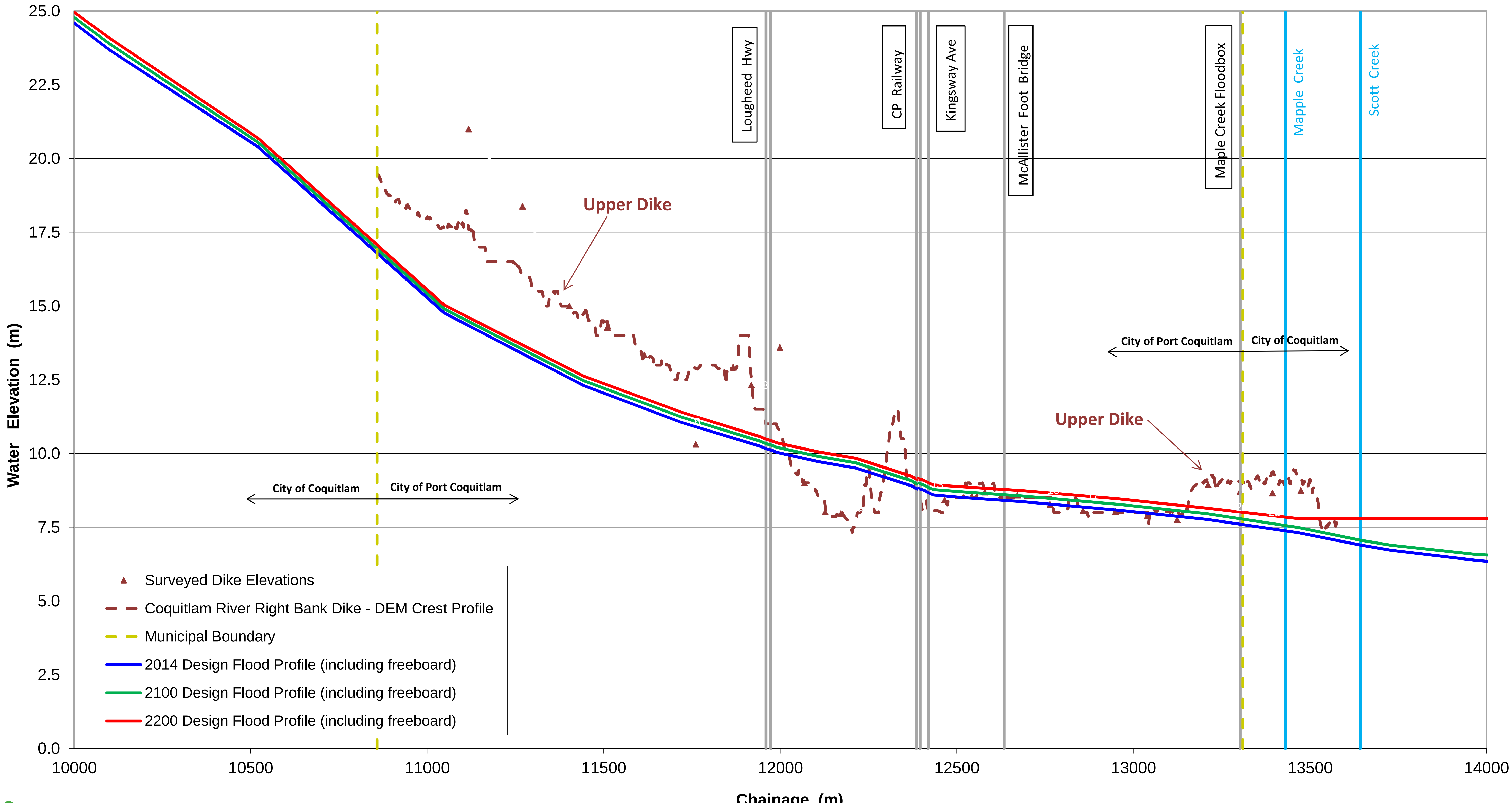
Coquitlam River Profiles - Lower Dike
Scenario 3 - Year 2200
FIGURE 4b



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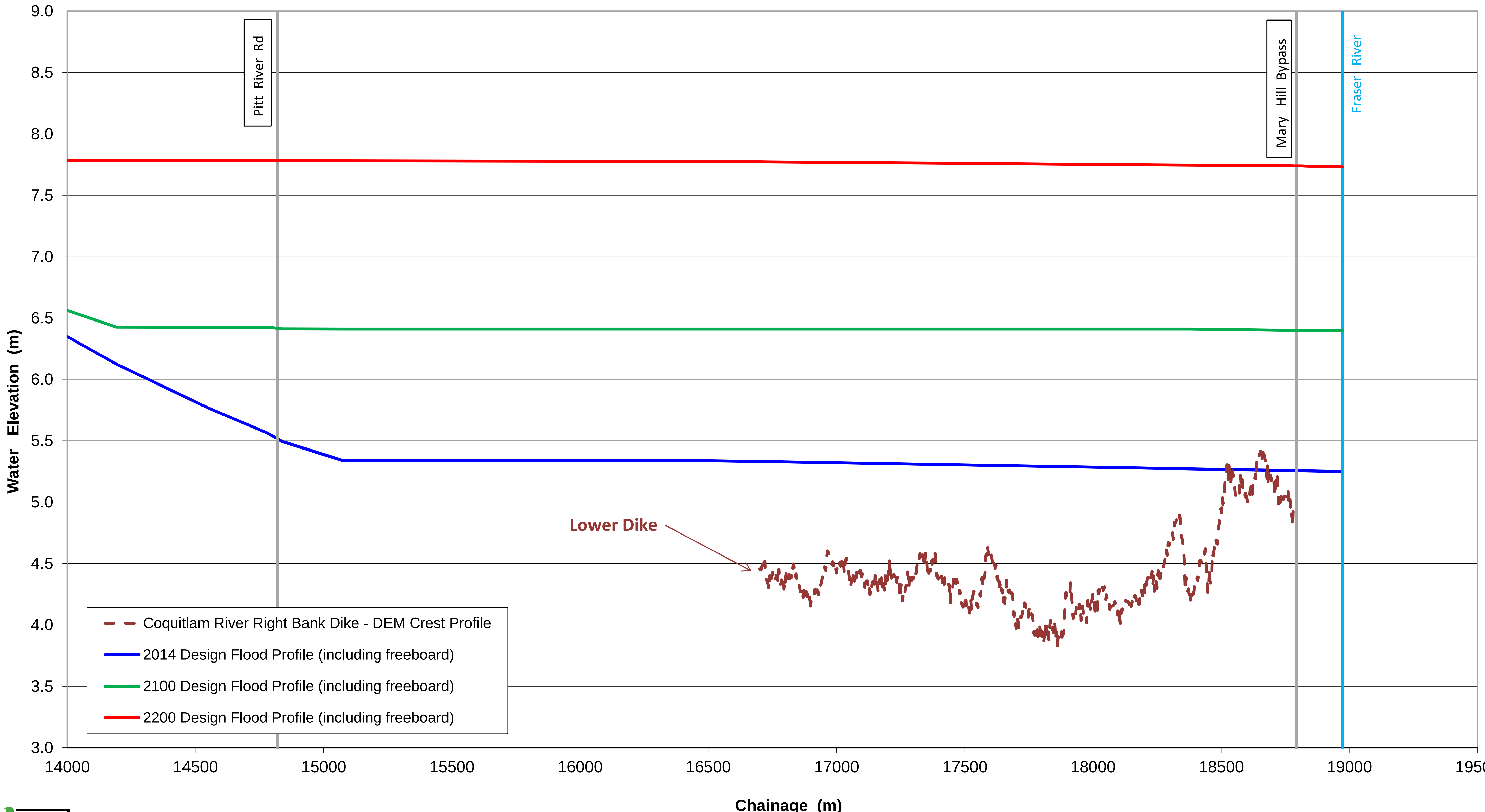
Coquitlam River Profiles - Upper Dike
Scenario Comparison
FIGURE 5a



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Coquitlam River Profiles - Lower Dike
Scenario Comparison
FIGURE 5b

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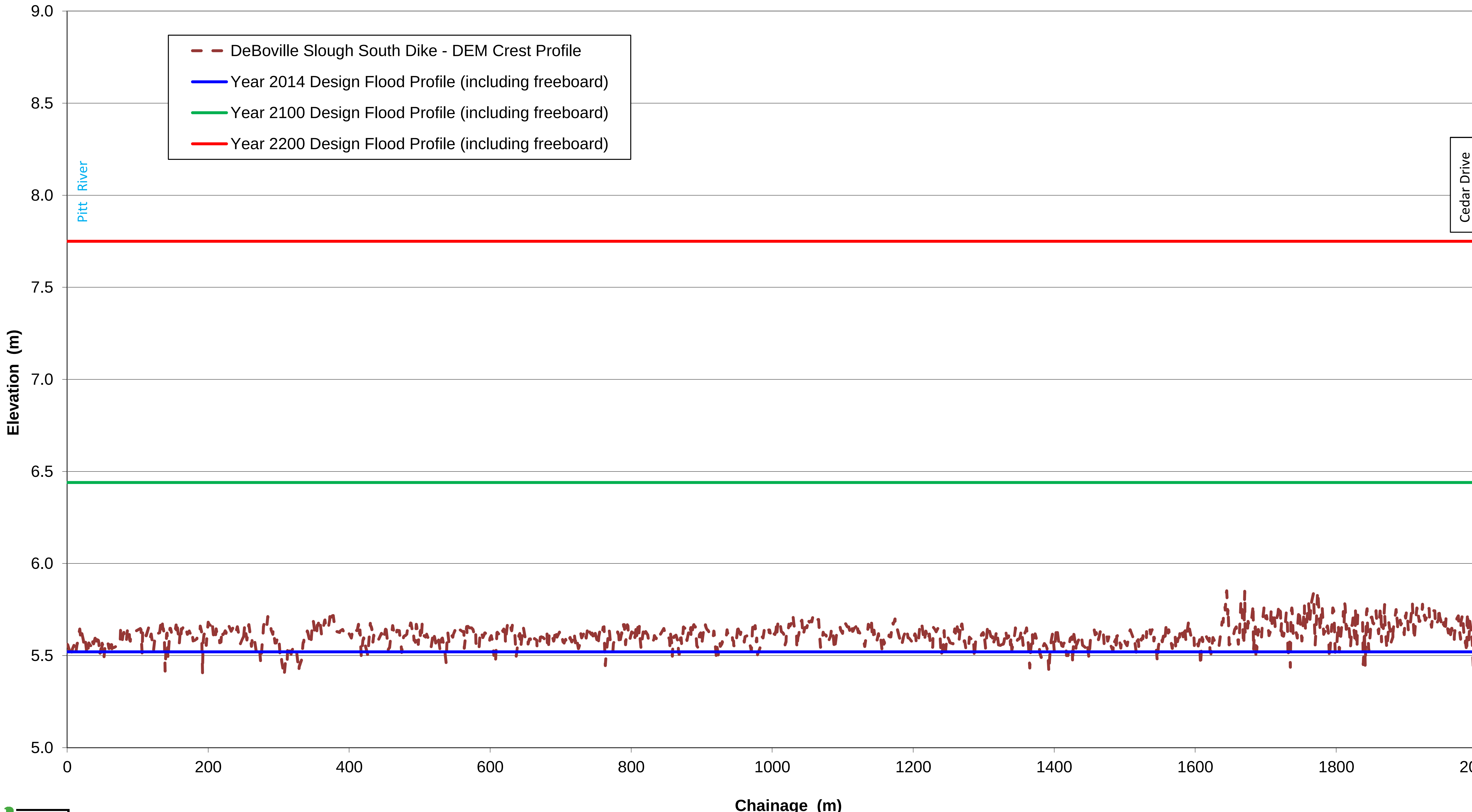

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Pitt River - DeBoville Slough Design Flood Profiles
Scenario Comparison
FIGURE 6

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Appendix A

Floodplain Maps

Notes

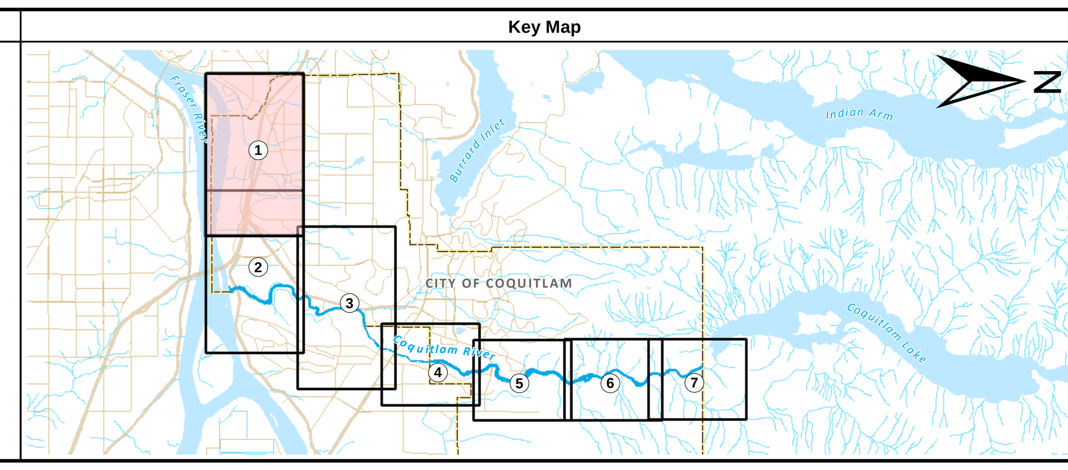
Fraser River design flood is approximately 500-year return period.
Coquitlam River design flood is 200-year return period.

Legend

- Municipal Boundary
- Dike
- Design Flood Level Flood Extent without Freeboard (Year 2014-No Climate Change)
- x.x m (with Freeboard) / x.x m (without Freeboard) — Flood Contour for Year 2014 Climate Change Scenario (with and without Freeboard)
- Mike11 Computational Network

Note: Mike 11 features from NHC 2008 report.

Key Map



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City of Coquitlam
Coquitlam and Fraser Rivers Floodplain Mapping Year 2014

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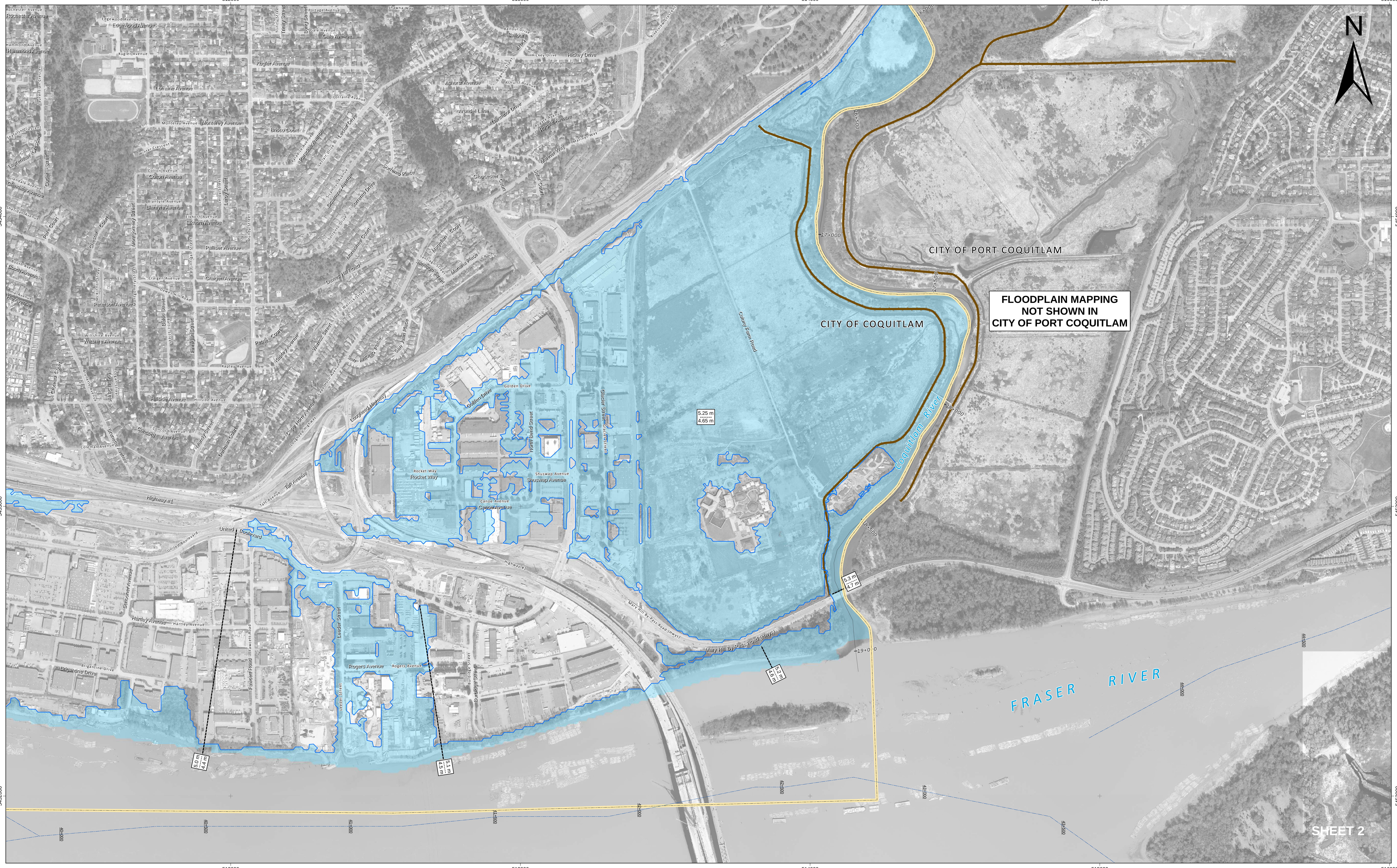
Date	Project No.	Checked
July 2018	456-092	
Sheet No.	**Drawn**	**Approved**
1 of 8	JL	



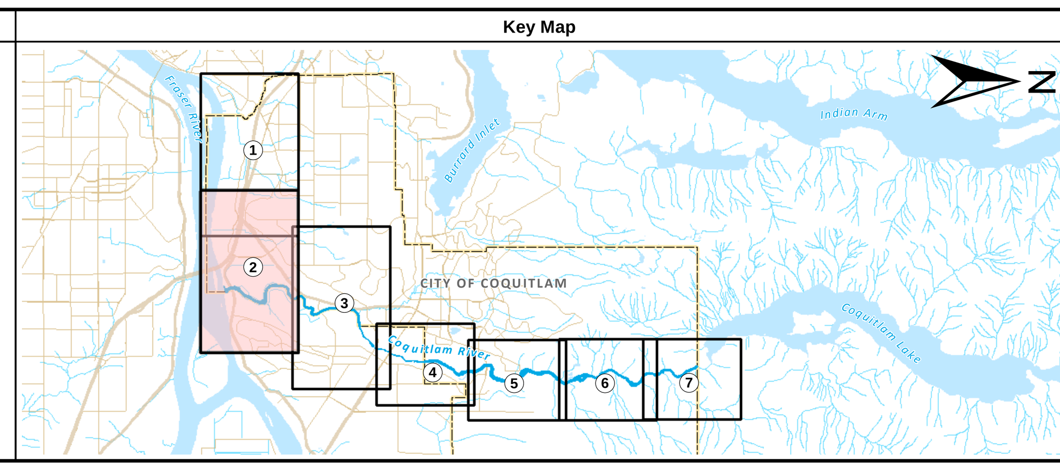
Notes

Fraser River design flood is approximately 500-year return period.
Coquitlam River design flood is 200-year return period.

Legend

- Municipal Boundary
- Dike
- Design Flood Level Flood Extent without Freeboard (Year 2014-No Climate Change)
- x.x m / x.x m — *with Freeboard* / Flood Contour for Year 2014 Climate Change Scenario (with and without Freeboard) / *without Freeboard*
- Mike11 Computational Network
- Note: Mike 11 features from NHC 2008 report.

Key Map



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City of Coquitlam
Coquitlam and Fraser Rivers Floodplain Mapping Year 2014

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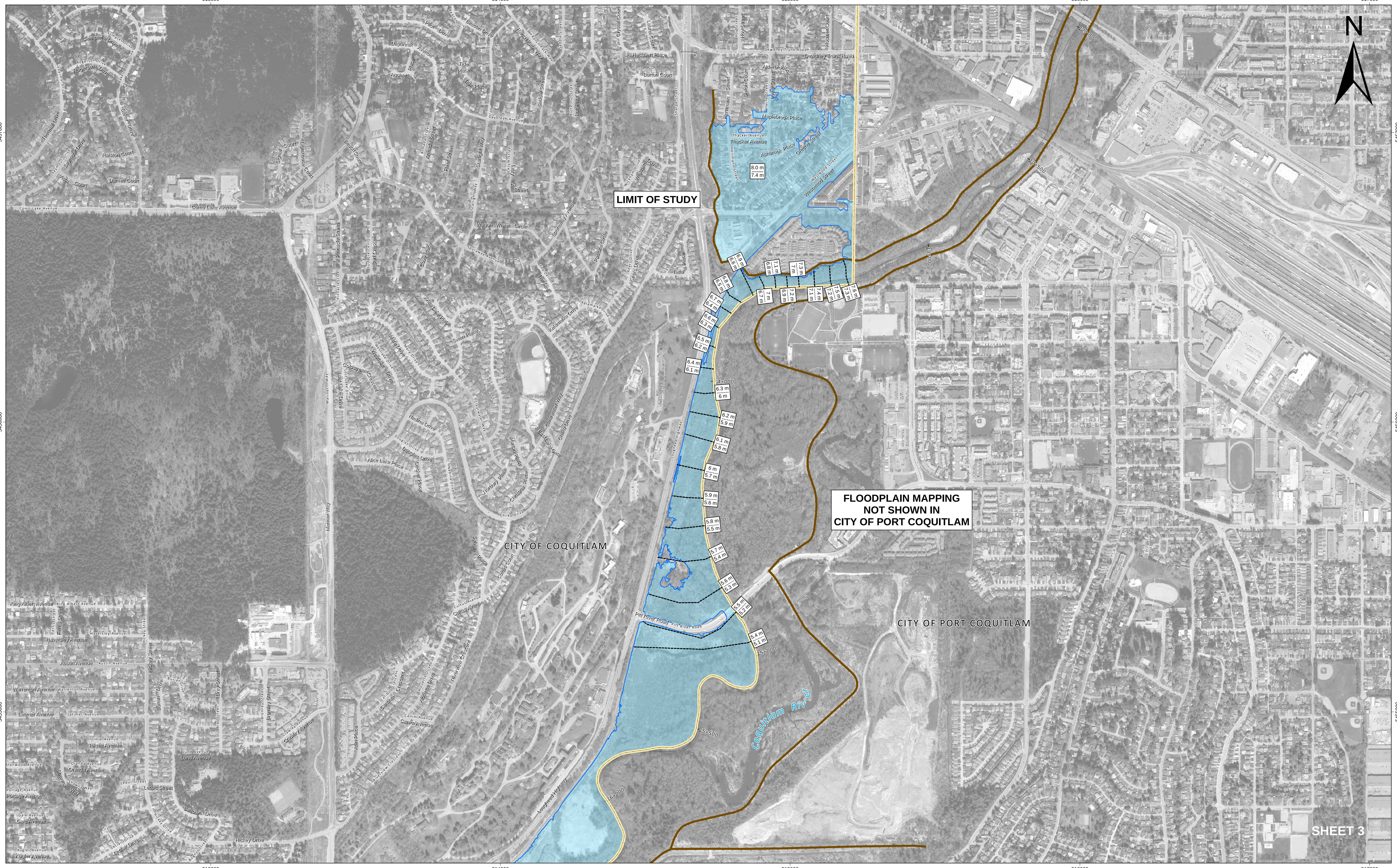
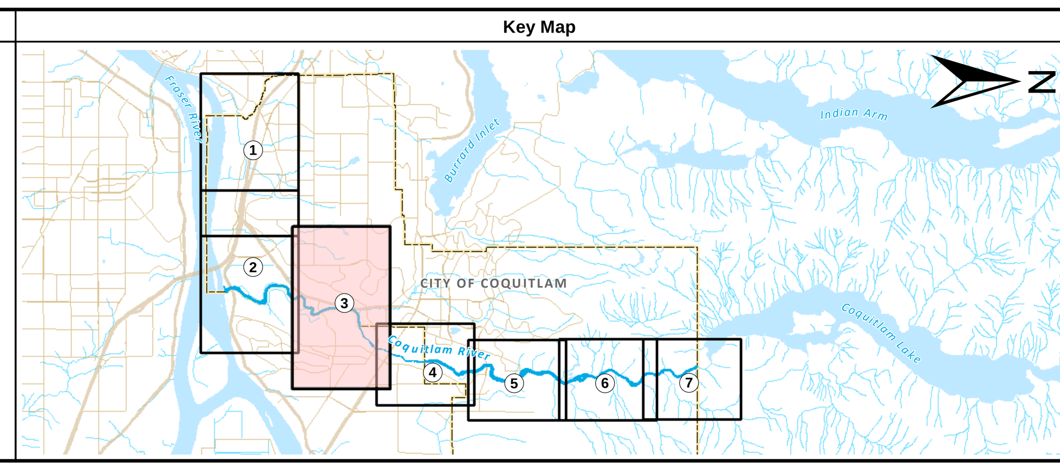
2 of 8	JL	



Notes	Legend
Fraser River design flood is approximately 500-year return period. Coquitlam River design flood is 200-year return period.	Municipal Boundary Dike Design Flood Level Flood Extent without Freeboard (Year 2014-No Climate Change) x.x m / x.x m — with Freeboard / without Freeboard — Flood Contour for Year 2014 Climate Change Scenario (with and without Freeboard) Mike11 Computational Network Note: Mike 11 features from NHC 2008 report.

Key Map



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City of Coquitlam
Coquitlam and Fraser Rivers Floodplain Mapping Year 2014

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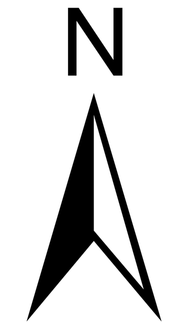
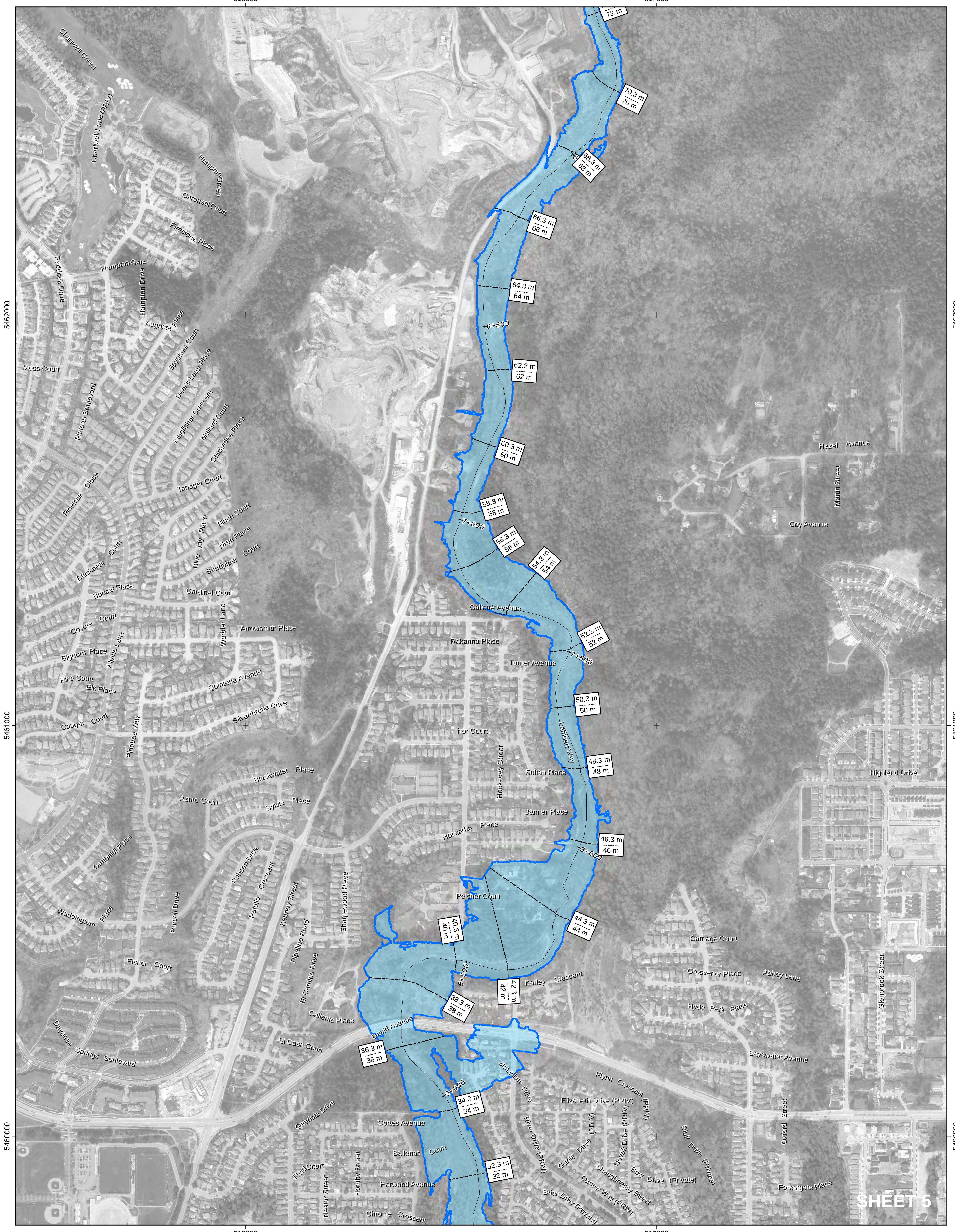
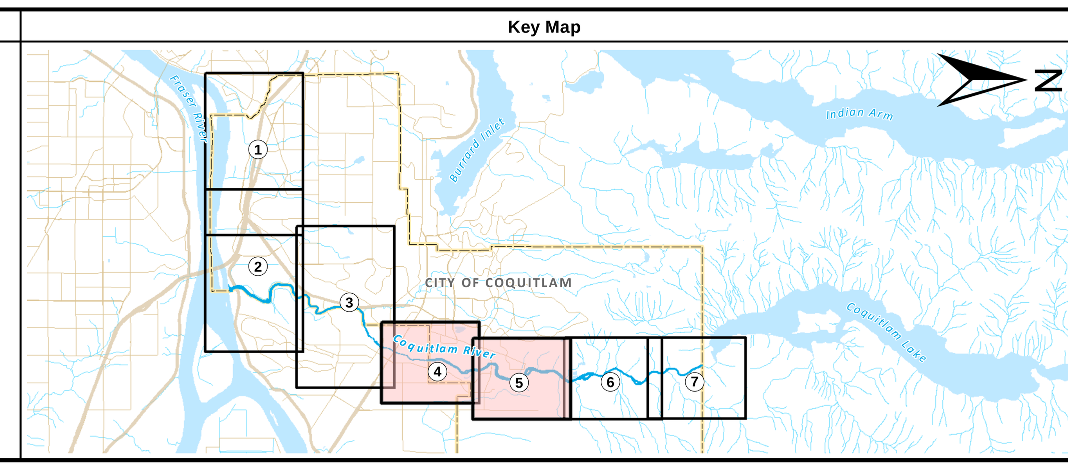
3 of 8	JL	





Notes	Legend	Key Map
Fraser River design flood is approximately 500-year return period. Coquitlam River design flood is 200-year return period.	Municipal Boundary Dike Design Flood Level Flood Extent without Freeboard (Year 2014-No Climate Change) x.x m / x.x m — *with Freeboard* / *without Freeboard* — Flood Contour for Year 2014 Climate Change Scenario (with and without Freeboard)	

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City of Coquitlam
Coquitlam and Fraser Rivers Floodplain Mapping Year 2014

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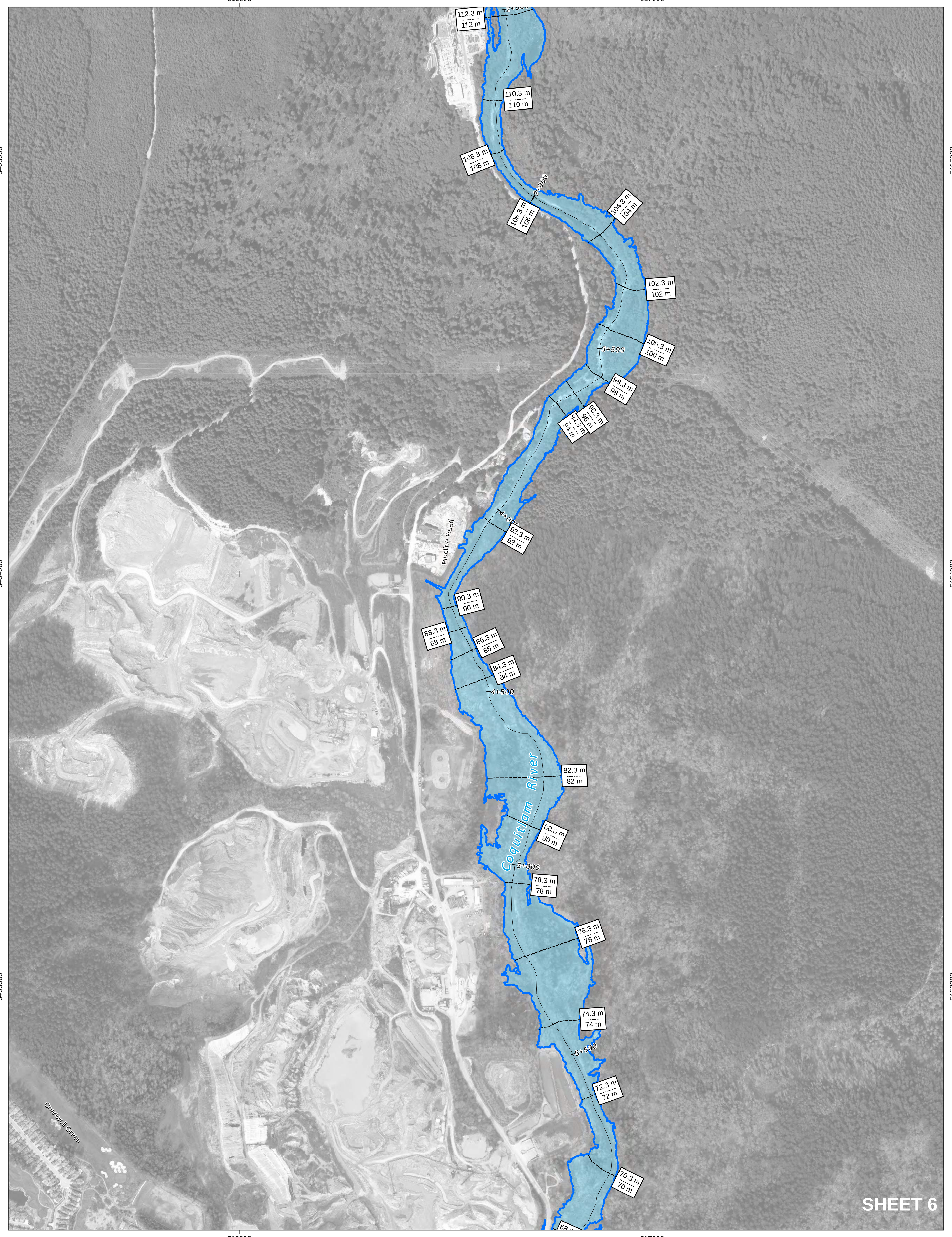
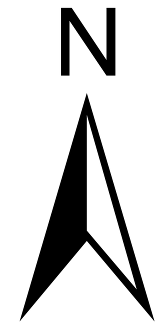
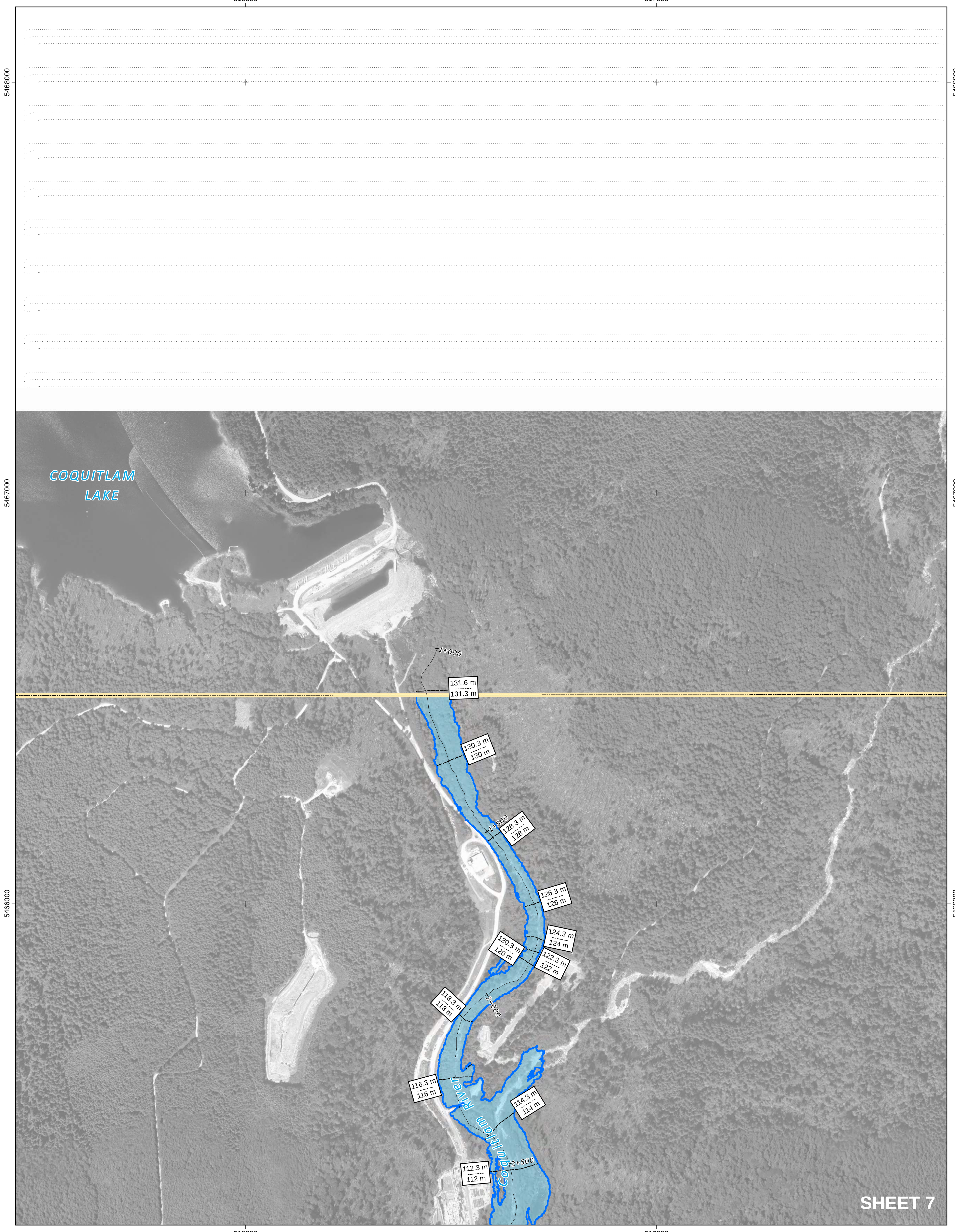
Sheet No.	**Drawn**	**Approved**
4 of 8	JL	







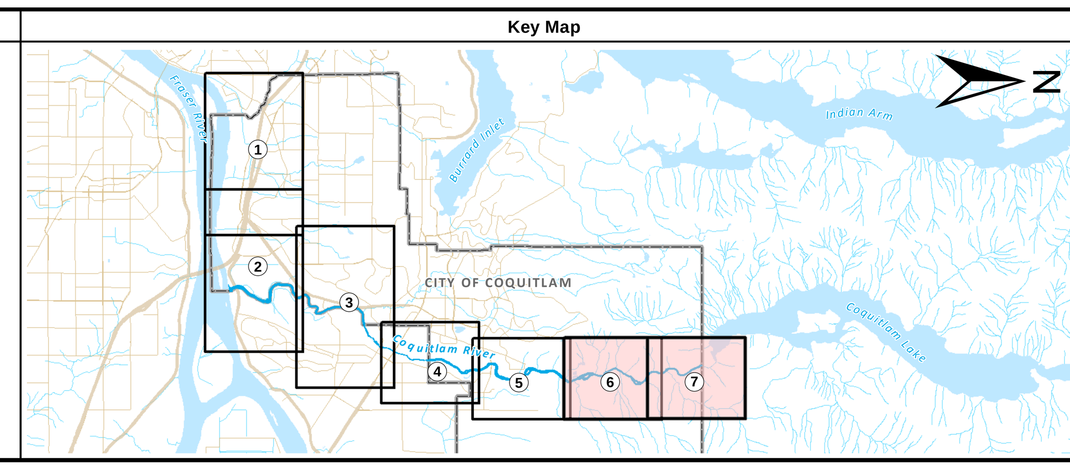
Notes

Fraser River design flood is approximately 500-year return period.
Coquitlam River design flood is 200-year return period.

Legend

- Municipal Boundary
- Dike
- Design Flood Level Flood Extent without Freeboard (Year 2014-No Climate Change)
- x.x m / x.x m — *with Freeboard* / *without Freeboard* — Flood Contour for Year 2014 Climate Change Scenario (with and without Freeboard)

Key Map



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City of Coquitlam
Coquitlam and Fraser Rivers Floodplain Mapping Year 2014

Scale: 100 0 100 (m) — 1:5,000

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August 2017	456-092	
Sheet No.	**Drawn**	**Approved**
5 of 8	JL	

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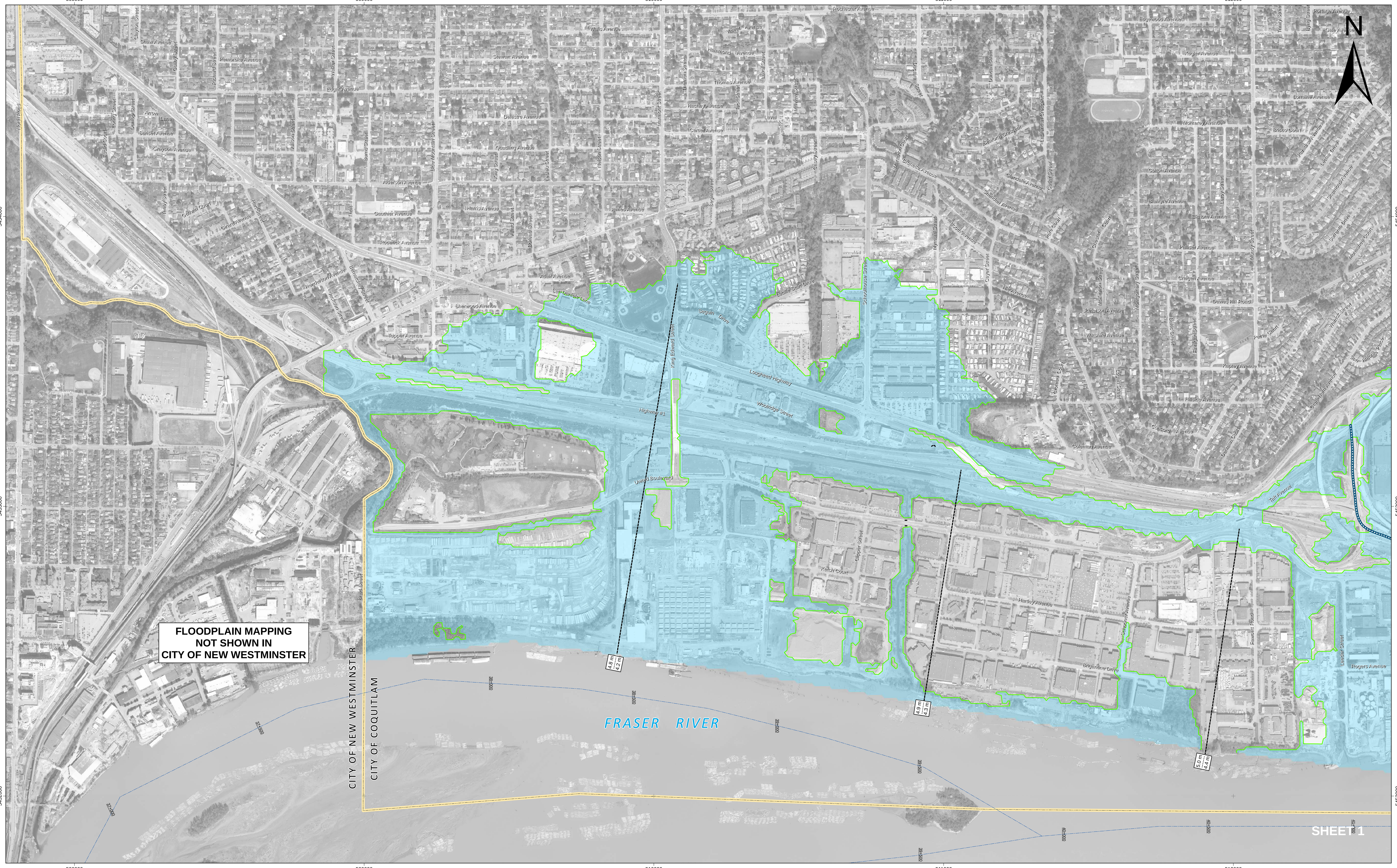
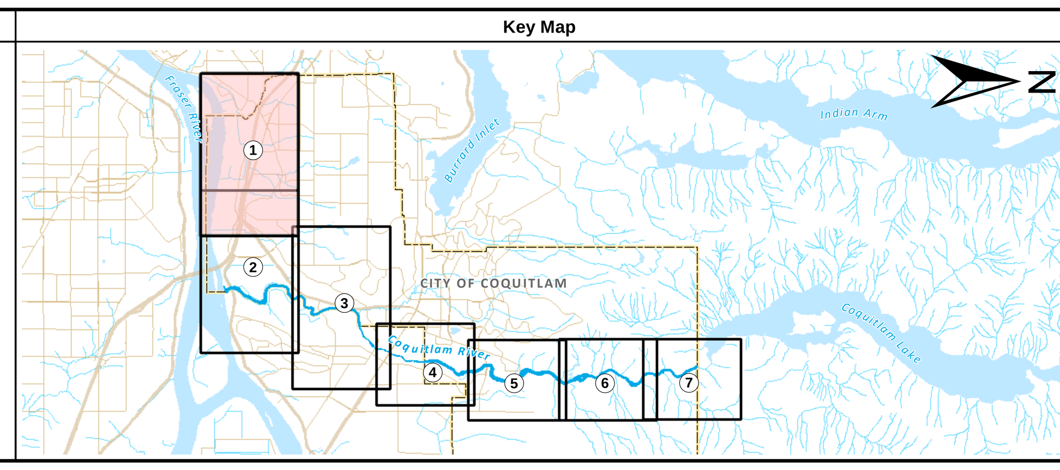


Notes
Fraser River design flood is approximately 500-year return period. Coquitlam River design flood is 200-year return period.

Legend

- Municipal Boundary
- Dike
- Design Flood Level Flood Extent without Freeboard (Year 2100-No Climate Change)
- x.x m (with Freeboard) / x.x m (without Freeboard) — Flood Contour for Year 2014 Climate Change Scenario (with and without Freeboard)
- Mike11 Computational Network
- Note: Mike 11 features from NHC 2008 report.

Key Map



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City of Coquitlam
Coquitlam and Fraser Rivers Floodplain Mapping Year 2100

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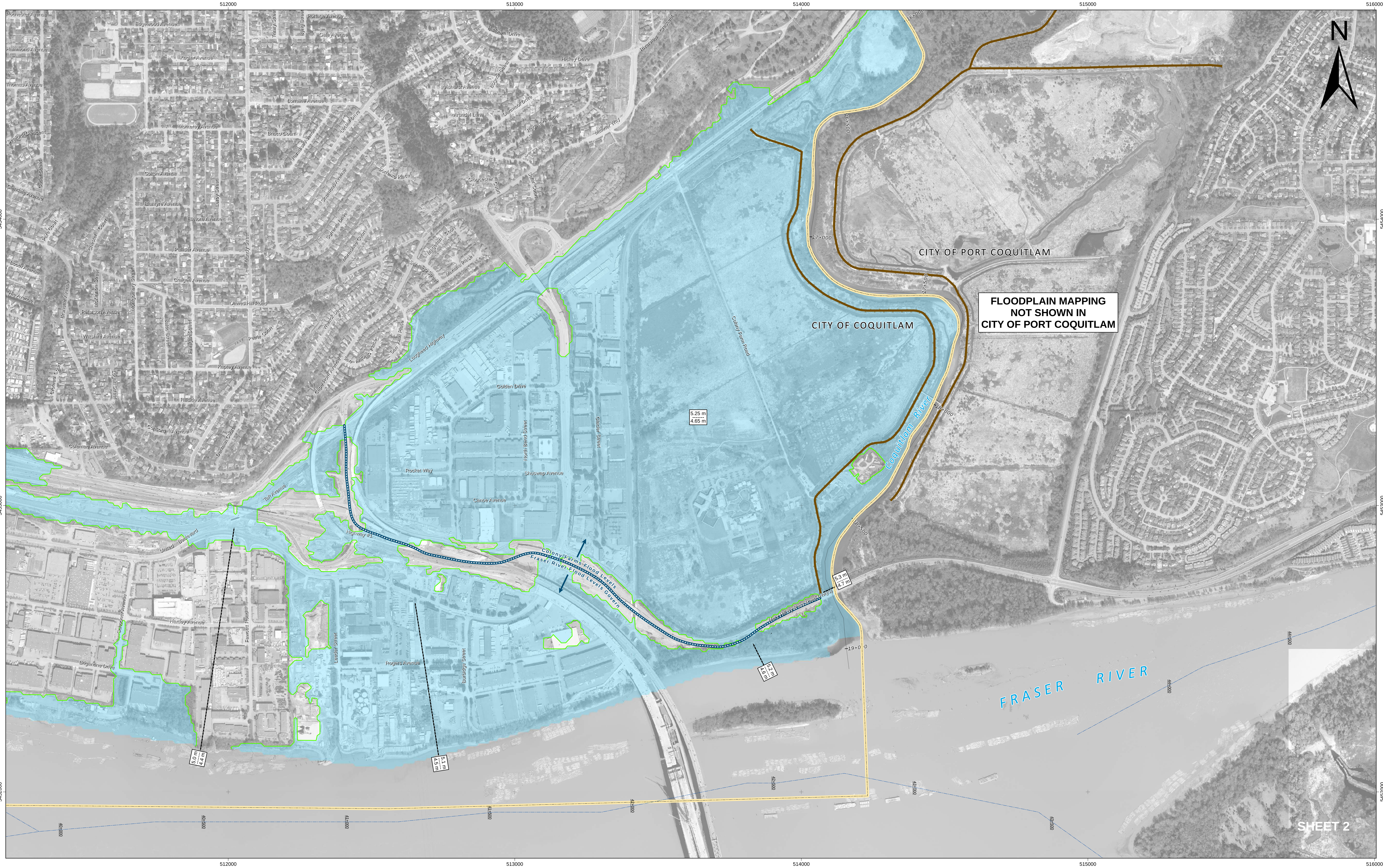
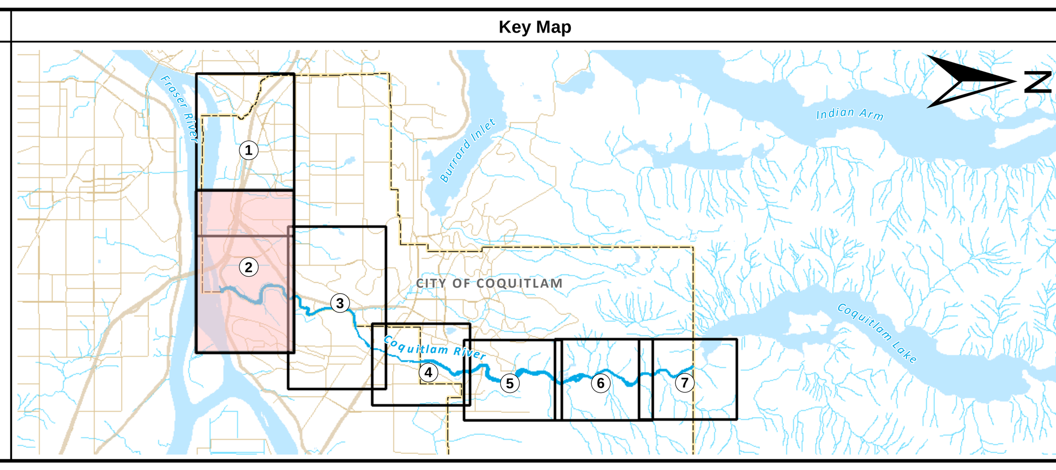


Notes	Legend
Fraser River design flood is approximately 500-year return period. Coquitlam River design flood is 200-year return period.	Municipal Boundary Dike Design Flood Level Flood Extent without Freeboard (Year 2100-No Climate Change) x.x m / x.x m — *with Freeboard* / Flood Contour for Year 2014 Climate Change Scenario (with and without Freeboard) / *without Freeboard* Mike11 Computational Network Note: Mike 11 features from NHC 2008 report.

Key Map



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City of Coquitlam
Coquitlam and Fraser Rivers Floodplain Mapping Year 2100

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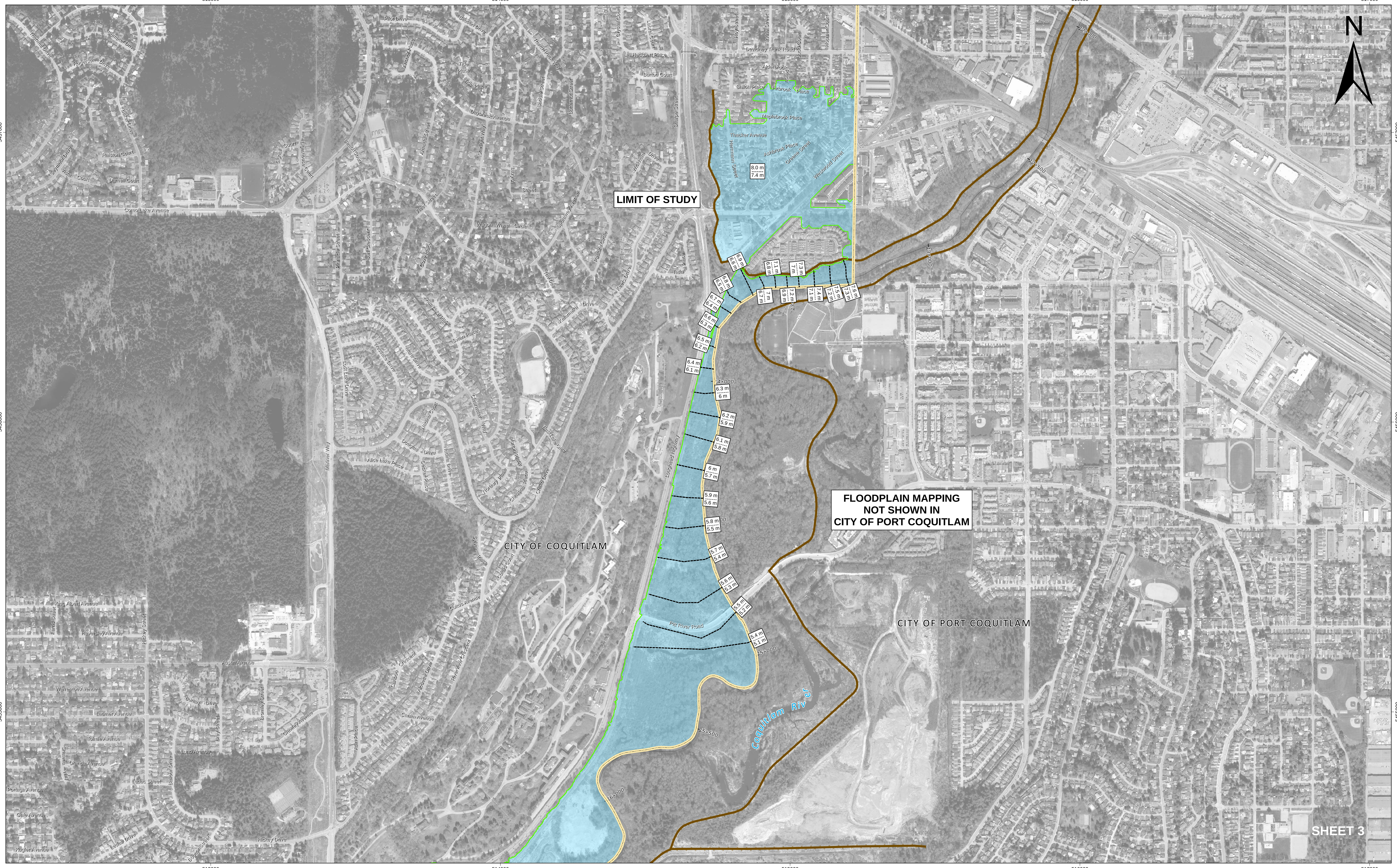


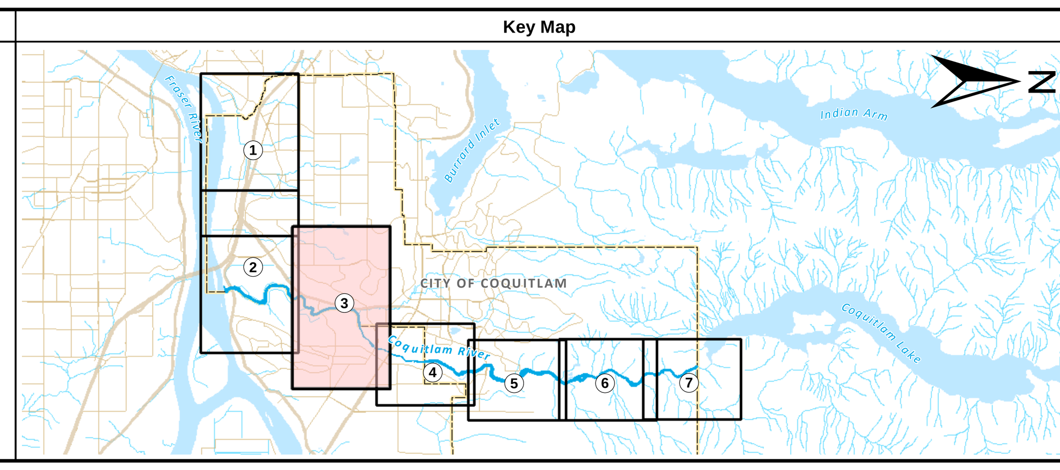
Notes

Fraser River design flood is approximately 500-year return period.
Coquitlam River design flood is 200-year return period.

Legend

- Municipal Boundary
- Dike
- Design Flood Level Flood Extent without Freeboard (Year 2100-No Climate Change)
- with Freeboard / without Freeboard — Flood Contour for Year 2014 Climate Change Scenario (with and without Freeboard)
- Mike11 Computational Network
- Note: Mike 11 features from NHC 2008 report.

Key Map



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City of Coquitlam
Coquitlam and Fraser Rivers Floodplain Mapping Year 2100

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July 2018	456-092	
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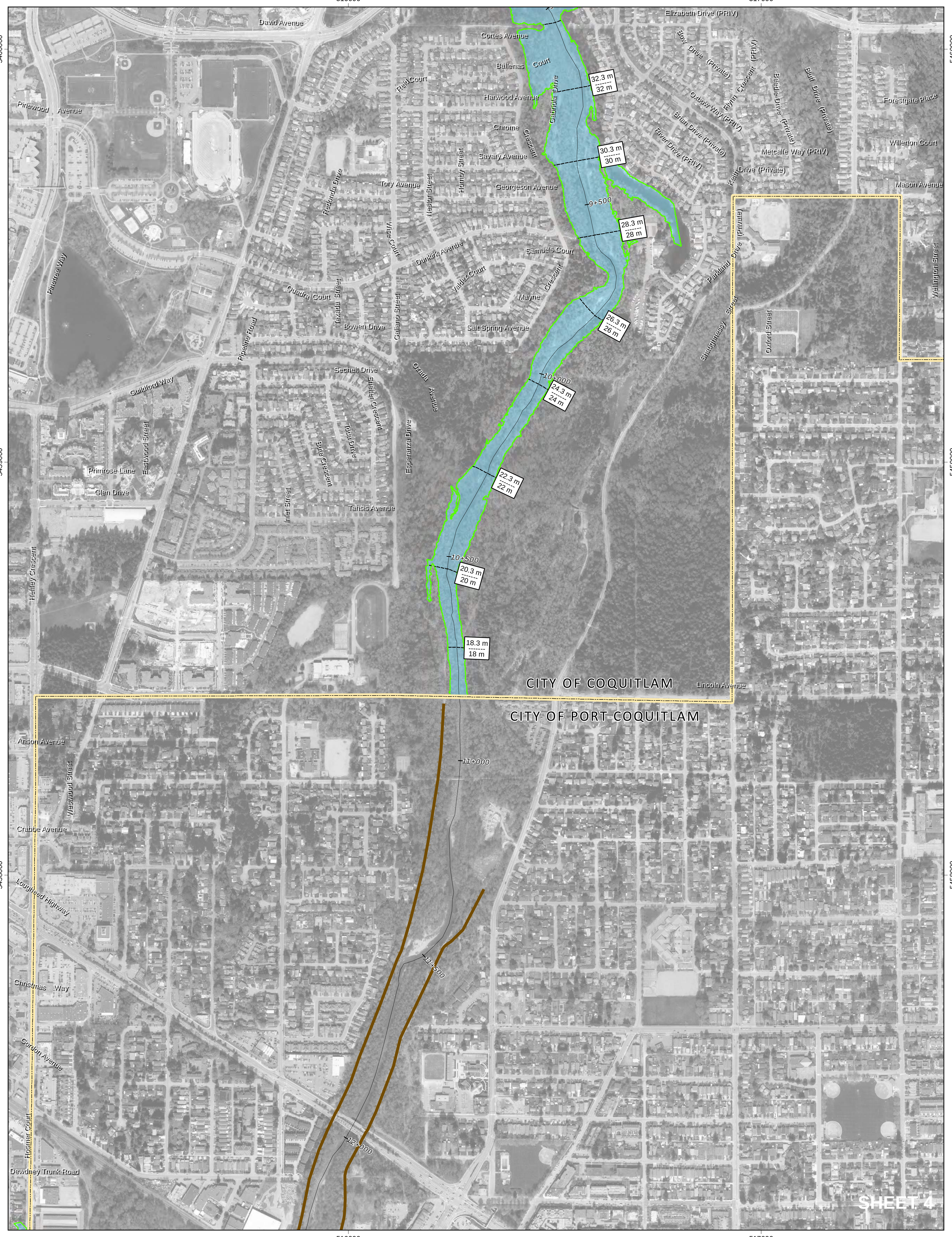

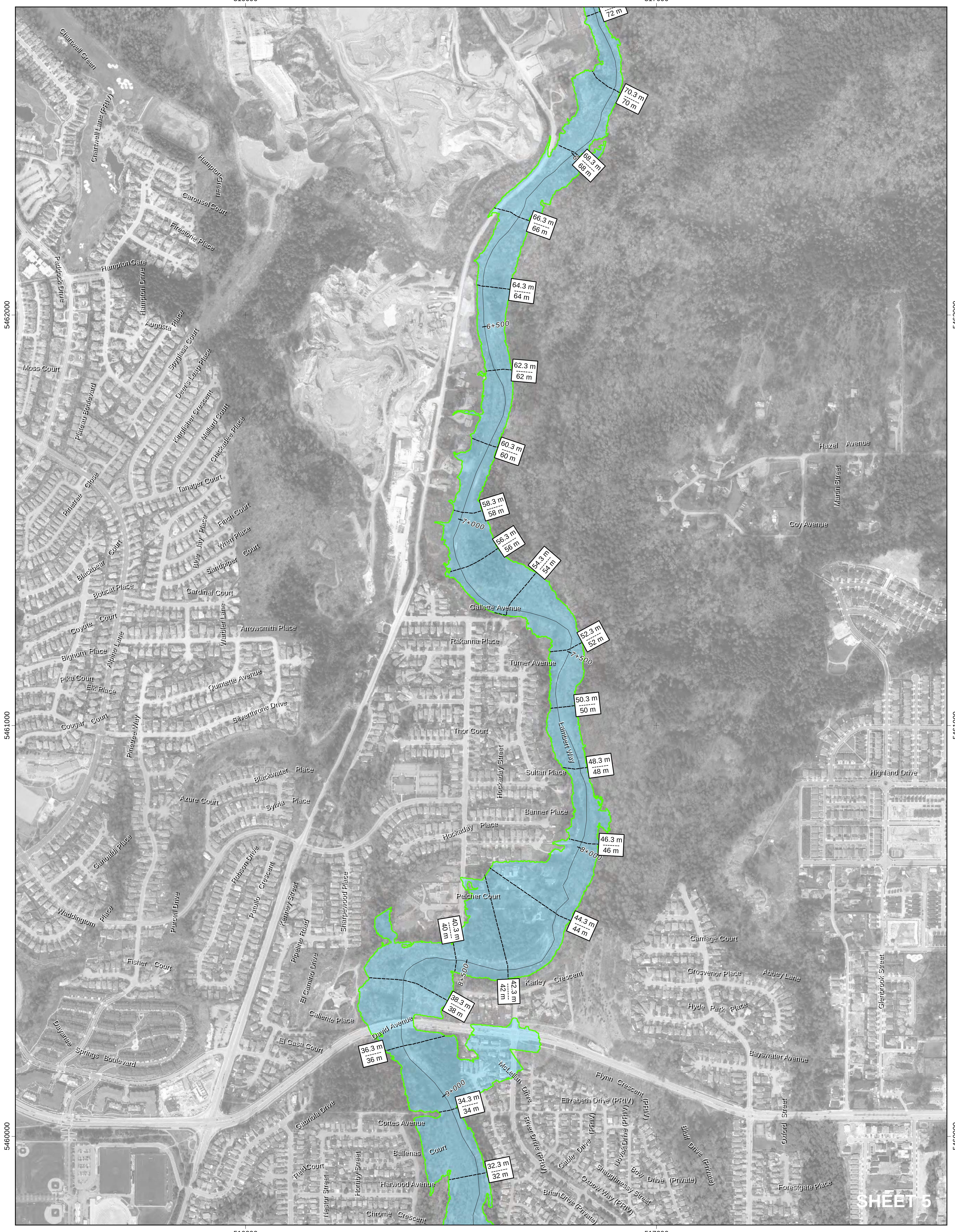

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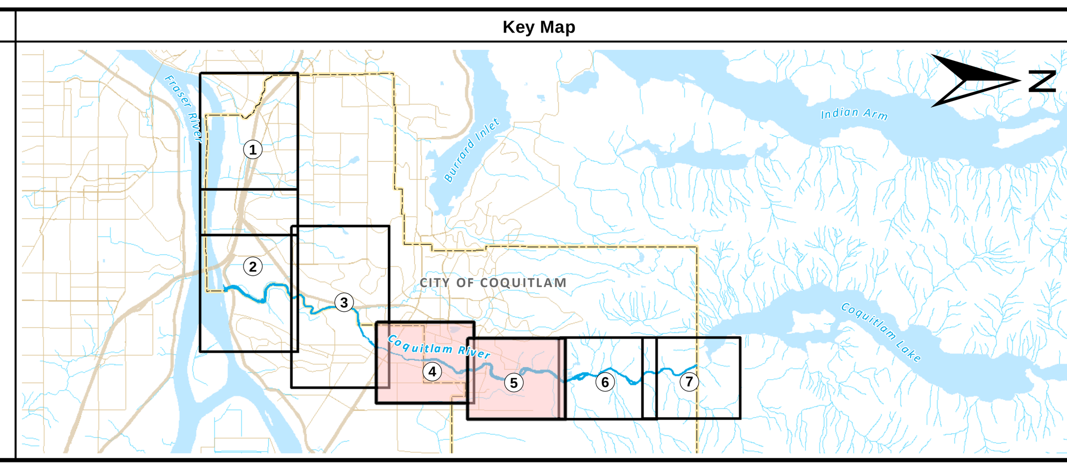
Notes	Legend
Fraser River design flood is approximately 500-year return period. Coquitlam River design flood is 200-year return period.	Municipal Boundary Dike Design Flood Level Flood Extent without Freeboard (Year 2100-No Climate Change) x.x m / x.x m — *with Freeboard* / *without Freeboard*: Flood Contour for Year 2014 Climate Change Scenario (with and without Freeboard)

Key Map



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City of Coquitlam
Coquitlam and Fraser Rivers Floodplain Mapping Year 2100

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Date	Project No.	Checked
August 2017	456-092	
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4 of 8	JL	

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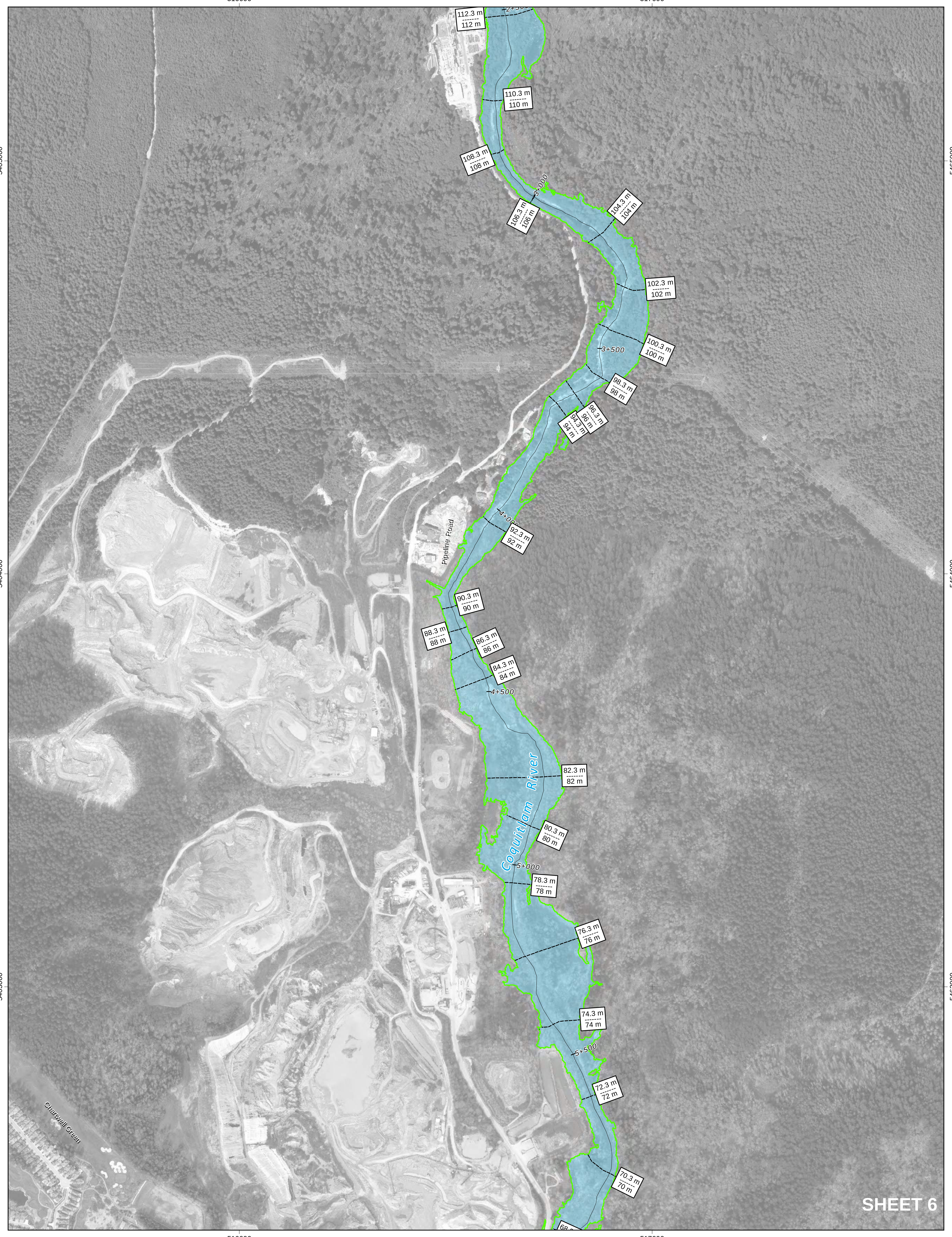
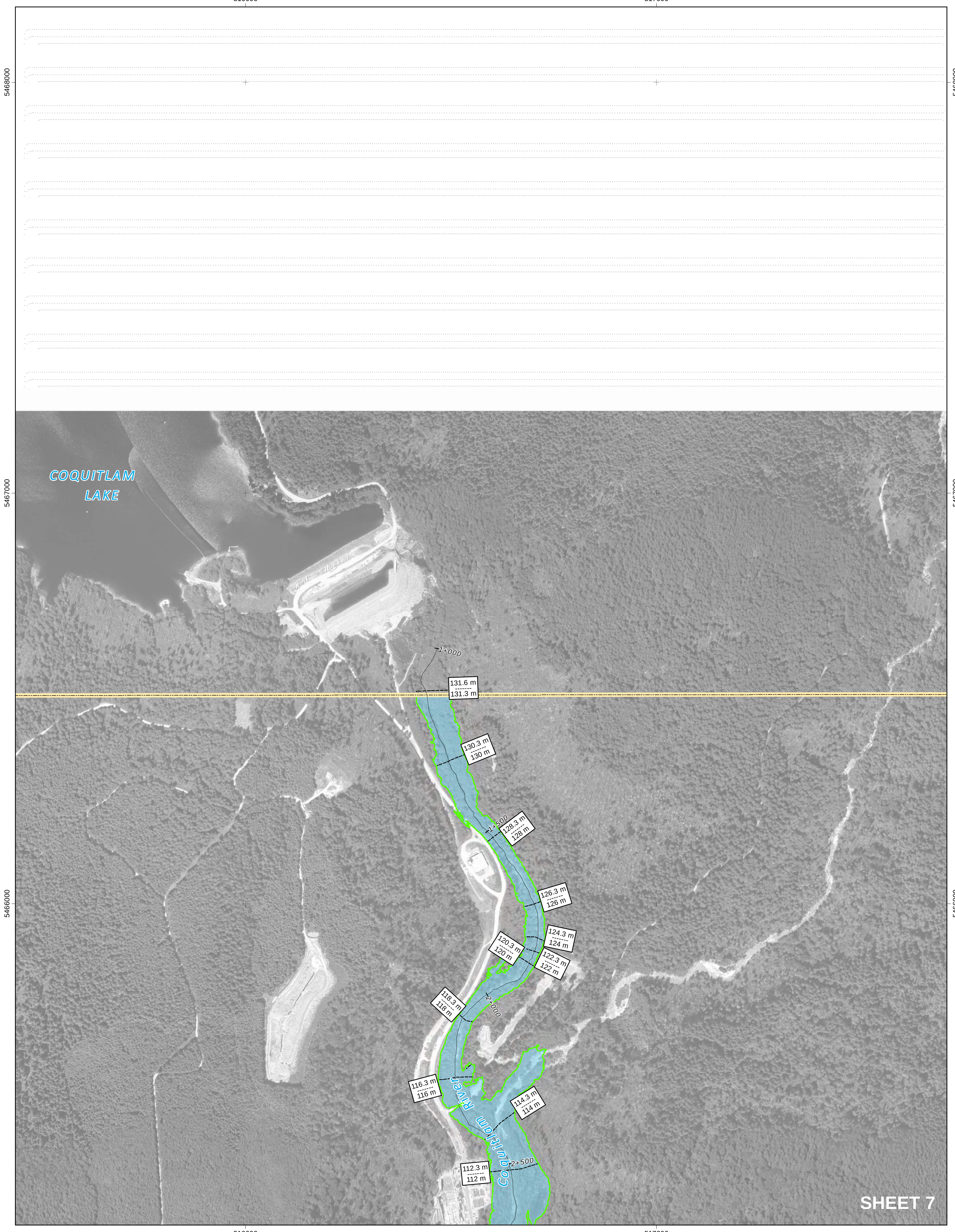
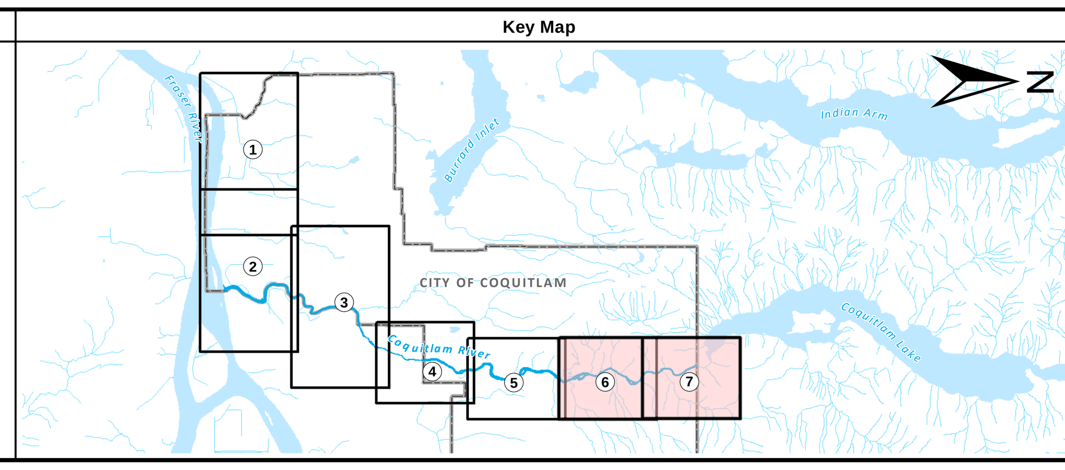




Notes	Legend
Fraser River design flood is approximately 500-year return period. Coquitlam River design flood is 200-year return period.	Municipal Boundary Dike Design Flood Level Flood Extent without Freeboard (Year 2100-No Climate Change) x.x m / x.x m — *with Freeboard* / *without Freeboard* — Flood Contour for Year 2014 Climate Change Scenario (with and without Freeboard)

Key Map



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City of Coquitlam
Coquitlam and Fraser Rivers Floodplain Mapping Year 2100

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Date	Project No.	Checked
August 2017	456-092	
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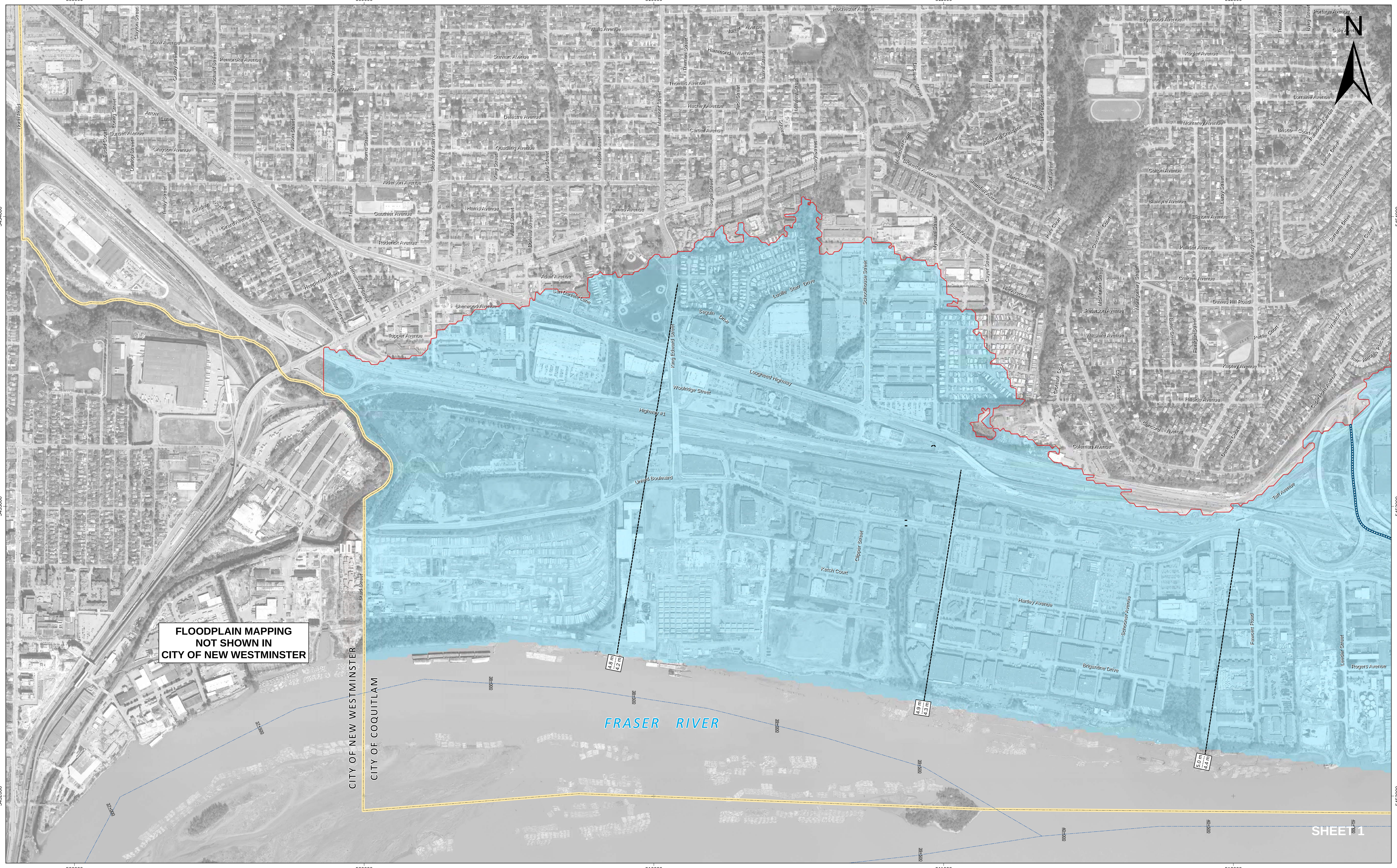
5 of 8	JL	



Notes

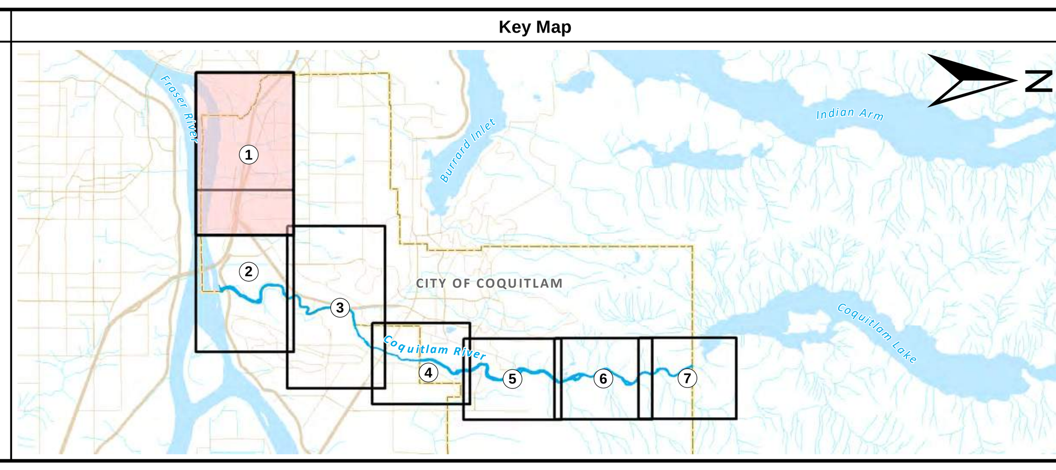
Fraser River design flood is approximately 500-year return period.
Coquitlam River design flood is 200-year return period.

Legend

- Municipal Boundary
- Dike
- Design Flood Level Flood Extent without Freeboard (Year 2200-No Climate Change)
- Flood Contour for Year 2014 Climate Change Scenario (with and without Freeboard) — x.x m *with Freeboard* / x.x m *without Freeboard*
- Mike11 Computational Network

Note: Mike 11 features from NHC 2008 report.

Key Map



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Coquitlam and Fraser Rivers Floodplain Mapping Year 2200

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March 2018	456-092	
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1 of 8	JL	

Notes

Fraser River design flood is approximately 500-year return period.
Coquitlam River design flood is 200-year return period.

Legend

Municipal Boundary

Dike

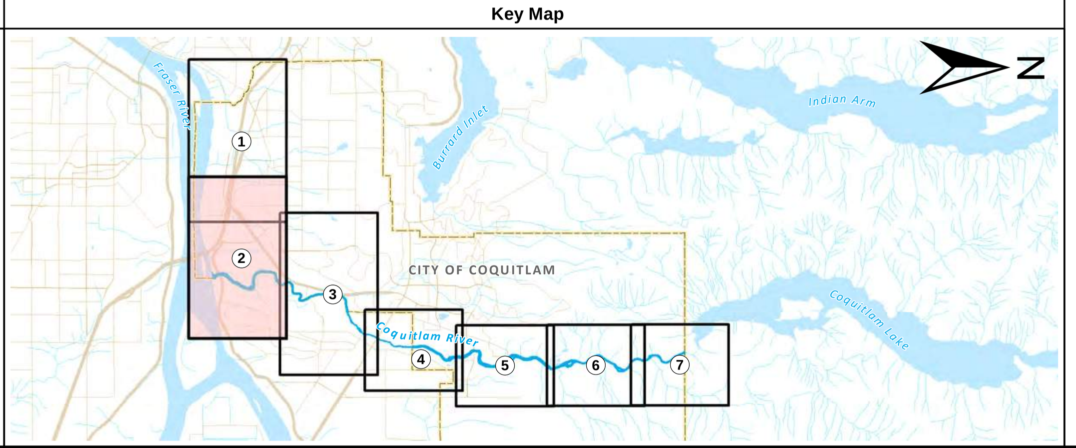
Design Flood Level Flood Extent without Freeboard (Year 2200-No Climate Change)

x.x m / x.x m — *with Freeboard* / *without Freeboard* — Flood Contour for Year 2014 Climate Change Scenario (with and without Freeboard)

Mike11 Computational Network

Note: Mike 11 features from NHC 2008 report.

Key Map



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City of Coquitlam
Coquitlam and Fraser Rivers Floodplain Mapping Year 2200

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March 2018	456-092	
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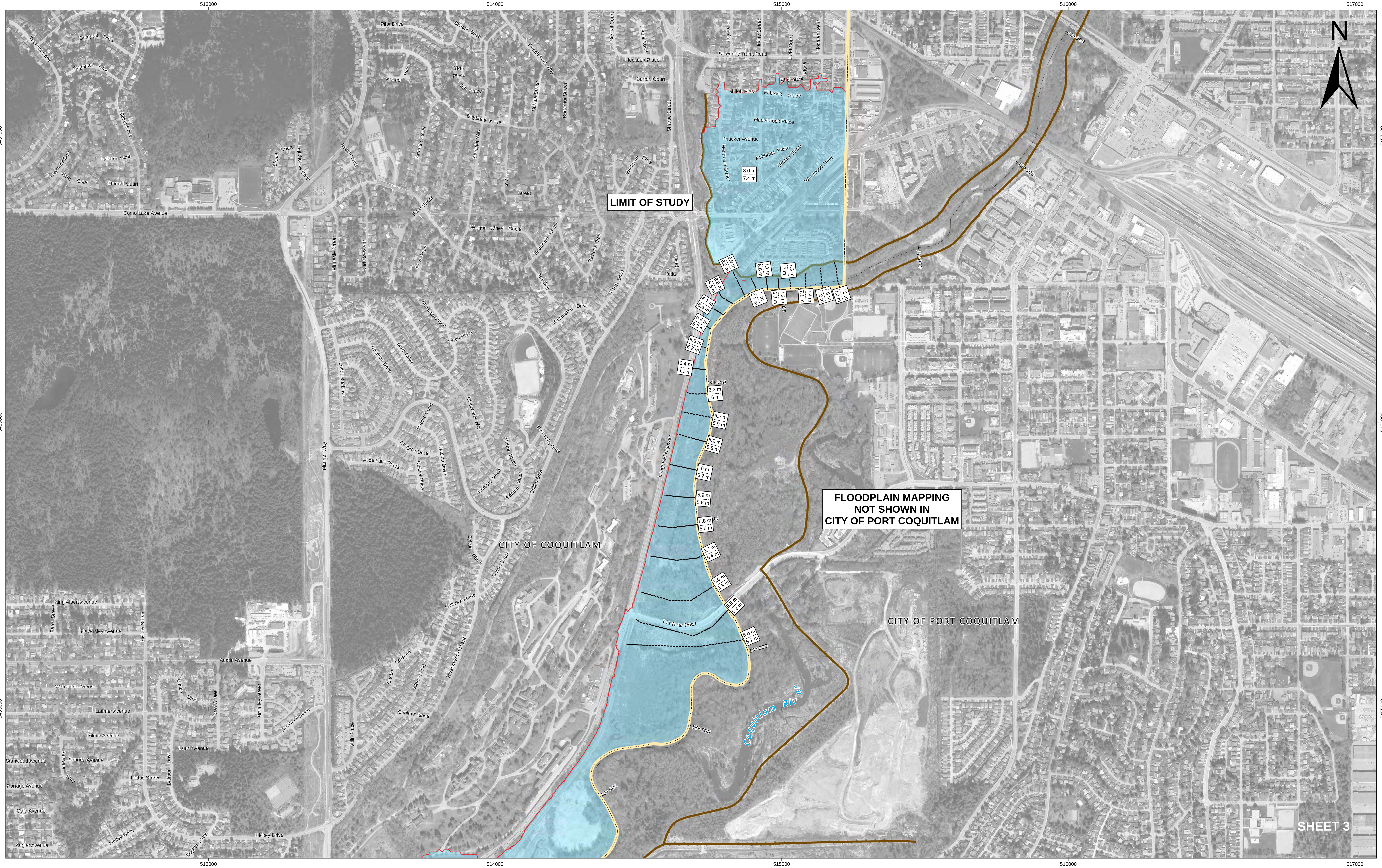
2 of 8	JL	



Notes
Fraser River design flood is approximately 500-year return period. Coquitlam River design flood is 200-year return period.

Legend

- Municipal Boundary
- Dike
- Design Flood Level Flood Extent without Freeboard (Year 2200-No Climate Change)
- x.x m / x.x m — *with Freeboard* / Flood Contour for Year 2014 Climate Change Scenario (with and without Freeboard) / *without Freeboard*
- Mike11 Computational Network

Note: Mike 11 features from NHC 2008 report.

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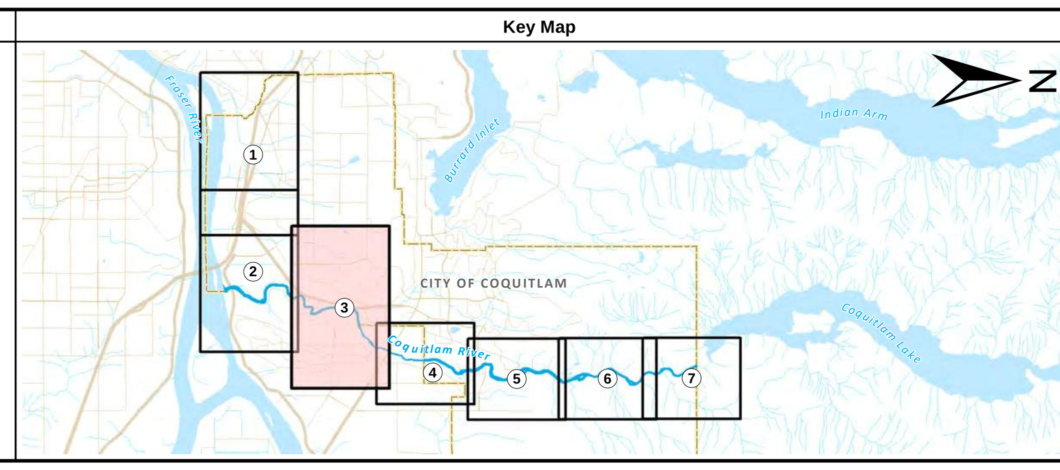

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City of Coquitlam
Coquitlam and Fraser Rivers Floodplain Mapping Year 2200

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March 2018	456-092	
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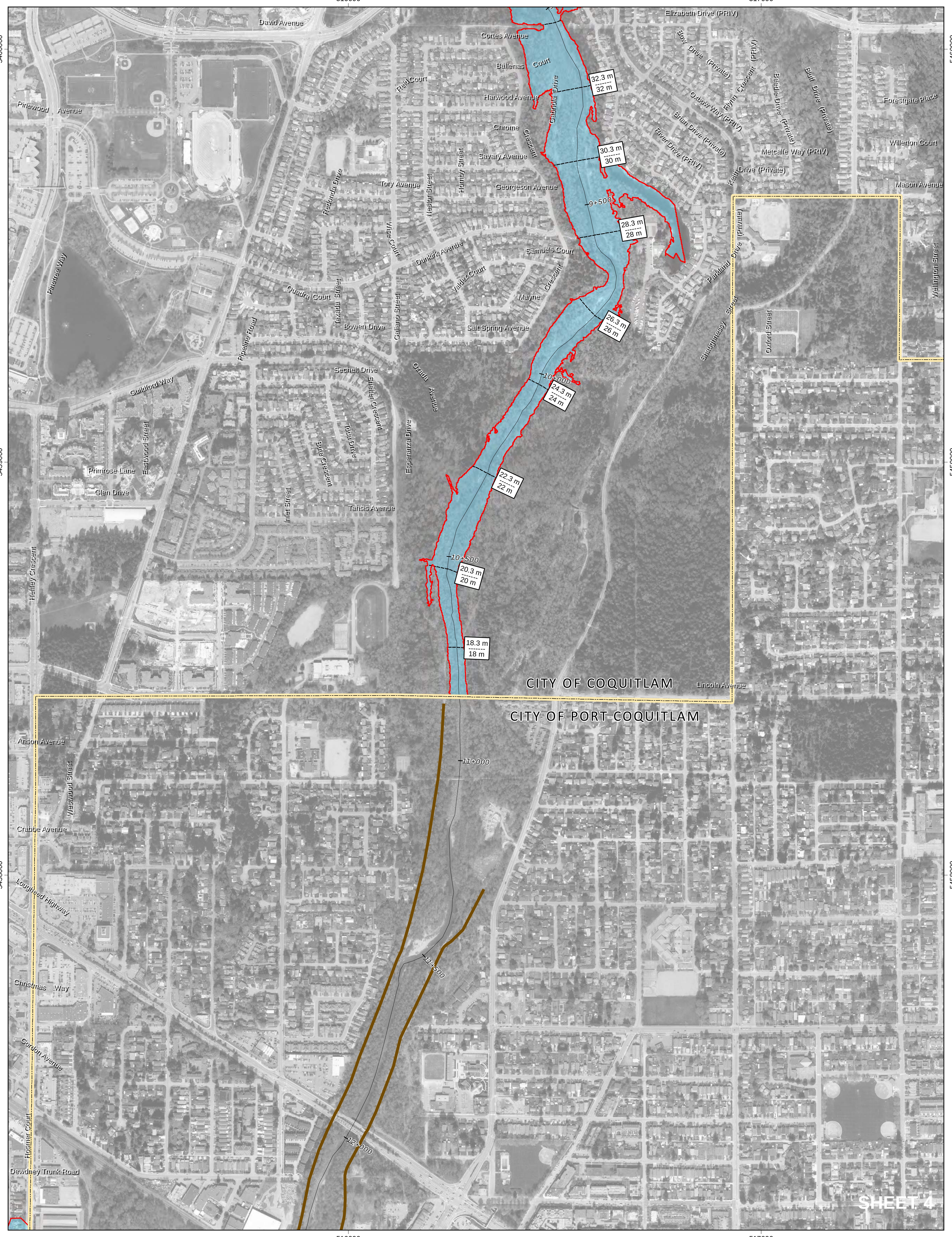

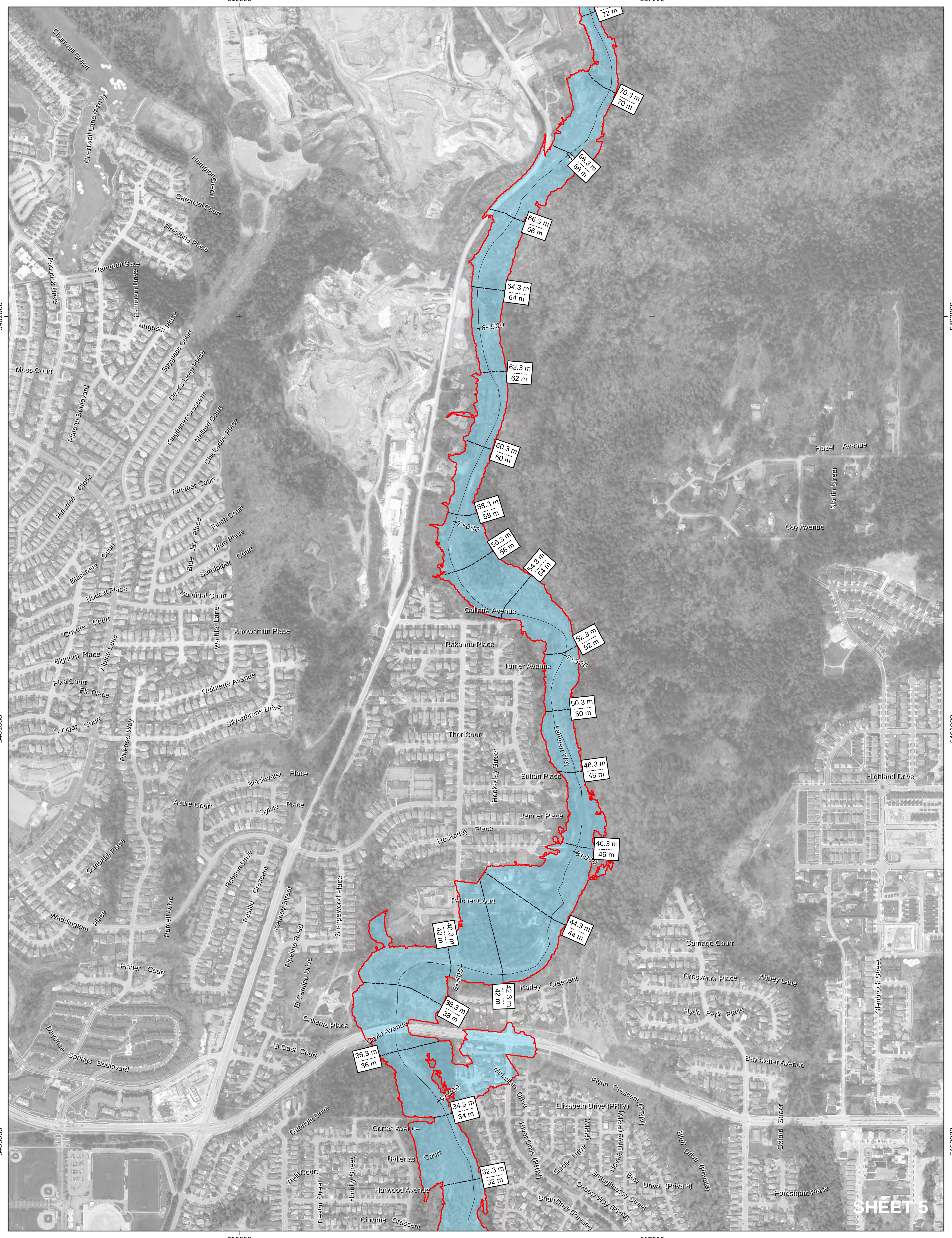

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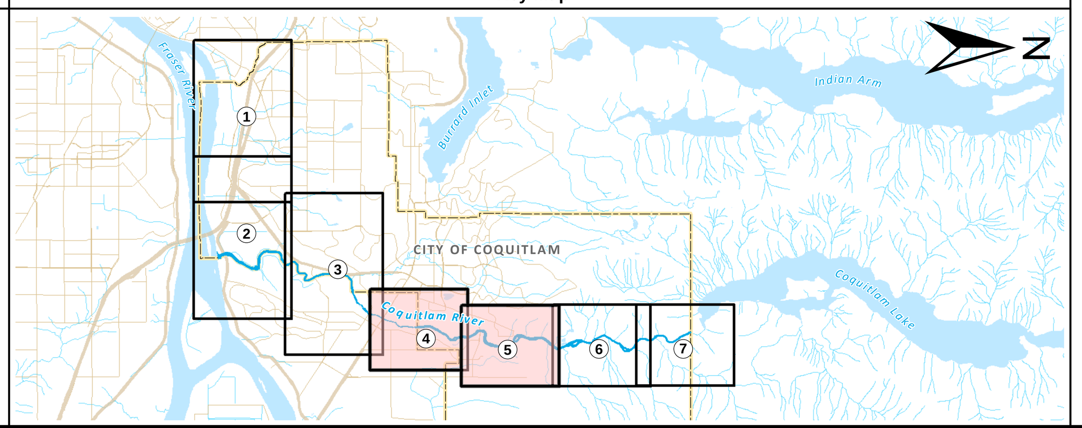
Notes	Legend
Fraser River design flood is approximately 500-year return period. Coquitlam River design flood is 200-year return period.	Municipal Boundary Dike Design Flood Level Flood Extent without Freeboard (Year 2200-No Climate Change) x.x m / x.x m — *with Freeboard* / *without Freeboard*: Flood Contour for Year 2014 Climate Change Scenario (with and without Freeboard)

Key Map



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City of Coquitlam
Coquitlam and Fraser Rivers Floodplain Mapping Year 2200

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August 2017	456-092	
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4 of 8	JL	

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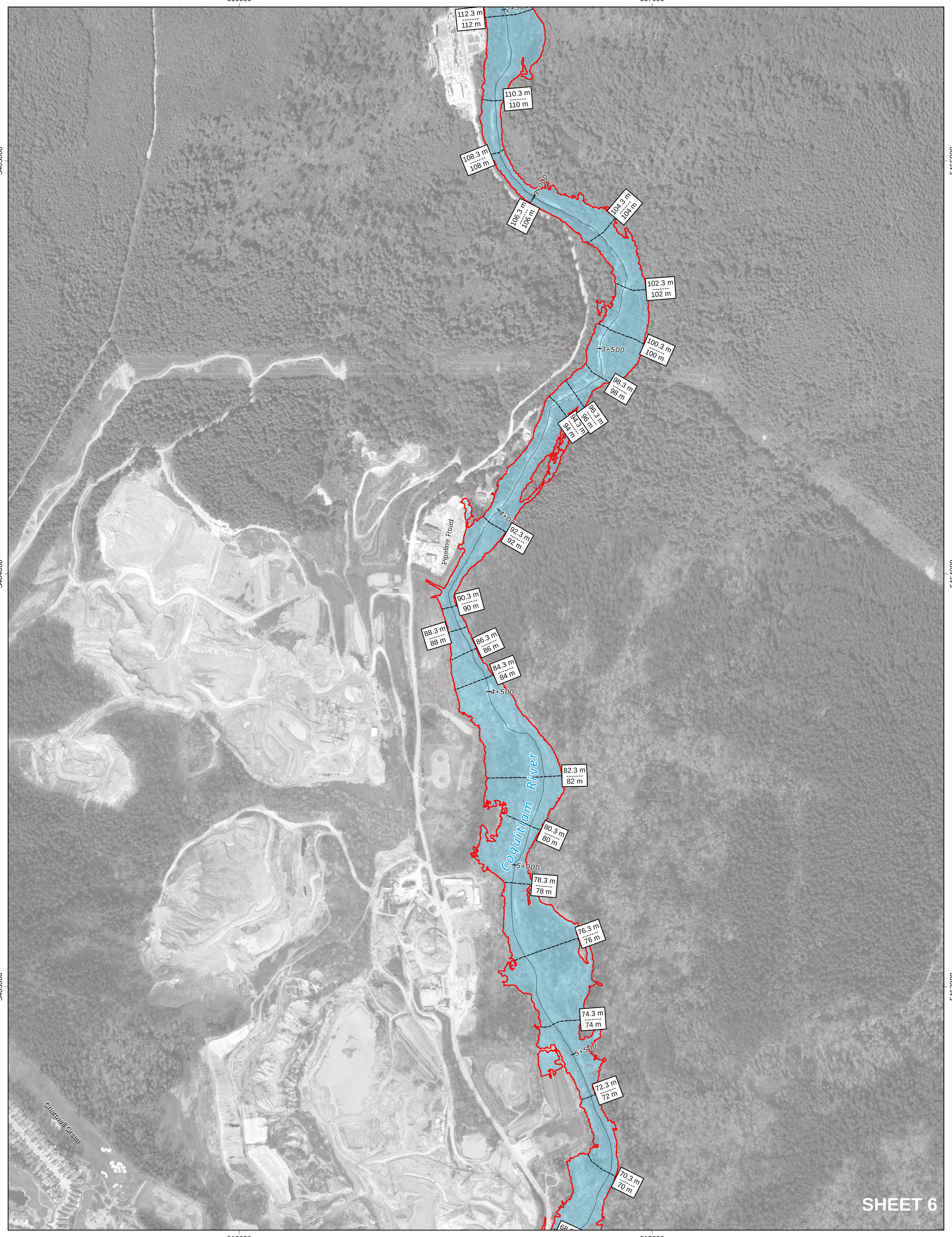
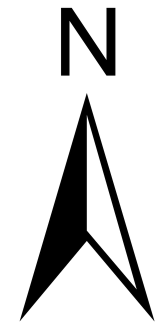
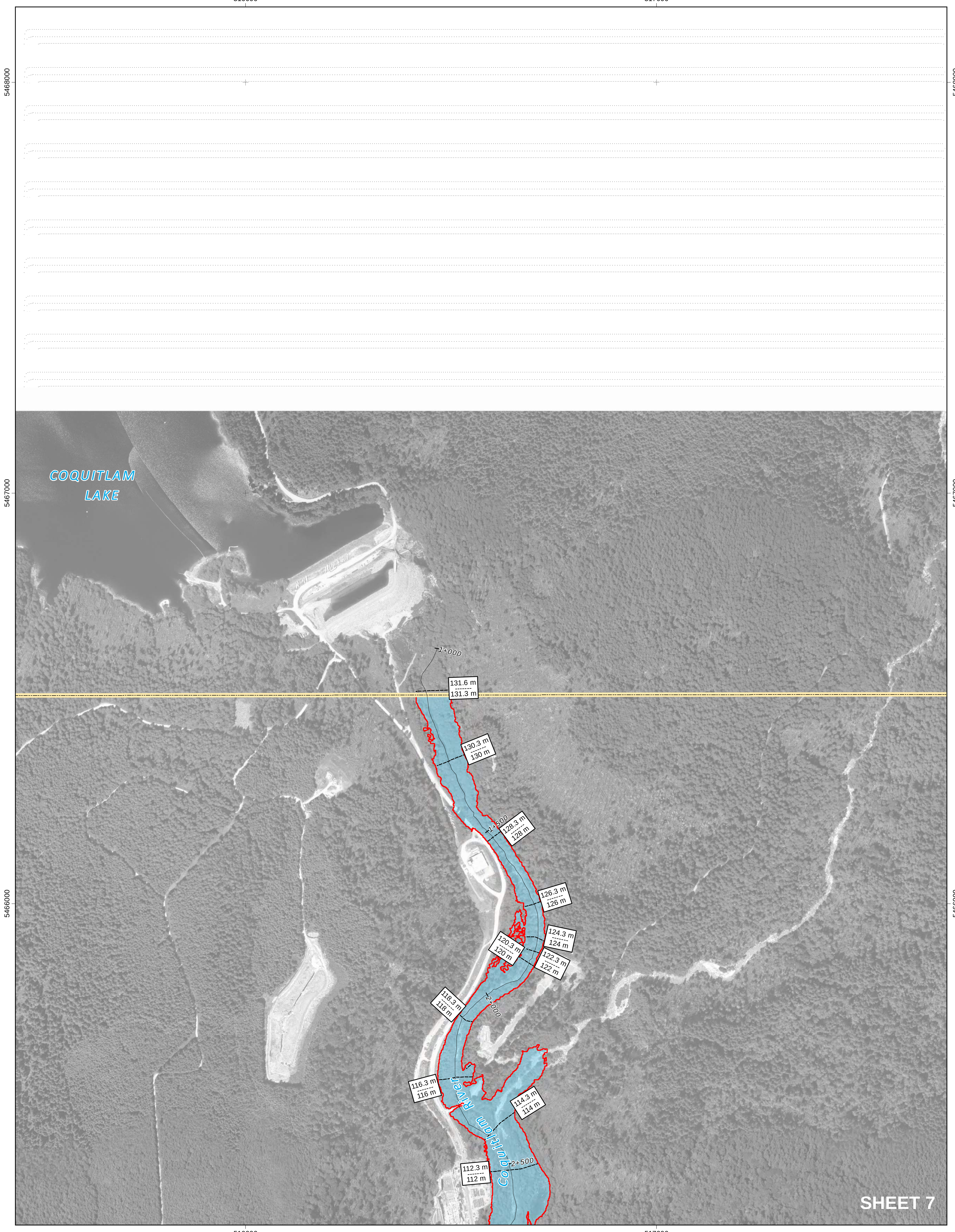






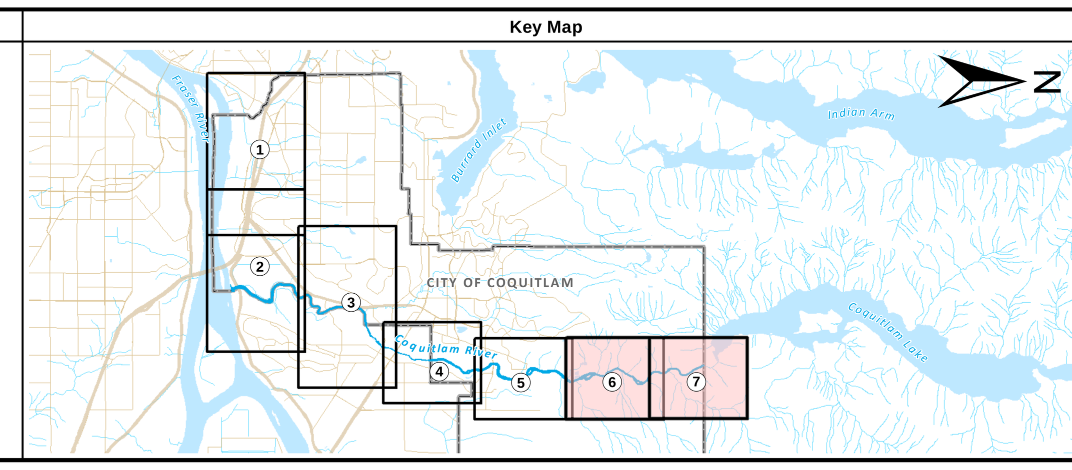
Notes

Fraser River design flood is approximately 500-year return period.
Coquitlam River design flood is 200-year return period.

Legend

- Municipal Boundary
- Dike
- Design Flood Level Flood Extent without Freeboard (Year 2200-No Climate Change)
- x.x m / x.x m — *with Freeboard* / Flood Contour for Year 2014 Climate Change Scenario (with and without Freeboard) / *without Freeboard*

Key Map



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City of Coquitlam
Coquitlam and Fraser Rivers Floodplain Mapping Year 2200

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August 2017	456-092	
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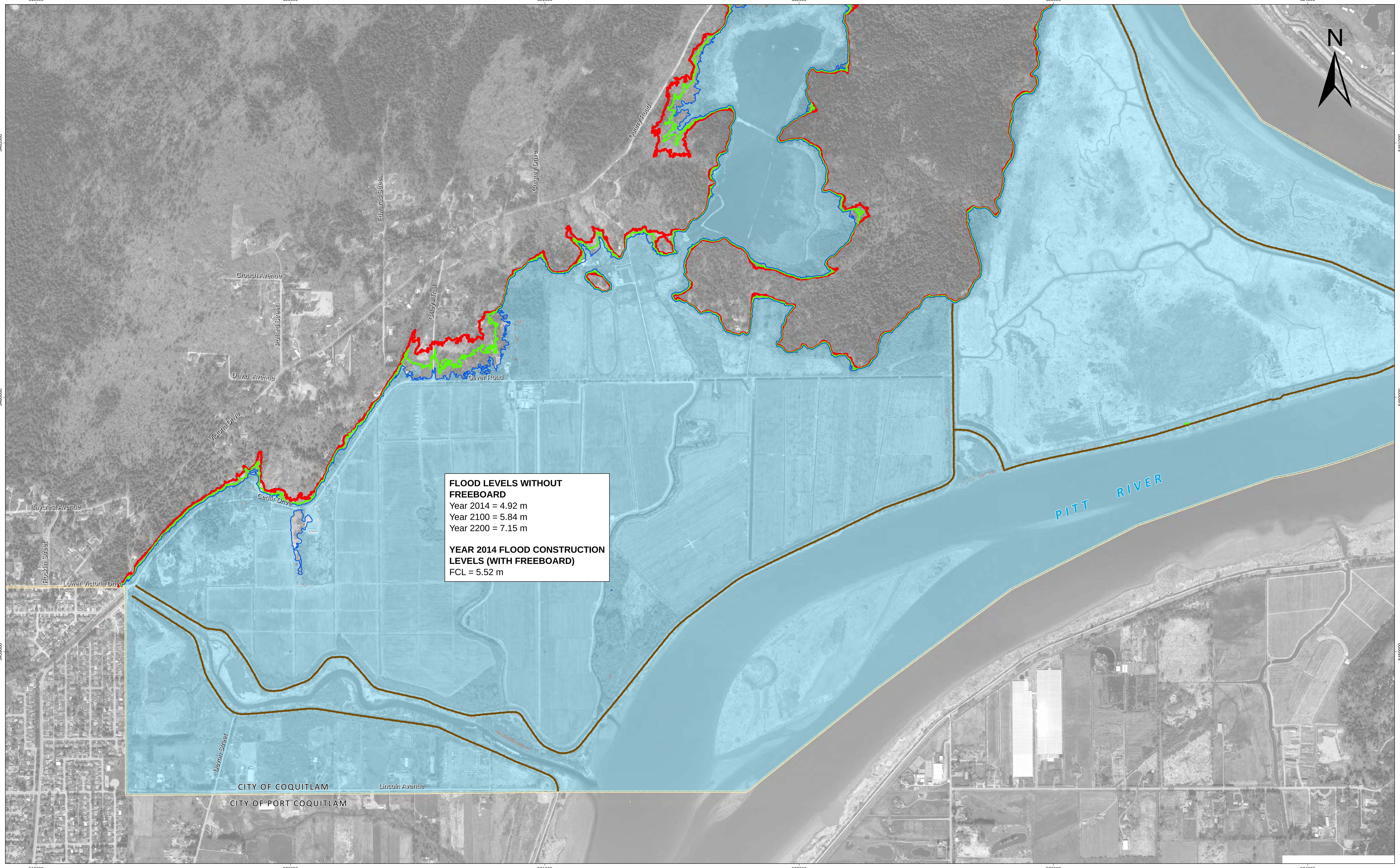
5 of 8	JL	



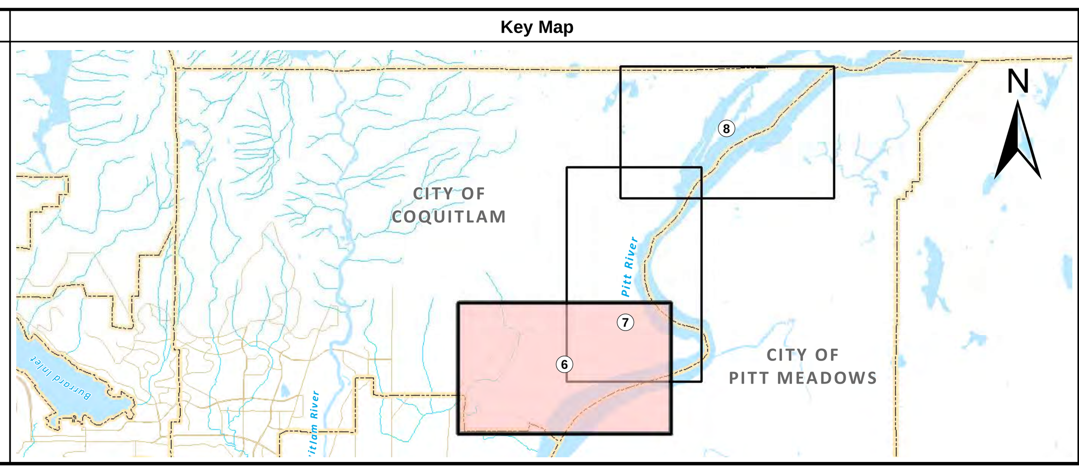
Notes

Pitt River design flood is based on the Fraser River freshet peak water levels (approximately 500-year return period).

Legend

- Municipal Boundary
- Dike
- Design Flood Level Flood Extent without Freeboard (Year 2014-No Climate Change)
- Flood Extent without Freeboard (Year 2100 Climate Change)
- Flood Extent without Freeboard (Year 2200 Climate Change)

Key Map



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City of Coquitlam
Pitt River Floodplain Mapping

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Date	Project No.	Checked
August 2017	456-092	
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6 of 8	JL	

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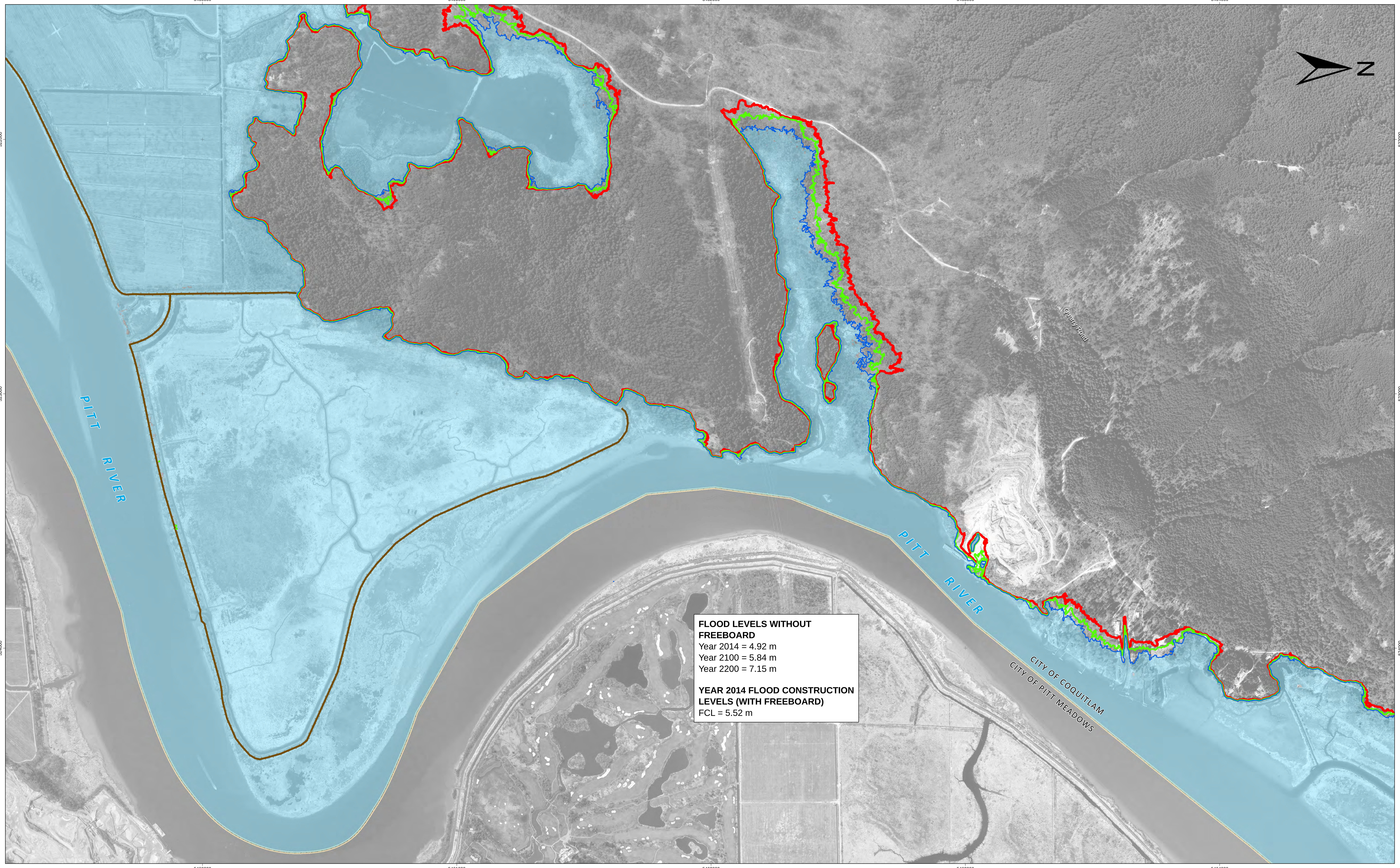


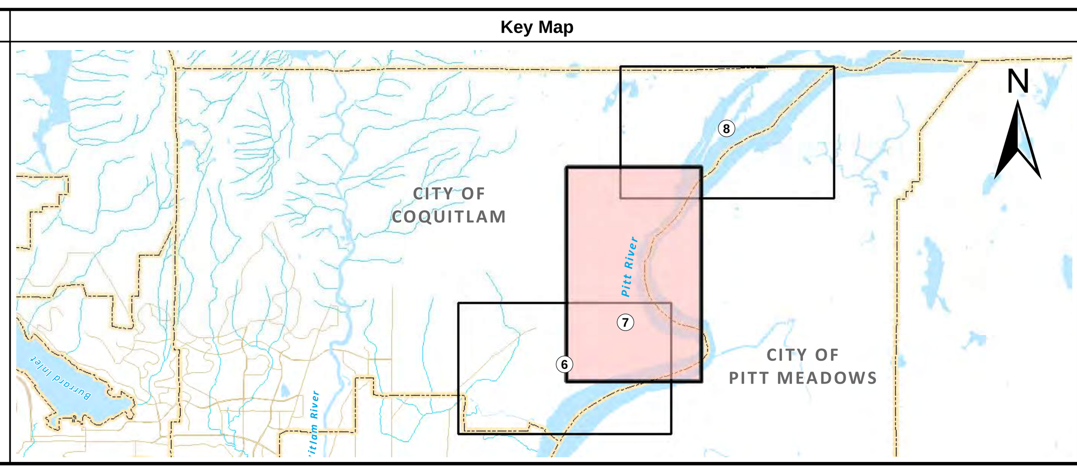
Notes

Pitt River design flood is based on the Fraser River freshet peak water levels (approximately 500-year return period).

Legend

- Municipal Boundary
- Dike
- Design Flood Level Flood Extent without Freeboard (Year 2014-No Climate Change)
- Flood Extent without Freeboard (Year 2100 Climate Change)
- Flood Extent without Freeboard (Year 2200 Climate Change)

Key Map



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City of Coquitlam
Pitt River Floodplain Mapping

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Date	Project No.	Checked
August 2017	456-092	
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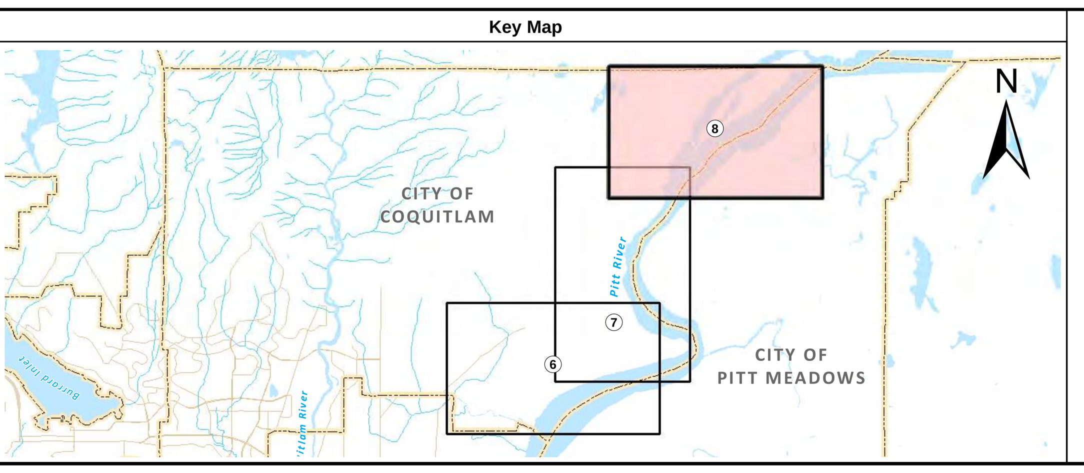
Notes

Pitt River design flood is based on the Fraser River freshet peak water levels (approximately 500-year return period).

Legend

- Municipal Boundary
- Dike
- Design Flood Level Flood Extent without Freeboard (Year 2014-No Climate Change)
- Flood Extent without Freeboard (Year 2100 Climate Change)
- Flood Extent without Freeboard (Year 2200 Climate Change)

Key Map



KERR WOOD LEIDAL
consulting engineers

City of Coquitlam
Pitt River Floodplain Mapping

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August 2017	456-092	
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Appendix B

Design Flood Levels

Appendix B. Design Flood Levels

River	Chainage (m)	Design Flood Level (m GSC incl. freeboard)		
		Year 2014	Year 2100	Year 2200
Coquitlam River	Coquitlam Lake Dam			
	1+000	132.73	132.88	133.01
	1+290	130.37	130.56	130.74
	1+420	129.19	129.39	129.58
	1+638	127.22	127.40	127.56
	1+780	125.36	125.51	125.65
	2+256	117.85	118.01	118.17
	2+731	110.35	110.52	110.69
	3+105	105.12	105.27	105.43
	3+439	100.45	100.58	100.72
	3+773	95.12	95.25	95.38
	4+108	89.80	89.92	90.04
	4+442	84.48	84.59	84.70
	4+784	80.88	80.99	81.10
	5+127	77.28	77.39	77.49
	5+469	73.68	73.79	73.89
	5+762	70.73	70.84	70.94
	6+054	67.77	67.89	68.00
	6+347	64.81	64.94	65.05
	6+698	61.18	61.30	61.41
	7+049	57.55	57.66	57.77
	7+380 (Gallette Avenue Alignment)	53.68	53.79	53.89
	7+415	53.27	53.38	53.48
	7+733	49.05	49.19	49.33
	7+969	46.47	46.58	46.68
	8+137	44.74	44.84	44.93
	8+362	42.86	42.98	43.09
	8+515	40.48	40.59	40.69
	8+723	37.71	37.84	37.96
	8+790 (David Avenue Bridge)	36.90	37.03	37.15
	8+806	36.71	36.83	36.96
	9+040	34.30	34.45	34.59
	9+316	31.10	31.22	31.34
	9+606	27.99	28.13	28.27
	9+759	26.78	26.92	27.06
	9+890 (Salt Spring Avenue Alignment)	25.59	25.76	25.92
	10+102	23.67	23.88	24.07
	10+311	22.04	22.22	22.38
	10+520	20.40	20.55	20.70
	10+858 (Port Coquitlam Boundary)	16.80	16.94	17.08

Appendix B. Design Flood Levels

River	Chainage (m)	Design Flood Level (m GSC incl. freeboard)		
		Year 2014	Year 2100	Year 2200
Coquitlam River - Port Coquitlam Section	10+858 (Port Coquitlam Boundary)	16.80	16.94	17.08
	11+049	14.76	14.90	15.03
	11+443	12.31	12.47	12.63
	11+721	11.05	11.23	11.40
	11+944	10.24	10.41	10.57
	11+949 (Lougheed Hwy Westbound)	10.21	10.39	10.54
	11+954	10.19	10.36	10.51
	11+967	10.14	10.31	10.47
	11+973 (Lougheed Hwy Eastbound)	10.12	10.29	10.44
	11+980	10.10	10.26	10.42
	12+107	9.73	9.91	10.06
	12+214	9.51	9.68	9.84
	12+372	8.90	9.07	9.23
	12+386 (Railway Bridge North)	8.82	8.99	9.15
	12+390	8.80	8.97	9.12
	12+397 (Railway Bridge South)	8.78	8.96	9.11
	12+402	8.77	8.95	9.10
	12+414	8.71	8.88	9.04
	12+419 (Kingsway Bridge)	8.68	8.85	9.01
	12+424	8.64	8.82	8.98
	12+517	8.51	8.70	8.87
	12+634 (McAllister Ped. Bridge)	8.41	8.60	8.78
	12+684	8.37	8.56	8.74
	12+958	8.08	8.28	8.46
	13+210	7.77	7.95	8.14
	13+310 (Port Coquitlam Boundary)	7.59	7.77	8.01

Appendix B. Design Flood Levels

River	Chainage (m)	Design Flood Level (m GSC incl. freeboard)		
		Year 2014	Year 2100	Year 2200
Coquitlam River	13+310 (Port Coquitlam Boundary)	7.59	7.77	8.01
	13+431 (Maple Creek Mouth)	7.38	7.56	7.84
	13+468	7.32	7.49	7.79
	13+643 (Scott Creek Mouth)	6.90	7.06	7.79
	13+729	6.72	6.89	7.79
	13+967	6.39	6.58	7.79
	14+190	6.13	6.43	7.78
	14+550	5.77	6.43	7.78
	14+808	5.56	6.43	7.78
	14+818 (Pitt River Road Bridge)	5.56	6.43	7.78
	14+830	5.56	6.43	7.78
	14+840	5.49	6.41	7.78
	15+074	5.34	6.41	7.78
	16+139	5.34	6.41	7.78
	16+411	5.34	6.41	7.77
	16+733	5.33	6.41	7.77
	17+430	5.33	6.41	7.76
	18+022	5.33	6.41	7.75
	18+378	5.33	6.41	7.75
	18+784	5.33	6.40	7.74
	18+794 (Mary Hill Bypass Bridge)	5.29	6.40	7.73
	18+806	5.25	6.40	7.73
	18+974 (Fraser River)	5.25	6.40	7.73
Fraser River	42+617 (Coquitlam River)	5.25	6.40	7.73
	42+407	5.21	6.39	7.72
	42+300 (Port Mann Bridge)	5.20	6.36	7.69
	41+882	5.16	6.25	7.55
	41+502	5.12	6.17	7.47
	41+158	5.08	6.12	7.42
	40+766	5.03	6.08	7.36
	40+332	4.99	6.11	7.41
	39+926	4.95	6.12	7.42
	39+490	4.91	5.93	7.24
	39+470 (Como Creek Mouth)	4.91	5.93	7.24
	39+151	4.86	5.98	7.28
	38+759	4.82	5.90	7.19
	38+430 (Nelson Creek Mouth)	4.79	5.92	7.20
	38+352	4.78	5.92	7.20
	37+939	4.73	5.87	7.15
	37+528	4.69	5.84	7.13
	New Westminster Boundary			
Pitt River	Pitt Lake			
	All chainages	5.52	6.44	7.75
	Fraser River			