Skeena River and Bulkley River Flood Study

Floodplain Inundation Mapping Report

Prepared for:

The Village of Hazelton

April 13, 2021

Internal Ref: 675878 › Final › V1

SNC·LAVALIN

Signature Page

Prepared By:

C. B. ROBERTSON
46521
13 Apr 2021

C. Beth Robertson, P.Eng.
Hydrotechnical Engineer
Environment & Geoscience
Engineering, Design & Project Management

Apr. 13 '21

Winston Wade, P.Eng.
Hydrotechnical Engineer
Environment & Geoscience
Engineering, Design & Project Management

Reviewed By:

Karisa Petho, B.Jour., EP
Project Manager
Environment & Geoscience
Engineering, Design & Project Management

Ahmed Bouayad, P.Eng.
Engineer
Clean Power
Power

Executive Summary

As requested, SNC-Lavalin Inc. (SNC-Lavalin) has conducted a Skeena River and Bulkley River Flood Study and prepared this Flood Inundation Mapping report for the Village of Hazelton (Village) and Gitanmaax Band (Band). This work was completed under an agreement with the Village and was executed July 23, 2020.

The purpose of this report is to map potential inundation that may be experienced by the Village and Band in the event Skeena River and Bulkley River experience 200-year flood flows with an allowance for climate change.

This work was completed through collection of publicly available data, information provided by the Village and Band, anecdotal flood evidence gathered from reports and residents, hydrometric data for Skeena River and Bulkley River, topographic and bathymetric data surveyed along Skeena River and Bulkley River, and recent LiDAR data for the area. This information was processed to evaluate how climate change could potentially affected 200-year flood flows and generate a calibrated and validated two-dimensional hydraulic model using Hydraulic Engineering Center River Analysis System (HEC-RAS).

Results from the modelling were used to produce flood inundation maps for the 200-year flood with allowance for climate change and 0.6 m of freeboard. Along Skeena River, results demonstrated overtopping of the existing dike structures and an inundation of Government Street, the sewer lift station (Ferry Road), school playing field, residents along Cunningham Street and River Road, a portion of River Road, and ‘Ksan campground and facilities. Along Bulkley River, results demonstrated inundation of ‘Ksan historical village and much of the Anderson Flats Provincial Park.

Based on the flood inundation presented within this report, SNC-Lavalin directs the Village and Band to refer to our *Skeena River and Bulkley River Flood Study – Floodplain Mitigation Plan* (SNC-Lavalin 2021) prepared under separate cover for further discussion on flood hazards, flood risks, and recommendations for future planning and flood mitigation.

Table of Contents

Signature Page

Executive Summary i

1 Introduction 1

1.1 Setting 1
1.2 History of Floods 3

2 Project Description 5

2.1 Objective 5
2.2 Guidelines 5

3 Flood Inundation Assessment 7

3.1 Data Collection 7
3.1.1 Review Existing Information 7
3.1.2 Acquisition of LiDAR Data 7
3.1.3 Site Survey and Inspection 8
3.2 Hydrological Analysis 10
3.2.1 Skeena River Flood Peaks 10
3.2.2 Bulkley River Flood Peaks 14
3.2.3 Skeena River versus Bulkley River – Timing of Peaks 16
3.2.4 Skeena River and Bulkley River Daily Flows 16
3.3 Hydraulic Analysis 16
3.3.1 Geometry 17
3.3.1.1 Roughness Coefficients 17
3.3.2 Boundary Conditions 23
3.3.3 Calibration and Validation 24
3.3.3.1 Calibration - August 27, 28, 29, 2020 24
3.3.3.2 Validation – June 7, 2007 Event 27
3.3.3.3 June 1, 1936 and June 12, 1972 Events 29

Table of Contents (Cont'd)

3.3.4 Design Flow Model Simulation ... 32
3.3.5 Sensitivity Analysis ... 34
3.3.5.1 Downstream Boundary Condition ... 34
3.3.5.2 Inflow Boundary Condition ... 36
3.3.5.3 Channel Roughness ... 37
3.3.5.4 Overbank Roughness ... 39
3.3.6 Summary and Freeboard ... 40
3.4 Flood Inundation Mapping ... 40
3.4.1 Base Map Preparation ... 41
3.4.2 Skeena River 200-year ... 41
3.4.3 Bulkley River 200-year ... 41
3.4.4 Limitations ... 41
4 Summary 42
5 Notice to Reader 43
6 References 44

In-Text Figures

Figure 1-1: The Village of Hazelton and Gitanmaax Terraces. ... 2
Figure 1-2: Chronological Summary of Significant Skeena River and Bulkley River Floods. ... 4
Figure 2-1: Overview of Study Area. ... 6
Figure 3-1: Surveyed Cross Sections. ... 9
Figure 3-2: Water Survey of Canada Stations Used in Study. ... 13
Figure 3-3: Bulkley River WEL for 207 m^3/s (August 27, 2020), Simulated and Observed. ... 25
Figure 3-4: Skeena River WEL for 1336 M3/S Upstream and 1543 M3/S Downstream of Bulkley River Confluence (August 27, 2020), Simulated and Observed. ... 25
Figure 3-5: Skeena River WEL for 1186 m3/s Upstream and 1385 m3/s Downstream of Bulkley River Confluence (August 28, 2020), Simulated and Observed. ... 26
Figure 3-6: Bulkley River WEL for 193 m3/s (August 29, 2020), Simulated and Observed. ... 26
Figure 3-7: Skeena River Profile – 200-year (plus Climate Change) Simulated WEL. ... 33
Figure 3-8: Bulkley River Profile – 200-year (plus climate change) Simulated WEL. ... 33
Figure 3-9: Skeena River Downstream Boundary Sensitivity Analysis. ... 35
Figure 3-10: Bulkley River Downstream Boundary Sensitivity Analysis. ... 35
Figure 3-11: Skeena River Inflow Boundary Condition Sensitivity Analysis. ... 36
Figure 3-12: Bulkley River Inflow Boundary Condition Sensitivity Analysis. ... 37

Table of Contents (Cont'd)

In-Text Figures (Cont'd)

Figure 3-13: Skeena River Channel Manning n Sensitivity Analysis. 38
Figure 3-14: Bulkley River Channel Manning n Sensitivity Analysis. 38
Figure 3-15: Skeena River Overbank Manning *n* Sensitivity Analysis. 39
Figure 3-16: Bulkley River Overbank Manning *n* Sensitivity Analysis. 40

In-Text Tables

Table 3-1: Water Survey of Canada Stations used to Generate an Extended Period of Record for Skeena River at Glen Vowell 11
Table 3-2: Flood peak discharge estimates for Skeena River at Glen Vowell 11
Table 3-3: Water Survey of Canada Stations used to Generate an Extended Period of Record for Bulkley River Near Hazelton 15
Table 3-4: Flood peak discharge estimates for Bulkley River near Hazelton 15
Table 3-5: Estimated Daily Flows during the Survey 16
Table 3-6: Average Absolute Difference in Simulated WEL and Observed WEL 24
Table 3-7: Estimated High-water Marks June 7, 2007 (Skeena 5209 m^3/s; Bulkley 2020 m^3/s) 28
Table 3-8: Estimated High-water Marks June 1, 1936 (Skeena 6969 m^3/s; Bulkley 1564 m^3/s) 31
Table 3-9: Estimated High-water Marks June 12, 1972 (Skeena 6202 m^3/s; Bulkley 1702 m^3/s) 31
Table 3-10: Estimated High-water Marks June 12, 1972 (Skeena 5537 m^3/s; Bulkley 1702 m^3/s) 32
Table 3-11: Difference in Simulated WELs using Normal Depth = 0.0009 and Normal Depth = 0.0013 ... 34
Table 3-12: Difference in Simulated WELs using 10% Higher and Lower Flows 36
Table 3-13: Difference in Simulated WELs using 10% Higher and Lower Channel Manning n's. 37
Table 3-14: Difference in Simulated Wels using 15% Higher and Lower Overbank Manning *n*'s. 39

Appendices

A: Flood Inundation Map – 200-Year Flow with Climate Change Allowance and 0.6 m Freeboard
B: Flood Inundation Map – 2-Year Flow with Climate Change Allowance
C: Flood Inundation Map – 25-Year Flow with Climate Change Allowance

P:\CP\VILLAGE OF HAZELTON\675878\50_DEL\53_FINAL_RPTS_20210413_675878_RPT_FLOODPLAIN_MAPPING_FINAL.DOCX

1 Introduction

SNC-Lavalin Inc. (SNC-Lavalin) is pleased to provide this Skeena River and Bulkley River Flood Study - Flood Inundation Mapping report to the Village of Hazelton (Village) and Gitanmaax Band (Band) as proposed in our request for proposal response entitled *Request for Proposal: Flood Risk Assessment, Flood Mapping, and Flood Mitigation Plan 2019-01, Issue Date: October 15, 2019,* and submitted November 15, 2019.

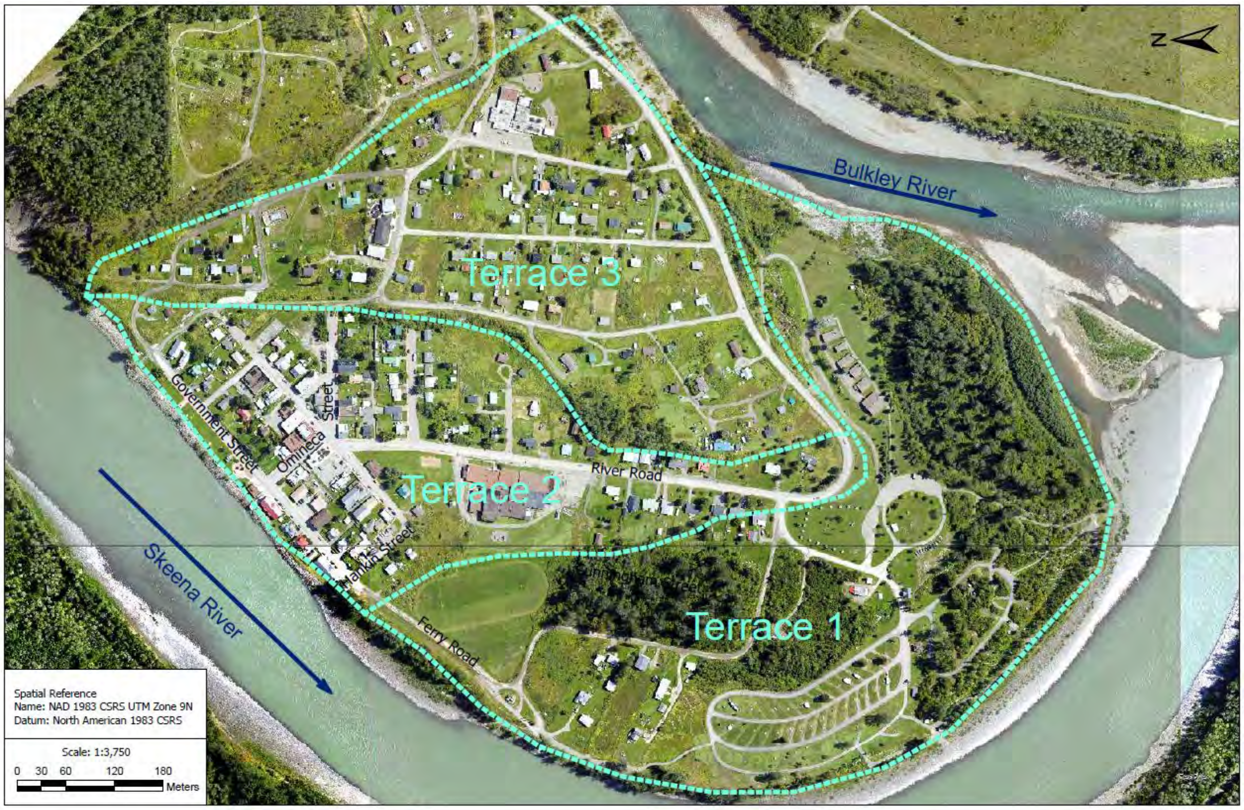
The village of Hazelton, Gitanmaax, and surrounding regions have experienced significant flood events, including most recently in June 2007 when several communities had to evacuate the area. As a result, the Village and Band have set a priority to assess the nature of future floods due to climate change to understand the potential impacts. Both organizations are stakeholders and are keen to be informed of flood risks to the community in order to assist decision makers on flood mitigation matters. To succeed in their mandate, the Village and Band require updated flood inundation mapping with an added consideration of climate change.

This report includes an assessment of flood inundation attributed to Skeena River and Bulkley River that flow adjacent to the village of Hazelton and Gitanmaax lands. The Village and Band seek to anticipate future mitigation projects to protect community assets within their boundaries. As such, this report should be reviewed in conjunction with our *Skeena River and Bulkley River Flood Study – Flood Mitigation Plan Report* (SNC-Lavalin 2021), which is provided under separate cover and includes a flood hazard assessment, qualitative risk assessment, and proposed mitigation options.

1.1 Setting

The village of Hazelton and Gitanmaax are both situated at the confluence of Skeena River and Bulkley River. The communities are built on a series of terraces formed by these rivers (Turner, Van Heek, and Dodd 2010) and are shown in Figure 1-1. The lowest terrace (Terrace 1) includes low lying forested areas and sloughs, as well as ‘Ksan Historical Village and campground, several residences, and a sewer pump station. It was reported that local inhabitants of this lowest terrace are accustomed to frequent flooding (Reginal District of Kitimat-Stikine [RDKS] 1974). The next terrace (Terrace 2) is about 2 m higher and includes downtown village of Hazelton businesses and residents. Limited flooding was reported on this terrace (RDKS 1974). The highest terrace (Terrace 3) is about 2 m higher (includes mostly residents near Bench Road) and flooding is not considered to be a hazard at this location (RDKS 1974).

Figure 1-1: The Village of Hazelton and Gitanmaax Terraces.



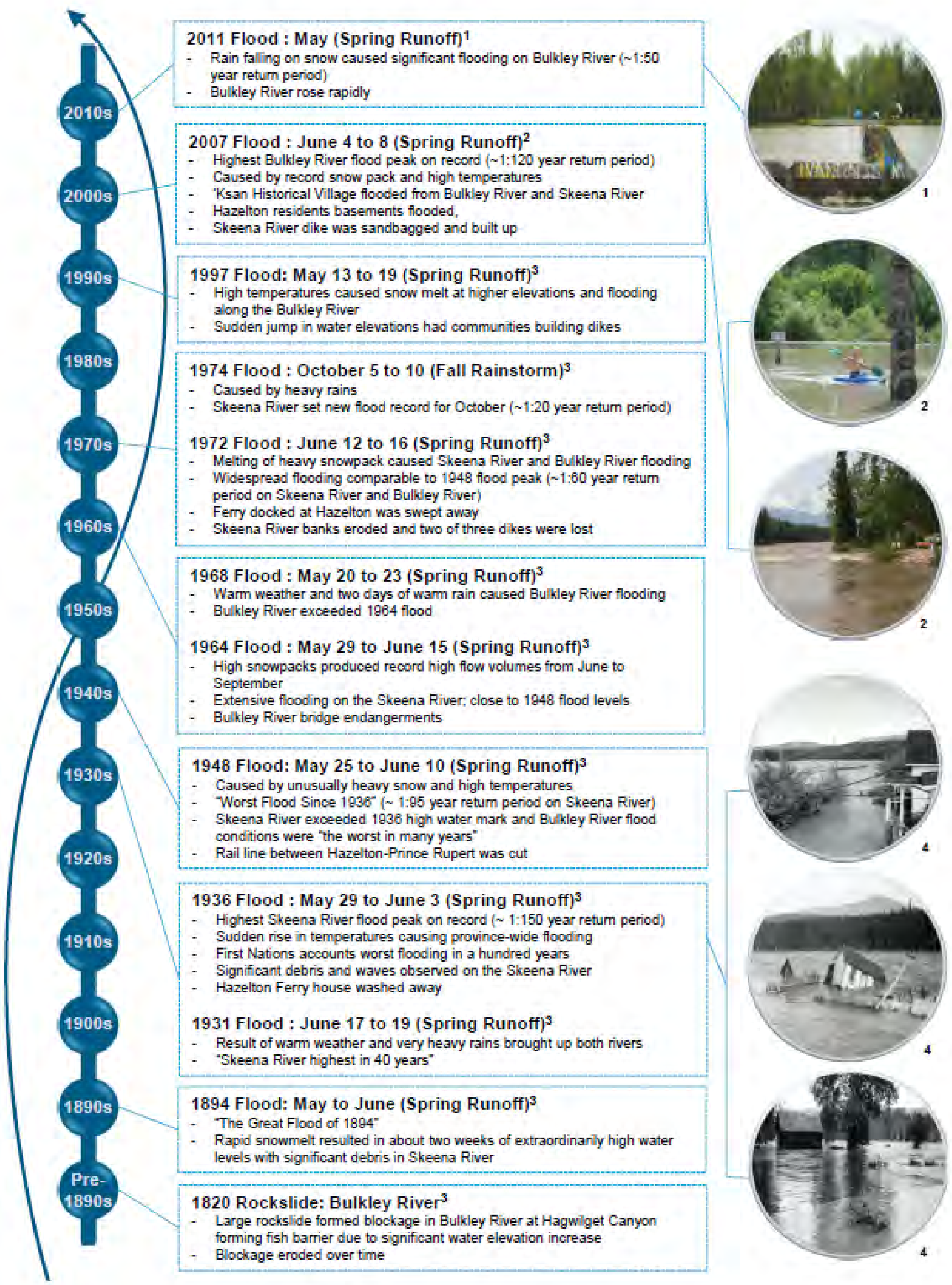
The Skeena River, the second largest river located entirely in British Columbia (BC), originates in the province's northwest Skeena Mountains. From its headwaters, the Skeena River generally flows south through several mountain ranges and rolling hills before reaching the village of Hazelton and Gitanmaax. The drainage area of the Skeena River just upstream of the village of Hazelton is about 26,000 km^2. Flooding flows are dominated by spring snowmelt runoff with major floods being combined with high temperatures and rainfall. There are occasional records of flood peaks during fall and winter storms with rain falling on limited snowpack (Ministry of Environment Land and Parks [MOELP] 1993). The floodplain of the Skeena River at the village of Hazelton is formed by alluvial sediments deposited in the overbank zone during flood events. The Skeena River exhibits a meandering planform and migrates laterally across its floodplain over time when not confined by bank protection (such as riprap rock at the village of Hazelton) or natural bedrock. Bank erosion is typically observed on the outside bends through a meander, while sediment deposition occurs on the inside bends in the form point bars, which was observed in the study reach. During low flow periods, a large portion of the point bars sit above the water level as majority of the flow concentrates within the deeper portions of the channel, however, as water level rises during a flood event, the point bars will become inundated.

The Bulkley River, a major tributary of the Skeena River, originates near Bulkley Lake on the Nechako Plateau. From its headwaters, the Bulkley River generally flows northwest adjacent to the Hazelton Mountains and Skeena Mountains and through Bulkley Canyon to Hagwilget Canyon before meeting up with the Skeena River at the village of Hazelton and Gitanmaax. The drainage area of the Bulkley River just upstream of 'Ksan Historical village is about 12,100 km^2. Flooding flows are dominated by snowmelt runoff in the spring, with major floods occurring when rainfall and snowmelt are combined, however, similar to Skeena River, some flood peaks occur from a fall or winter storm, likely due to rainfall on a light snowpack. The Bulkley River has minimal floodplain along the majority of its reach due to steep valley slopes and exposed bedrock confining the flows to a well-defined channel. Several bedrock canyons can be found along the upper reaches of the Bulkley River (e.g., Hagwilget Canyon). The confined channel of the Bulkley River is steeper and more efficient at transporting sediment than the Skeena River. The effects can be observed at the confluence near the village of Hazelton and Gitanmaax. As the Skeena River lacks the capacity to transport sediment loads from the Bulkley River, large gravel bars are deposited at the confluence and a short distance downstream. This results in elevated channel bed at the confluence and increase flooding risks of the adjacent areas.

1.2 History of Floods

Numerous flood events were recorded for the study area since the establishment of the Village of Hazelton in the 1860’s. These events generally occurred during spring freshet flows, but occasional peaks took place during fall storms (MOELP 1993). A chronological summary of some of the most significant floods in the past 200 years is provided in Figure 1-2.

Figure 1-2: Chronological Summary of Significant Skeena River and Bulkley River Floods.



1. Interior News 2011
2. Interior News 2007
3. September 2006
4. Lina Gasser, Village of Hazelton

2 Project Description

2.1 Objective

The objective of this report is to outline the information provided by others and collected by SNC-Lavalin during our site survey, provide a summary of the hydrological analysis to estimate the design flow (and other flows), present detailed information on the selected analytical modelling method, and provide results of the modelling analyses to highlight locations that are expected to experience flooding for the selected design event. This report does not provide a hazard analysis or mitigation methods to proactively manage flooding hazards, that information is available under separate cover (SNC-Lavalin 2021).

This project included flood assessment at the confluence of the Skeena River and Bulkley River using two-dimensional (2D) modelling of the 200-year design flow including potential effects from climate change. The study area was limited to:

› Skeena River: 3 kilometres (km) upstream to 2 km downstream of the confluence; and

› Bulkley River: 2 km upstream of the confluence.

The study area is presented in Figure 2-1. This area encompasses the village of Hazelton flood affected limits and most of the Gitanmaax Band flood affected limits.

2.2 Guidelines

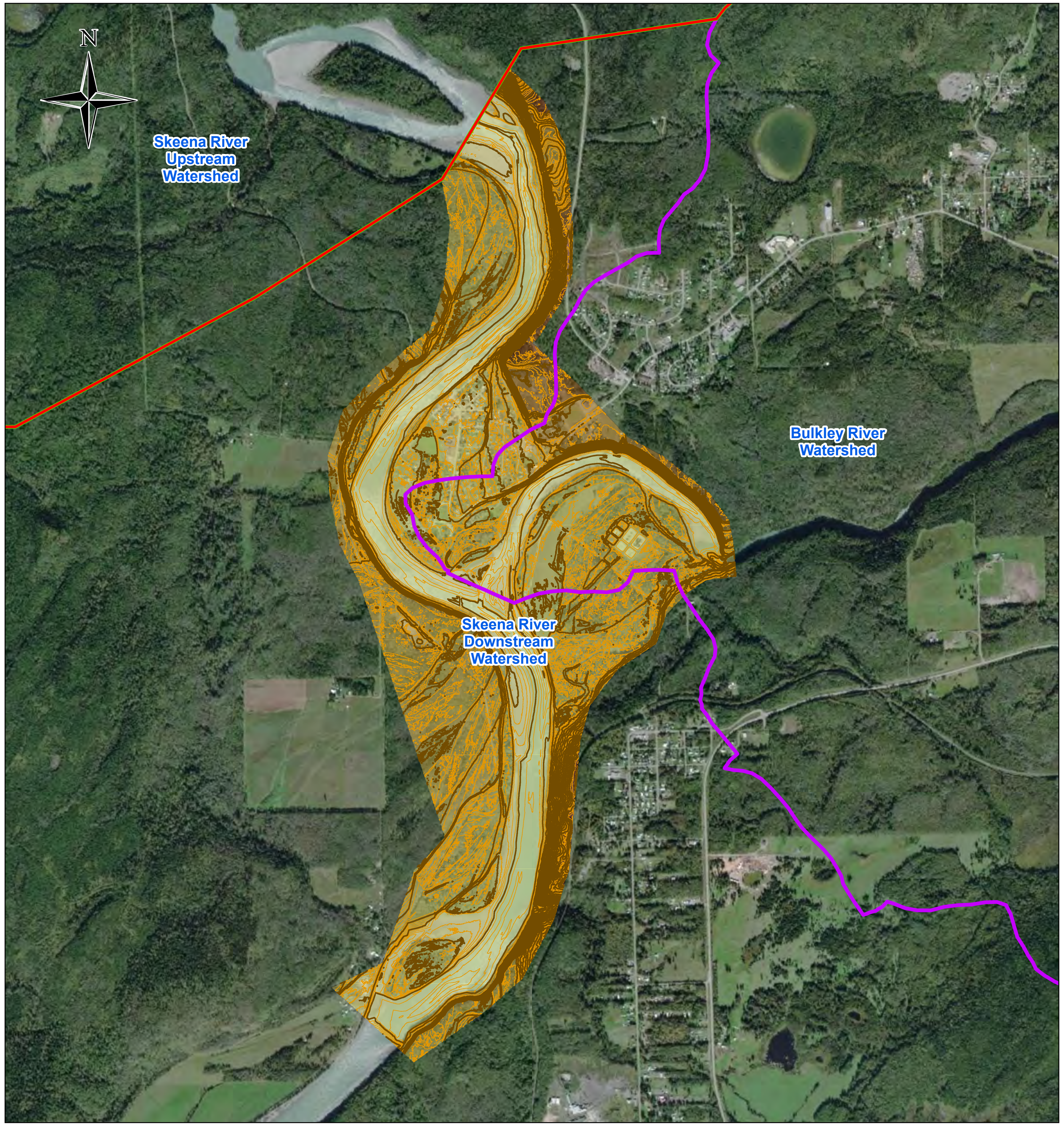
This report is guided by the publicly available reference documents that include but are not limited to the following:

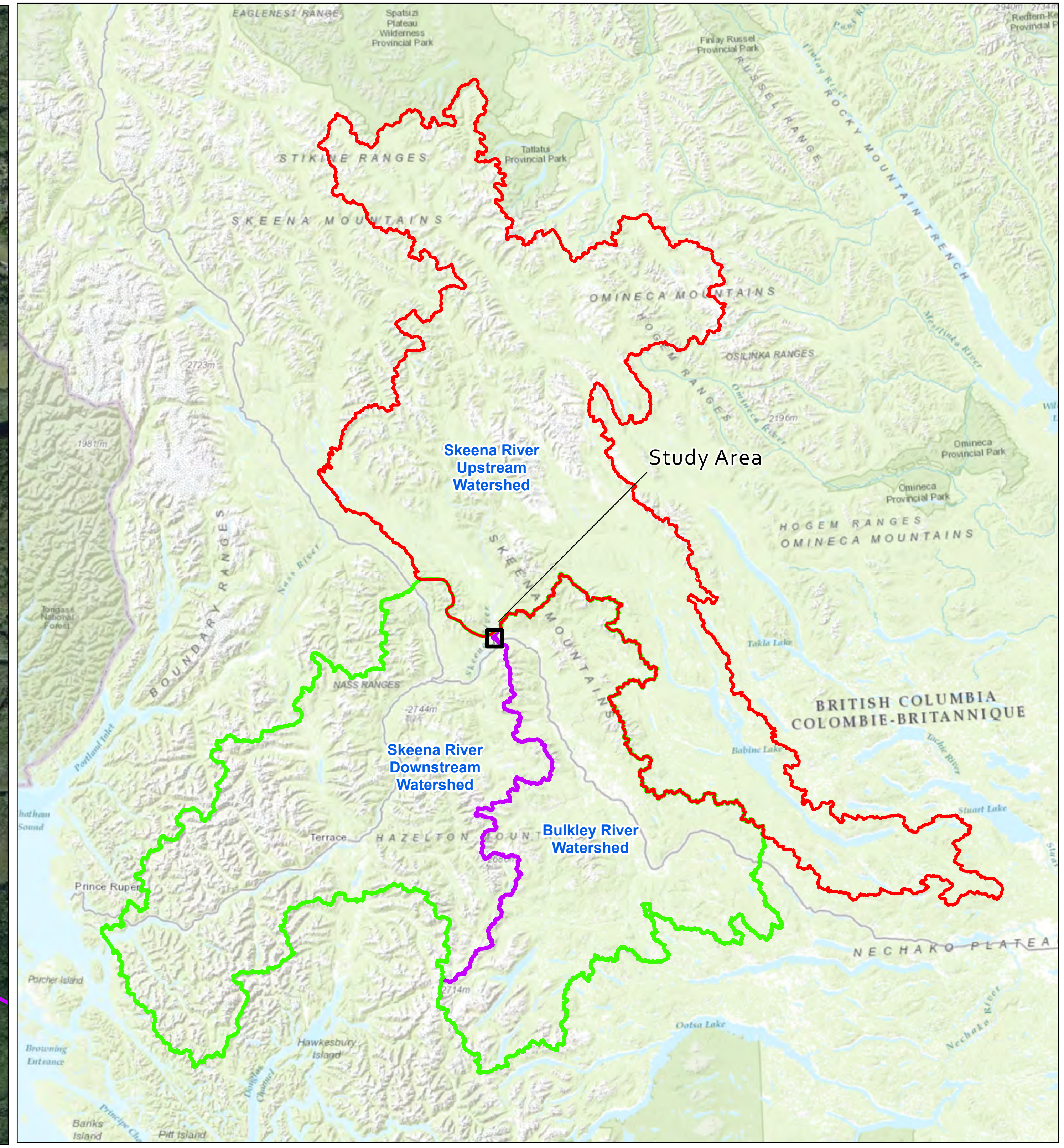
› Association of Professional Engineers and Geoscientists of British Columbia (APEGBC) Professional Practice Guidelines – Flood Mapping in BC (2017);

› Engineers and Geoscientists British Columbia (EGBC) Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC (2018);

› BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (MFLNRO) – Specifications for Airborne LiDAR for the Province of British Columbia (2020); and

› BC Ministry of Water, Land and Air Protection (MWLAP) – Flood Hazard Area Land Use Management Guidelines (2004).





LEGEND

Contours (5m)

Contours (1m)

Digital Terrain Model

Value

308.72

199.555

Skeena River and Buckley River Watersheds

Bulkley River

Skeena River Downstream

Skeena River Upstream

REFERENCES

1. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
2. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.

Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m
Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m

SNC • LAVALIN

CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton, Kitimat-Stikine, BC

Overview of Study Area

BY: ECH	SCALE:	DATE: 2021-03-05	REF No: REV: 0
CHK'D: CBR	PROJ COORD SYS: NAD83 Environmental Albers		**Figure 2-1**

MXD Path: \\Sli2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx

3 Flood Inundation Assessment

SNC-Lavalin's methodology for the flood analyses and the flood inundation mapping is provided in the sections that follow and include data collection methods, hydrological analysis, hydraulic analysis, and flood inundation mapping.

3.1 Data Collection

3.1.1 Review Existing Information

Relevant background information specific to the project was provided by the Village and Band or was gathered from provincial ministries, agencies, or other sources. A summary of the available information collected is as follows:

- A Design Brief of the Floodplain Mapping Study – Skeena and Bulkley Rivers at Hazelton (MOELP 1993);
- Flood Plain Study (RDKS 1974);
- Flooding and Landslide Events Northern British Columbia 1820 – 2006 (Septer 2006);
- Flood photographs and newspaper stories (Interior News 2007); and
- Flood photographs (provided by Lina Gasser, January 2021).

Furthermore, SNC-Lavalin engaged in conversation with Village staff, Band members, and a local newspaper to obtain anecdotal and photographic evidence of the 2007 flood event.

3.1.2 Acquisition of LiDAR Data

SNC-Lavalin obtained Light Detection and Ranging (LiDAR) data and orthophotos of the study area. The data was collected by McElhanney Ltd. in mid-August of 2019. A small portion to the southwest was flown in 2012.

The data had a point-density of eight points per square metre. The vertical data accuracy is 15 centimetres (cm) in open areas and 50 cm in heavy vegetation areas to a confidence level of 95%. The swath overlap for parallel lines was at 50%. Kinematic GPS data was collected along existing roads and open areas as a quality control measure with over 100 points. The results provided a good RSME result for vertical accuracy (0.026 metres (m)). The LiDAR data follows Specifications for Airborne LiDAR for the Province of British Columbia (MFLNRO 2019) Quality Level 1 data.

The bare earth LiDAR (includes only ground elevation data) was used to derive a 1 m x 1 m resolution digital elevation model (DEM) surface that was used to develop model geometry. This DEM did not include channel bathymetry. In-channel cross sections were collected during the site survey.

Orthophotos were flown in conjunction with the August 2019 LiDAR capture. Image resolution is 20 cm pixel. The orthophotos were used to supplement the site survey observations and as a base image for floodplain mapping.

3.1.3 Site Survey and Inspection

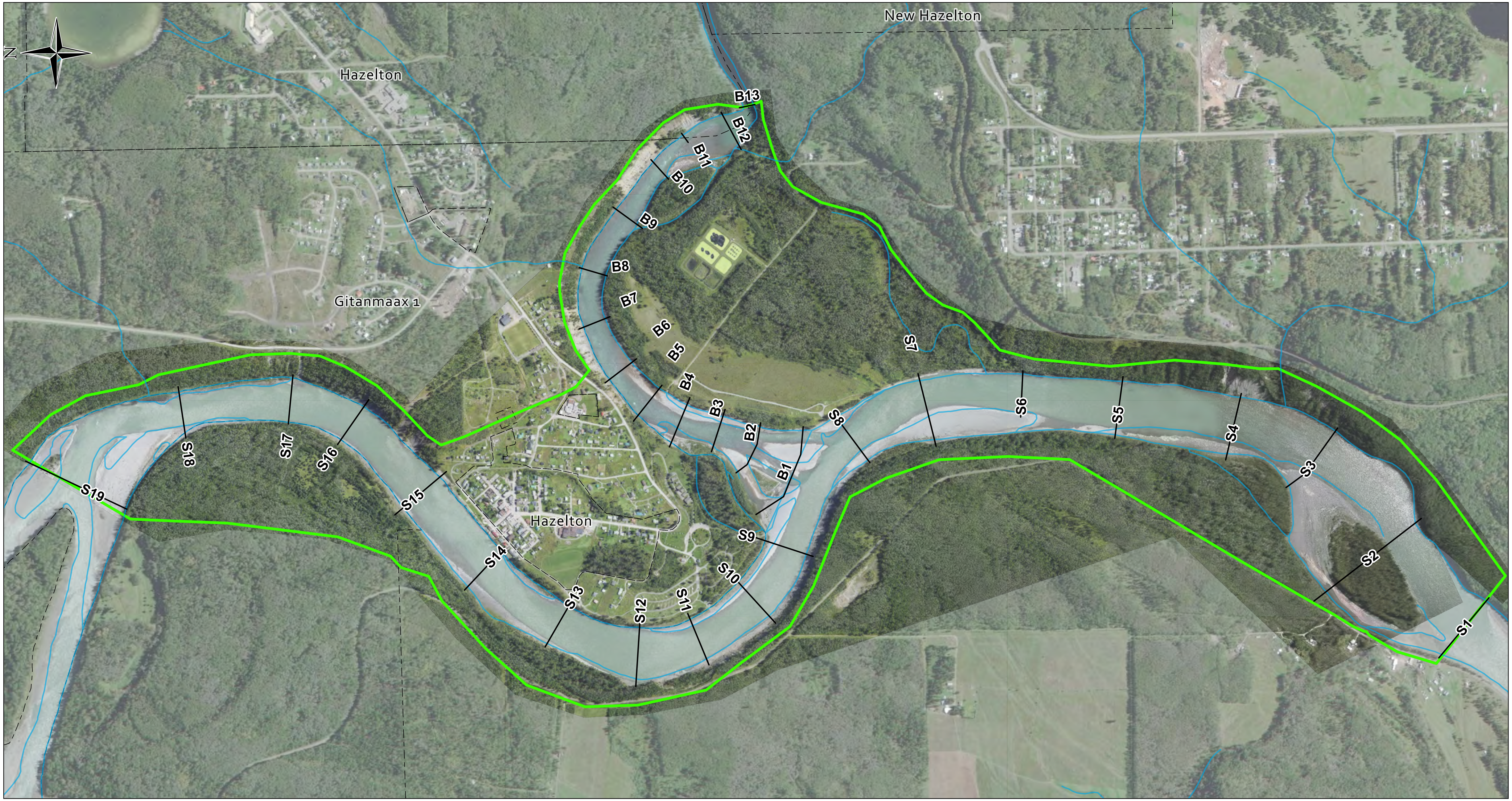
The survey and site inspection were completed by Ian Stanhope and Beth Robertson August 27 through 29, 2020. Stream flows were high and receding from a recent flood peak on August 23, 2020. Overbank topography and water elevation (WEL) information were collected from shore with an RTK GPS (Trimble TSC3/r8 RTK and Leica iCon GPS Base) on August 27, 2020. SNC-Lavalin hired Kermodei Adventures Inc. to supply a boat and operator on August 28 and 29, 2020. Bathymetry and WEL data were collected using an echo sounder (SatLab SLD-100) and RTK GPS.

The channel survey of Skeena River included 19 cross sections extending from about 3.8 km upstream of the Bulkley River confluence to about 2.9 km downstream of the confluence. The channel survey of Bulkley River included 13 cross sections extending from the Skeena River confluence to about 2.2 km upstream (i.e., at the mouth of Hagwilget Canyon). The extension of cross sections beyond the study area was done to reduce the effects of uncertainty at the boundary conditions in the hydraulic model.

A typical surveyed cross section included the channel bed, WEL on both banks, and overbank ground as far as was accessible. LiDAR data extents were loaded onto the RTK GPS interface to ensure overlap between the two datasets. Backwater channel information from the Skeena River islands upstream and downstream of the study extents was able to be collected by boat due to the relatively high-water levels. Limited information could be collected at cross section 11 on Bulkley River due to inability to wade (unsafe flow conditions) and inability to boat (too shallow and rocky) so assumptions were made based on LiDAR information and observations.

Water surface elevations were surveyed along the Skeena River and Bulkley River on August 27, 28, and 29, 2020. Elevations of high-water marks (both recent and older) were also collected. Photos of the surveyed cross sections and high-water marks were collected for each river.

Several survey points were collected along paved roadways. Comparison of these survey points to acquired LiDAR data showed these two datasets were within 0 cm to 6 cm (average 2 cm) of accuracy.



LEGEND

- Local Government Boundaries
- River or Stream - Definite
- River or Stream - Dry
- Surveyed Cross Sections
- 2D Model Boundary

REFERENCES

0 105 210 420 630 840 Meters

1. This map is based on the 2021 Floodplain Mapping Study prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 200-year return period events with an allowance for climate change plus 1.0 m of freeboard.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.
Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m
Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m
3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. xxx (cbr to write)
2. xxx

SNC • LAVALIN

CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton, Kitimat-Stikine, BC

Cross-Section Overview

BY: ECH	SCALE: 1:15,000	DATE: 2021-03-05	REF No: REV: 0
CHK'D: BR	PROJ COORD SYS: NAD 1983 CSRS UTM Zone 9N		Figure 3-1

MXD Path: \\Sl2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx

3.2 Hydrological Analysis

The design event estimated for the rivers was the 200-year flood, as designated by MWLAP (2004) for floodplain mapping in BC. A 200-year flood has a 0.5% chance of occurring every single year and may be exceeded. The 200-year discharge was estimated for Skeena River and Bulkley River.

3.2.1 Skeena River Flood Peaks

Skeena River at Glen Vowell (08EB003) is a Water Survey of Canada (WSC) station about 8 km upstream of the Village of Hazelton with a 24-year long period of record (1961 to 1985). A linear regression between mean daily maximums and instantaneous maximums could not be well established (only three instantaneous maximum records), therefore, the WSC station Skeena River above Babine River (08EB005), which is located about 65 km upstream of the village of Hazelton, was used to provide a relationship between mean daily maximums and instantaneous maximums. Skeena River above Babine River has 37-years of record (1971 to 2020), of which 31-years had both daily and instantaneous maximums. It was found that instantaneous maximums were about 1.06 times daily maximums. This relationship was used to fill in missing years for the instantaneous maximum discharge record for Skeena River at Glen Vowell.

The period of record at Skeena River at Glen Vowell was still outdated and relatively short (only 25-years), therefore, the WSC station Skeena River at Usk (08EF001), located about 120 km downstream of the Village of Hazelton and has an 84-year long period of record (1928 to 1931 and 1937 to 2020), was used to extend the Skeena River at Glen Vowell period of record with a correlation between instantaneous maximum peak flows. For Skeena River at Usk, it was found that instantaneous maximums were about 1.02 times daily maximums, which was used to create a complete record of instantaneous maximums. Usk and Glen Vowell instantaneous maximums for concurrent years were compared. Furthermore, only events that occurred within a few days of each other were compared (e.g., a fall flood at Glen Vowell was not compared to a spring flood at Usk). It was found that Skeena River at Glen Vowell discharges were generally 0.68 times that of Skeena River at Usk discharges. This relationship was used to extend the Skeena River at Glen Vowell record, giving a total of 88 instantaneous maximum discharges for a flow frequency analysis.

A summary of the WSC stations used in this analysis is provided in Table 3-1. A graphical representation is provided in

Figure 3-2.

Table 3-1: Water Survey of Canada Stations used to Generate an Extended Period of Record for Skeena River at Glen Vowell

WSC Station (#)	Drainage Area (km^2)	Location (relative to the Village of Hazelton, BC)	Period of Record (Years)	IMAX vs Daily
Skeena River at Glen Vowell (08EB003)	26,000	8 km upstream	25 (1961 – 1985)	n/a
Skeena River above Babine River (08EB005)	12,400	65 km upstream	37 (1971 – 2020)	1.06
Skeena River at Usk (08EF001)	42,300	120 km downstream	84 (1928 – 1931, 1937 – 2020)	1.02

One important year of record missing from the WSC record for Skeena River at Usk was 1936. This has been reported as the highest flood level that occurred since Village of Hazelton was established (MOELP 1993) and thought to be the worst flood in a hundred years (Septer 2006). Estimated to be 10,194 m^3/s for Skeena River at Usk (Septer 2006), it was converted to a peak flow of 6970 m^3/s for Skeena River at Glen Vowell. This extended the period of record to 89 instantaneous maximum discharges.

A flow frequency analysis of the extended instantaneous maximum dataset for Skeena River at Glen Vowell was performed to estimate the 200-year discharge and other lower return period flow estimates. Various distribution curves (e.g., Generalized Extreme Value, Log-normal, Gamma, Log Pearson III, etc.) were fitted to the data. Numerical Goodness-of-Fit tests were performed on the fitted data, including Anderson-Darling Test, Kolmogorov-Smirnov Test, and Least Squares Ranking. The preferred distribution according to numerical tests and visually fit was Log Pearson III. The resulting flood peak discharges are presented in Table 3-2. The Skeena River at Glen Vowell is only a short distance upstream of the study area and was used in the modelling without adjustment to the drainage area.

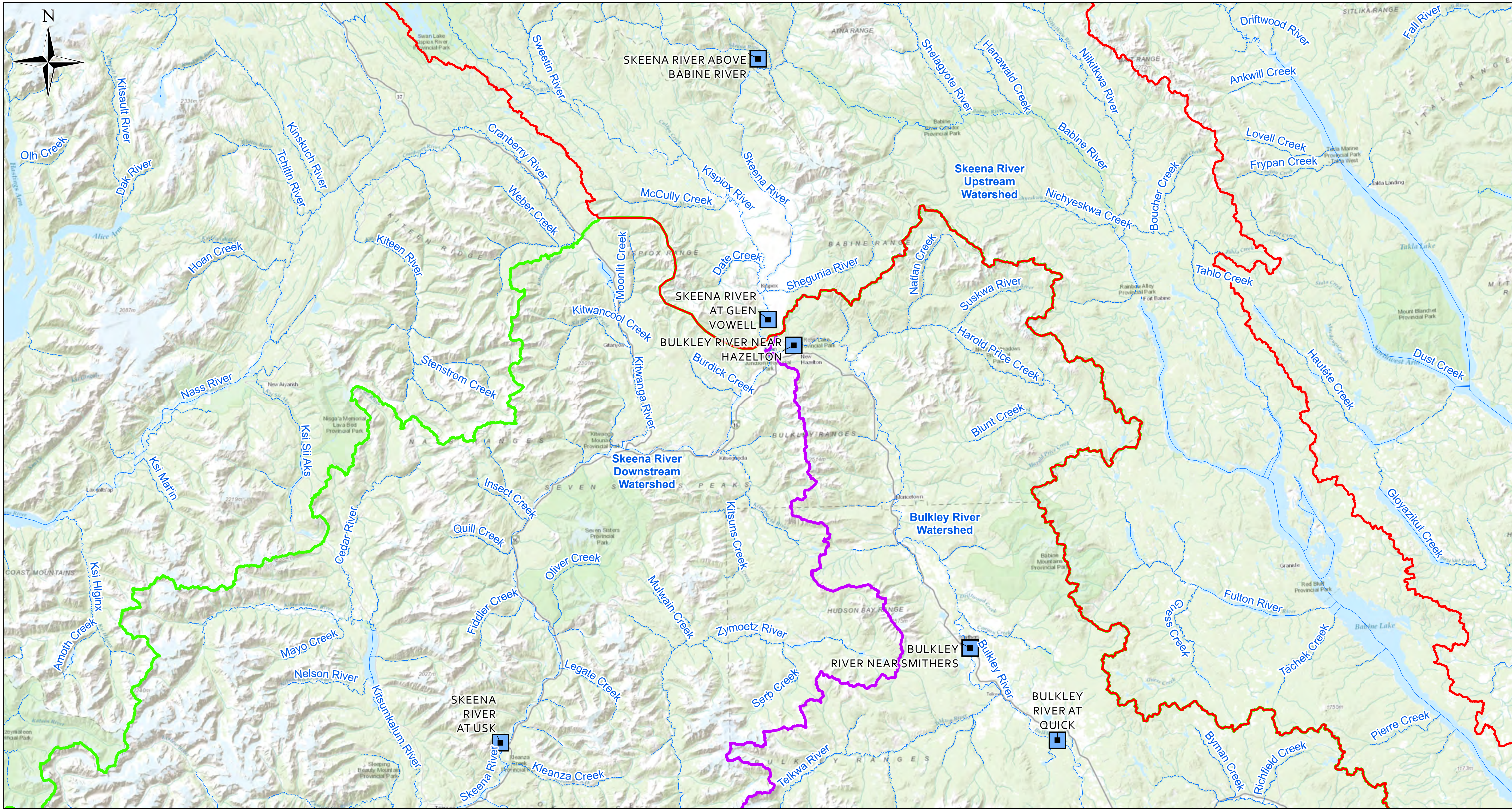
Table 3-2: Flood peak discharge estimates for Skeena River at Glen Vowell

Return Period	Peak Discharge (m^3/s)	Climate Change affected Peak Discharge* (m^3/s)
2-year	3192	3511
5-year	4046	4450
10-year	4631	5094
25-year	5395	5934
50-year	5985	6583
100-year	6593	7252
200-year	7225	7948

*Calculated peak discharge includes a 10% increase to account for climate change.

With climate change, the assumption of stationarity for hydrometric data and the frequency analysis of floods will become increasingly unreliable (EGBC 2018), therefore, the potential effects of climate change were assessed using the recommended procedure by EGBC (2018) for flood magnitudes. This includes testing the stationarity of the data (i.e., does not vary with respect to time). The period of flood peak record was analysed to determine if a statistically significant historical trend or jump was present in the time series. A trend could indicate a gradual change in land use (e.g. development) in the drainage area or an increase in precipitation from climate change (AMEC 2014). A jump indicates an abrupt change in the system (e.g., construction of dam) (AMEC 2014).

The Spearman rank order correlation coefficient was used to detect any increasing or decreasing trends and the Mann-Whitney test was used to test for jumps. Using a significance level of 5%, no trends or jumps in the data were found, so the instantaneous flood peak record was considered to be stationary. Therefore, EGBC (2018) recommends applying a 10% increase in peak discharge to account for likely changes from future increased precipitation. The calculated climate change affected peak discharges are also shown in Table 3-2.



LEGEND

- Water Survey of Canada Stations
- Watercourse

Skeena River and Buckley River Watersheds

- Bulkley River
- Skeena River Downstream
- Skeena River Upstream

REFERENCES

0 4,500 9,000 18,000 27,000 36,000 Meters

1. Creeks, watersheds from DataBC and Base Imagery from ESRI

SNC · LAVALIN

CLIENT NAME: Village of Hazelton	PROJECT LOCATION: Hazelton, Kitimat-Stikine, BC

Water Survey of Canada Stations Used in the Study

BY: ECH	SCALE: 1:700,000	DATE: 2021-03-05	REF No: REV: 0
CHK'D: BR	PROJ COORD SYS: NAD 1983 CSRS UTM zone 9N		Figure 3-2

MXD Path: \\Sli2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx

3.2.2 Bulkley River Flood Peaks

Bulkley River near Hazelton (08EE001) is a WSC station about 6 km upstream of the mouth with a 13-year-long period of record (1928 – 1941). A linear regression between mean daily maximums and instantaneous maximums could not be established (no instantaneous maximum records). Therefore, the WSC stations Bulkley River near Smithers (08EE005) and Bulkley River at Quick (08EE004), which are located about 100 km and 130 km upstream of ‘Ksan, respectively, were used to provide a relationship between mean daily maximums and instantaneous maximums. Bulkley River near Smithers has 17-years of record (1947 – 1971; 2008 – 2019) and Bulkley River at Quick has 86-years of record (1931 – 2018), of which 10- and 15-years, respectively, had both daily and instantaneous maximums. It was found that instantaneous maximums were about 1.04 (Smithers) and 1.03 (Quick) times daily maximums, so an average of 1.035 was used at Hazelton. This relationship was used to fill in missing years for the instantaneous maximum discharge record for Bulkley River near Hazelton.

The period of record at Bulkley River near Hazelton was still outdated and relatively short (only 14-years), therefore, the WSC station Bulkley River at Quick was used to extend the Bulkley River near Hazelton period of record with a correlation between instantaneous maximum peak flows. For Bulkley River at Quick, it was found that instantaneous maximums were about 1.03 times daily maximums, which was used to create a complete record of instantaneous maximums. Quick and Hazelton instantaneous maximums for concurrent years were compared. Several of the flood peaks at Quick occurred during the fall, whereas flood peaks at Hazelton occurred during the spring within the same year. A record of Quick versus Hazelton spring peaks and fall peaks were produced (using daily maximum values where necessary to fill in missing values at either station). It was found that Bulkley River near Hazelton discharges had a linear relationship for the spring and fall discharges as follows:

- Spring: $Q_{Hazelton} = 1.99Q_{Quick} – 74.9$; and
- Fall: $Q_{Hazelton} = 0.98Q_{Quick} – 182.9$.

where Q = discharge (m^3/s).

These relationships were used to extend the Bulkley River near Hazelton record, giving a total of 91 instantaneous maximum discharges for a flow frequency analysis.

A summary of the WSC stations used in this analysis is provided in Table 3-3. A graphical representation is provided in

Figure 3-2.

Table 3-3: Water Survey of Canada Stations used to Generate an Extended Period of Record for Bulkley River Near Hazelton

WSC Station (#)	Drainage Area (km^2)	Location (relative to the village of Hazelton, BC)	Period of Record (Years)	IMAX vs Daily
Bulkley River near Hazelton (08EE001)	12,300	5 km upstream	14 (1928 – 1942)	n/a
Bulkley River near Smithers (08EE005)	8,940	100 km upstream	17 (1947 – 1971; 2009 – 2018)	1.04
Bulkley River at Quick (08EE004)	7,340	130 km upstream	86 (1931 – 2018)	1.03

A flow frequency analysis of the extended instantaneous maximum dataset for Bulkley River at Hazelton was performed to estimate the 200-year discharge and other lower return period flow estimates. Various distribution curves (e.g., Generalized Extreme Value, Log-normal, Gamma, Log Pearson III, etc.) were fitted to the data. Numerical Goodness-of-Fit tests were performed on the fitted data, including Anderson-Darling Test, Kolmogorov-Smirnov Test, and Least Squares Ranking. The preferred distribution according to numerical tests and visually fit was Lognormal III distribution. The resulting flood peak discharges are presented in Table 3-4. The Bulkley River near Hazelton is only a short distance upstream of the study area and was used in the modelling without adjustment to the drainage area.

Table 3-4: Flood peak discharge estimates for Bulkley River near Hazelton

Return Period	Peak Discharge (m^3/s)	Climate Change affected Peak Discharge* (m^3/s)
2-year	1051	1156
5-year	1349	1484
10-year	1523	1675
25-year	1722	1894
50-year	1860	2046
100-year	1989	2188
200-year	2113	2324

*Calculated peak discharge includes a 10% increase to account for climate change.

The period of record used in the flow frequency was analysed for change over time (i.e., stationarity) to assess if statistically significant trends or jumps were present in the time series. Again, the Spearman rank order correlation coefficient was used to detect any increasing or decreasing trends and the Mann-Whitney test was used to test for jumps using a significance level of 5% and no trends or jumps in the data were found. Therefore, a 10% increase in peak discharge to account for likely changes from future increased precipitation was applied, as recommended by EGBC (2018). The calculated future peak discharges are also shown in Table 3-4.

3.2.3 Skeena River versus Bulkley River – Timing of Peaks

For this study, it was proposed the Skeena River peak and Bulkley River peak would occur simultaneously. The feasibility of this scenario was assessed by examining the timing (i.e. date) of the historic Skeena River peaks and Bulkley River peaks. The two period of records were compared to see if coinciding annual peaks occurred within the same week (64%) and within the same three weeks (81%). It was concluded it is very likely the Skeena River and Bulkley River will peak simultaneously, so the design discharge was modelled as such. It should be noted, however, the return period of the peaks on Skeena River and Bulkley River rarely match each other (e.g., in 1948 a ~30-year flow on the Bulkley occurred with a 95-year flow on the Skeena). Therefore, simultaneous 200-year peak flows on Skeena Rivera and Bulkley River is a conservative estimate.

3.2.4 Skeena River and Bulkley River Daily Flows

For the purposes of the hydraulic model calibration, it was of interest to estimate stream flows during the survey dates (August 27, 28, and 29, 2020). Daily flow and water level records from Skeena River at Usk (flow and level), Skeena River at Glen Vowell (level), Skeena River near Babine River (flow and level), Bulkley River at Quick (flow) and Bulkley River at Hazelton (flow) were used to estimate the average daily flow on the Skeena River and Bulkley River. The travel time between gauges was considered (based on water levels) as well as the time of surveyed WEL measurements (approximately 8 am to 4 pm). Estimated values are given in Table 3-5.

Table 3-5: Estimated Daily Flows during the Survey

Date	Estimated Flow During Survey (m^3/s)	
	Skeena River	Bulkley River
August 27, 2020	1336	207
August 28, 2020	1186	199
August 29, 2020	1223	193

3.3 Hydraulic Analysis

A two-dimensional (2D) hydraulic model was developed to simulate flow in Skeena River and Bulkley River using the latest Hydraulic Engineering Center River Analysis System (HEC-RAS version 5.0.7). HEC-RAS is developed by the U.S. Army Corps of Engineer and it is widely used in the industry to model hydraulics of water flow through natural rivers and other channels. Advantages of using a 2D model (over 1D) for the floodplains is that flow routes and flow velocity directions are automatically calculated, flood depth grids are directly outputted, and detailed information of velocity and depth variation on the floodplain can be used for hazard mapping.

3.3.1 Geometry

The cross-sectional survey data collected during the August field trip and the DEM generated from LiDAR data for the study area were used to develop the model geometry. A continuous channel DEM was created by interpolating between surveyed cross sections, using channel point measurements between sections, and adjusting interpolated section channel widths based on the LiDAR DEM surface. Some manual smoothing of the transition from the Bulkley River to the Skeena River was needed. The continuous channel DEM generated was merged with the LiDAR DEM to create a complete topographic / bathymetric DEM for the study area.

The 2D model mesh was generated from the merged DEM surface. An unstructured computational mesh was used with a typical cell spacing of 20 m. In the channel, cells were oriented along stream profiles, in the direction of flow. Breaklines were added in areas of interest (e.g., along the dike) and where flow would travel along (e.g., roadways, backwater channels) so cell faces were aligned with these features. Breaklines were added along banks, roadways, around islands, and along low-lying flow paths (e.g., side channels, ditches). Cell spacing was refined to 5 m around the dike.

There is one flood control structure at the village of Hazelton, a 625 m long earthen berm dike. This structure was surveyed and compared to the elevations in the DEM surface. Elevation differences between the survey data and DEM data were (on average) about 3 cm lower in the DEM with an absolute difference of 5 cm. Since the DEM captured the dike structure well, elevations from the DEM surface were used.

3.3.1.1 Roughness Coefficients

Skeena River is a large river (~200 m wide) with lateral bars throughout the reach consisting predominantly of cobbles (see Photo 3-1). There is a heavily vegetated island at the downstream boundary with a right-side channel that only conveys flow during high flow conditions (see Photo 3-2). There is also a sparsely vegetated island on the upstream boundary with a left side channel that seems to convey flow regularly (Photo 3-3). The left bank adjacent to Government Street is covered in riprap rock (see Photo 3-4).

A base Manning's *n* value used for the Skeena River channel was 0.035. This was based on recommended values listed in Chow (1959) for a major steam with a regular section (0.025 – 0.060) and the previous flood mapping study (0.027 to 0.045 from MOELP 1993). These values provided a good starting point for calibration, but it is noted that they are for 1D modelling. For 1D modelling, Manning's n accounts for channel variations, cross section irregularity, obstructions, degree of meandering, and vegetation (Arcement and Schneider 1989). For 2D modelling, the geometry accounts for all these variations except vegetation (Friend and McBroom 2018). Some differences in calibrated Manning's n values were expected.

Photo 3-1: Looking Downstream Skeena River From Left Bank At Cross Section 10 (August 27,2020).

Photo 3-2: Looking Downstream Skeena River Right-Side Channel from Right Bank near Cross Section 2 (August 27,2020).

Photo 3-3: Looking Upstream Skeena River Left-Side Channel from Middle Island near Cross Section 19 (August 28, 2020).

Photo 3-4: Looking upstream Skeena River from left bank near cross section 14 (August 27,2020).

Bulkley River is about 100 m wide and steeper than Skeena River (0.3% versus 0.09%). The most upstream cross section of the reach is at the mouth of Hagwilget Canyon (see Photo 3-5). The Bulkley River then flows into a deep, wide pool (Photo 3-6). The main channel flow is then constricted to the right side, with a shallow, rocky bar dominating the left side (see Photo 3-7). The remaining channel is relatively uniform, with large boulders present throughout (see Photo 3-8). Lateral and medial cobble bars are present at the mouth, where the Bulkley River fans out as it meets the Skeena River (see Photo 3-9).

A base Manning's *n* value used for the channel was 0.05. This was based on recommended values listed in Chow (1959) for a major stream with irregular and rough sections (0.035 – 0.100) and the previous flood mapping study (0.045 from MOELP 1993). Again, these values were intended for 1D modelling and were used only as a starting point for calibration.

Photo 3-5: Looking Upstream Hagwilget Canyon at Upstream Extent of Bulkley River Study Reach (August 29, 2020).

Photo 3-6: Looking Across Bulkley River from the Right Side at Cross Section 12 (August 29, 2020).

Photo 3-7: Looking Across Bulkley River from Right Side near Cross Section 11 (August 29, 2020).

Photo 3-8: Looking Downstream Bulkley River from Right Bank near Cross Section 9 (August 29, 2020).

Photo 3-9: Looking Upstream Bulkley River from Medial Bar near Cross Section 1 (August 29, 2020).

Floodplain Manning's n values were based on recommended values listed in Chow (1959) and the US National Land Cover Database [NLCD] (EROS 2016). A land use classification shapefile of the floodplain was delineated using orthophoto imagery field observations and orthophoto imagery. Categories included:

Area	Chow	NLCD	Adopted
Trees	0.11 – 0.12	0.10 – 0.14	0.10 – 0.12
Campground, open field	0.030 – 0.050	0.04	0.045
Shrubs	0.035 – 0.070	0.085	0.060
Residential	n/a	0.08	0.08
Urban	n/a	0.10	0.10

3.3.2 Boundary Conditions

The upstream boundary conditions were flow inputs for Skeena River and Bulkley River (e.g., 200-year flow or August 28, 2020 flow).

The Skeena River and Bulkley River slopes were calculated from the surveyed WELs and found to be 0.0013 metres/metre (m/m) and 0.003 m/m, respectively. The downstream boundary condition was the normal depth assumption using the Skeena River slope estimated from surveyed water levels closer to the downstream end of the study reach (0.0009 m/m).

3.3.3 Calibration and Validation

The HEC-RAS model was calibrated by matching observed water surface elevation data for a known flow. This is done by adjusting the channel and overbank roughness parameters (Manning's n values) until the modelled water surface elevations reasonably matched the observed. The model was validated by simulating other (independent) flood events and comparing to observed water surface elevations to ensure the results were reasonable and the model could be used for a variety of floods.

3.3.3.1 Calibration - August 27, 28, 29, 2020

The initial calibration of the model was done using WELs collected during the site survey on August 27, 28, and 29, 2020 as this was the most extensive set of elevations. Flows for these dates were fluctuating; estimates of the flow during WEL measurements were estimated in Section 3.2.4. Manning's *n* values in the channel were adjusted until the simulated water surface elevations closely matched the observed water surface elevations, as shown in Figure 3-3 through Figure 3-6. A table of the average absolute difference in simulated and observed WEL is provided in Table 3-6. Calibrated Manning's *n* values were 0.036 for Skeena River (with areas of increased roughness, 0.038) and 0.054 for Bulkley River (with areas of increased roughness, 0.060).

Table 3-6: Average Absolute Difference in Simulated WEL and Observed WEL

Date	Estimated Flow (m^3/s)		Average Absolute Difference (Simulated WEL vs. Observed WEL)	
	Skeena River	Bulkley River	Skeena River	Bulkley River
August 27, 2020	1336	207	0.09	0.18
August 28,2020	1186	199	0.12	n/a
August 29,2020	1223	193	0.06 (no figure)	0.15

Figure 3-3: Bulkley River WEL for 207 m³/s (August 27, 2020), Simulated and Observed.

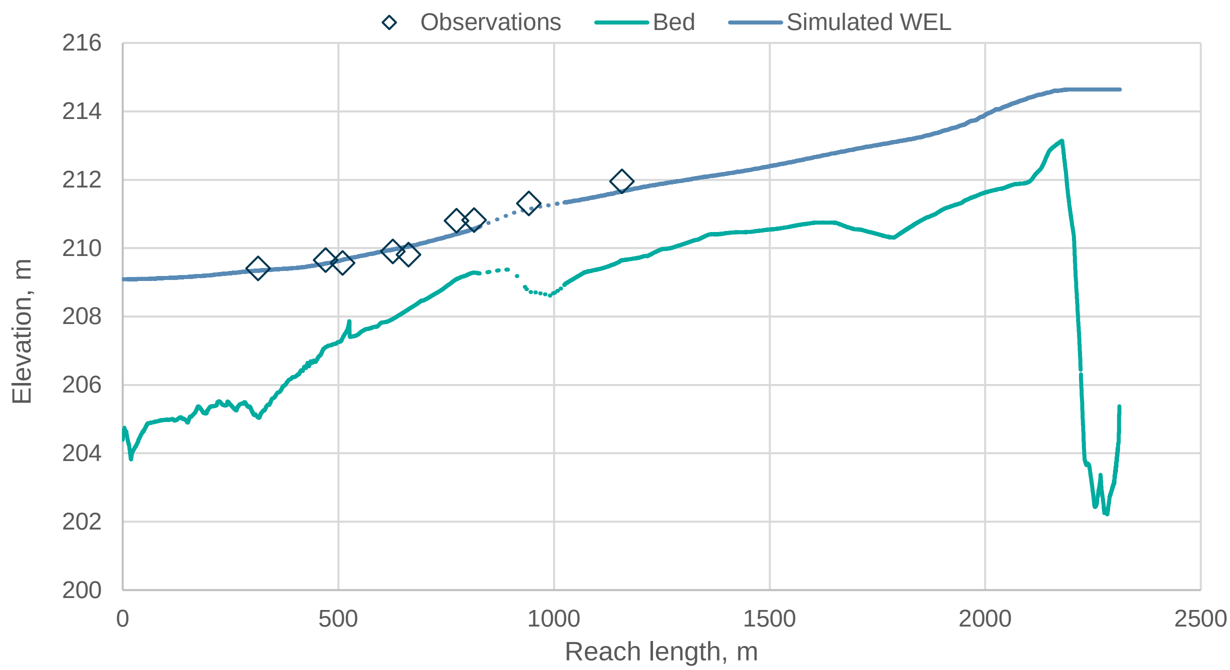


Figure 3-4: Skeena River WEL for 1336 M3/S Upstream and 1543 M3/S Downstream of Bulkley River Confluence (August 27, 2020), Simulated and Observed.

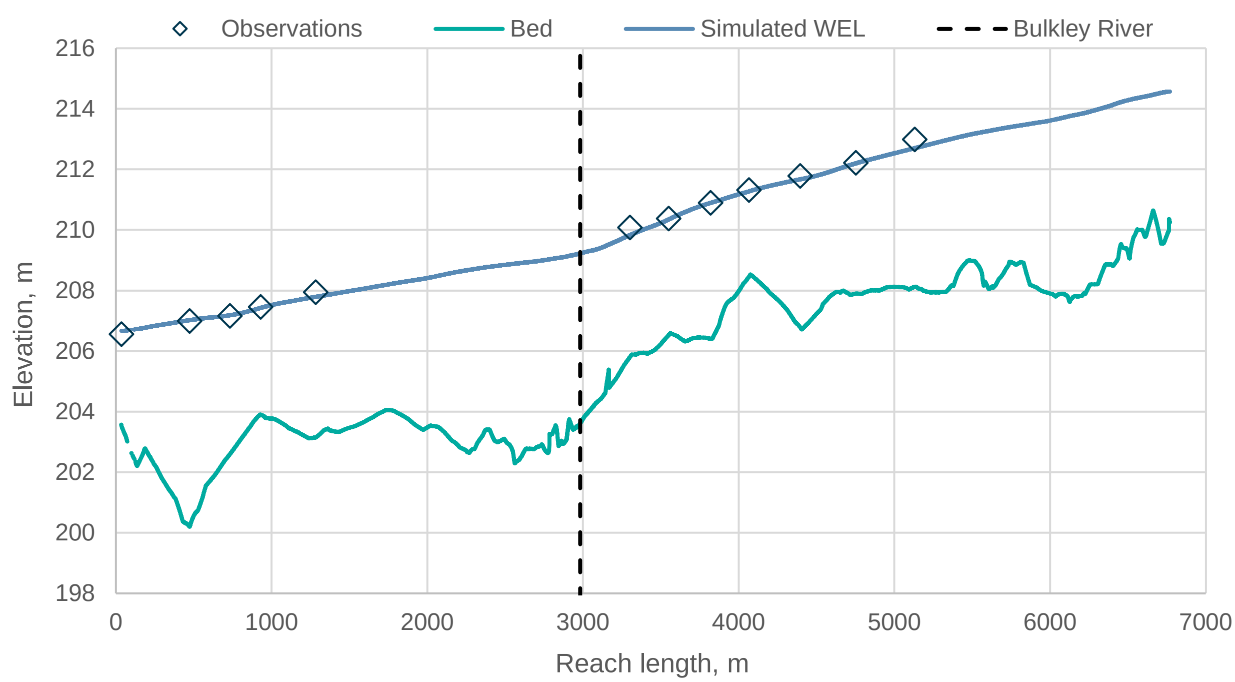


Figure 3-5: Skeena River WEL for 1186 m3/s Upstream and 1385 m3/s Downstream of Bulkley River Confluence (August 28, 2020), Simulated and Observed.

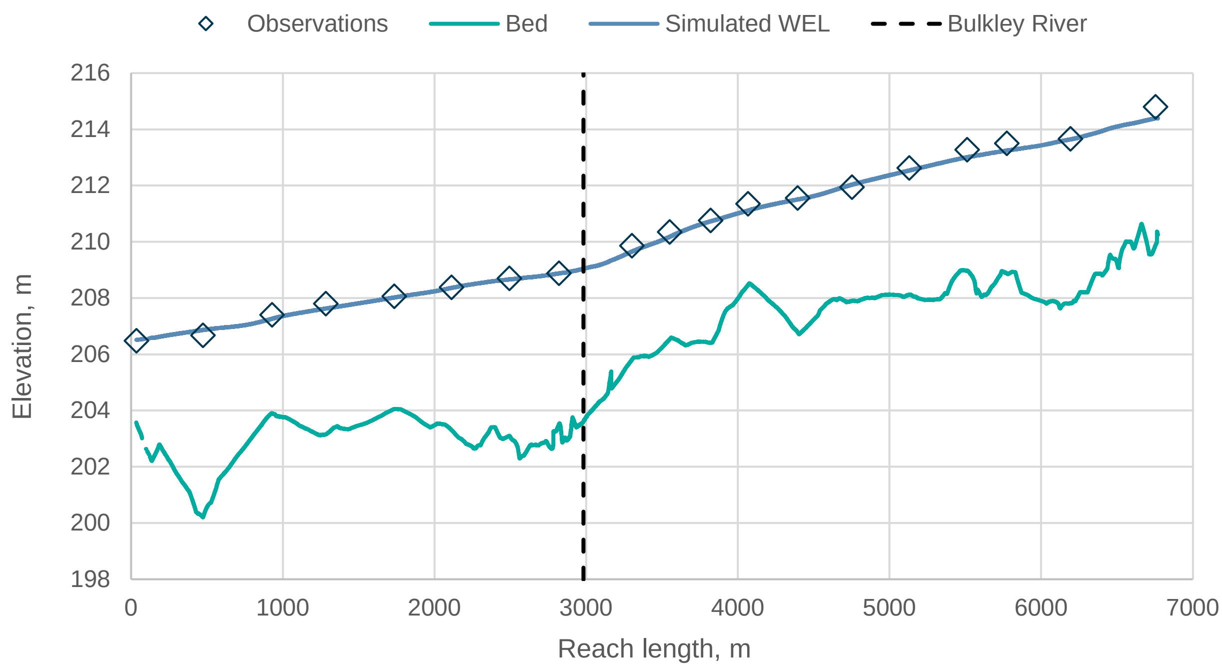
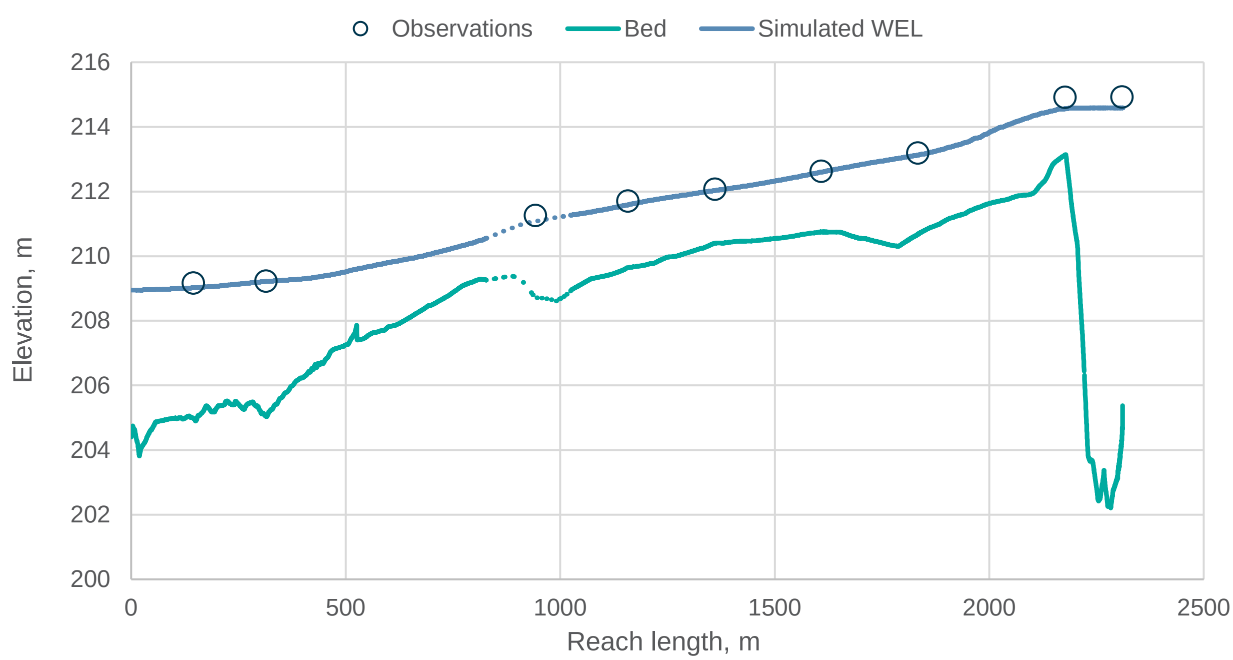


Figure 3-6: Bulkley River WEL for 193 m3/s (August 29, 2020), Simulated and Observed.



3.3.3.2 Validation – June 7, 2007 Event

The most recent major flood event at the village of Hazelton and Gitanmaax was in June 2007. The peak flow on the Skeena River at Usk was June 7, 2007; the peak flow on the Bulkley River at Quick was June 8, 2007. Based on newspaper reports from Interior News, it was estimated the peak at the village of Hazelton and Gitanmaax occurred on June 7, 2007. The peak flood discharge estimated on the Skeena (at Glen Vowell) was 5209 m^3/s which equates to about a 20-year return period. The flood peak discharge estimated on the Bulkley River (near Hazelton) was 2020 m^3/s, which equates to about a 100-year return period.

There were three historic high-water marks collected for this event, two photographs (see Photo 3-10 and Photo 3-11) and one anecdotal account. Photo 3-10 (from Interior News) was taken shortly after the flood peak event when flood waters were receding; peak WEL were estimated from the wetted totem pole. Photo 3-11 (provided by Lina Gasser) was assumed to be taken near peak elevations. Anecdotal high-water marks were provided by Norman Sampson (personal communication August 28, 2020); he remembers water levels reaching the gazebo structures by River Road near the ‘Ksan Historical Village; this elevation was estimated using the DEM.

Photo 3-10: Kayaker near ‘Ksan Road Shortly After Flood Peak (June 7, 2007, Interior News).

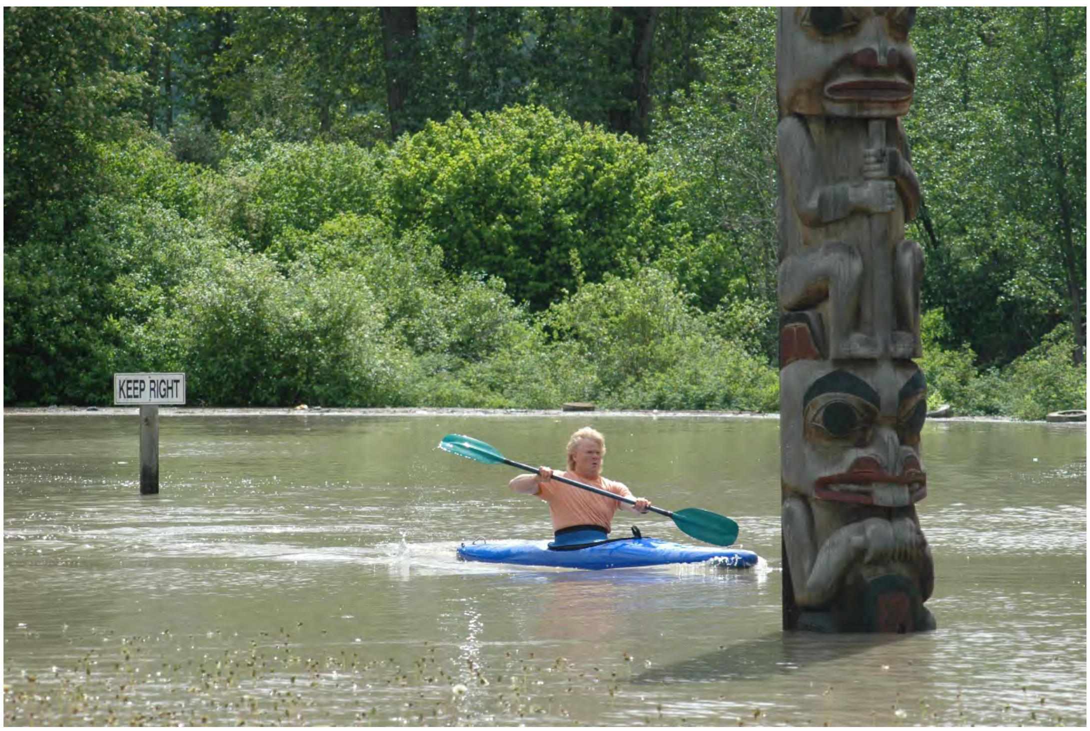


Photo 3-11: Hazelton Dock (June 2007, provided by Lina Gasser from the Village).

Estimated high-water marks from June 7, 2007 are summarized in Table 3-7. The model was run with the estimated peak values. A comparison of simulated and observed elevations is shown in Table 3-7. The simulation matches the observed WEL well (average absolute difference of 0.13 m). The largest discrepancy is the Totem Pole WEL; this value was estimated from a photo that was taken after the peak receded, so it could have been underestimated.

Table 3-7: Estimated High-water Marks June 7, 2007 (Skeena 5209 m^3/s; Bulkley 2020 m^3/s)

Source	Location (Easting (m), Northing (m))	Observed WEL (m)	Simulated WEL (m)	Difference (m) (Simulated – Observed)
Photo 3-10	Totem Pole (583990 m E, 6123355 m N)	214.90	215.19	0.29
Photo 3-11	Dock (584050 m E, 6124145 m N)	216.65	216.68	0.03
Anecdotal	Gazebos (584035 m E, 6123460 m N)	215.55	215.48	-0.07
			Average Absolute Difference	0.13

3.3.3.3 June 1, 1936 and June 12, 1972 Events

Historic high-water marks were available for the floods in 1936 and 1972 (RDKS 1974). In this study, anecdotal high-water mark information was collected from long-term residents and adjusted to a geodetic elevation. One significant known difference between these historic floods and the 2007 flood, is there was no dike adjacent to Government Street during the 1936 and 1972 floods. This is inferred from cross sections surveyed in 1979 and 1991 did not show the existence of a dike along Government Street (MOELP 1993). Therefore, the terrain layer geometry in the model was modified to remove the existing dike before running the 1936 and 1972 flood events.

There were several historical flood photos from 1936 provided by the Village. Photo 3-12 depicts the upstream extent of flooding along Government Street. It was estimated that the water's edge was about halfway between Omineca Street and Bay Street, or an elevation of approximately 217.3 m. Photo 3-13 depicts Hankin Street facing west toward the Skeena River. Water depth at the intersection of Government Street (behind power pole) was estimated to 0.5 m, or an elevation of approximately 216.9 m. Note that the exact date/time of the photos are unknown and may have been take before or after the flood peak.

No flood photos from 1972 were available.

Photo 3-12: Looking Southwest down Government Street, Hazelton, BC (June 1936).

Photo 3-13: Looking West down Hankin Street, Hazelton, BC (June 1936).

The estimated 1936 Skeena River (at Glen Vowell) and Bulkley River (near Hazelton) flows were 6969 m^3/s and 1564 m^3/s, respectively. This equates to about a 150-year return period for the Skeena River and about a 10-year return period for the Bulkley River. These flows were run in the 2D model and a summary of the observed and simulated WEL are provided in Table 3-8.

The simulated flood elevations were somewhat well matched (~0.2 – 0.5 m higher), except for the stump location.

Table 3-8: Estimated High-water Marks June 1, 1936 (Skeena 6969 m³/s; Bulkley 1564 m³/s)

Location (approximate coordinates UTM Z9)	Observed WEL (m)	Simulated WEL (m)	Difference (m) (Sim – Obs)
West of Government Rd, 50 m North of Hankin St. (584005 m E, 6124070 m North)	217.23*	217.56	0.33
East of Government Rd, 50 m North of Hankin St. (584010 m E, 6124045 m North)	217.17*	217.53	0.36
School Field (Sterritt's Barn) (583920 m East, 6123910 m North)	216.90*	217.14	0.24
Stump (583945 m East, 6123470 m North)	215.07*	216.42	1.35
Between Bay Street and Omineca Street (584130 m East, 6124170 m North)	217.3**	217.80	0.50
Hankin Street and Government Street (584010 m East, 6124050 m North)	216.9**	217.44	0.54
		Average Absolute Difference	0.56

*taken from RDKS 1974 report

** estimated from photos provided by Village

The estimated June 12, 1972 Skeena River (at Glen Vowell) and Bulkley River (near Hazelton) flows were 6202 m³/s and 1702 m³/s. This equates to about a 65-year return period and 25-year return period, respectively. These flows were run in the 2D model and a summary of the observed and simulated WEL are provided in Table 3-9 for the 1972 flood event.

Simulated WEL were generally much higher (+1.0 m) than the observed WEL. The Skeena River discharge was calculated from the WSC Glen Vowell daily flow record, which had a value of 5830 m³/s with they symbol 'E'. This indicates that there was no measured data available and the value was estimated from an indirect method, such as interpolation, extrapolation, or comparison with other streams. If we use the instantaneous maximum flow from Skeena River at Usk (8100 m³/s) and transfer it to Glen Vowell, we get a discharge of 5537 m³/s. This flow was run in the 2D model and a summary of the observed and simulated WEL are provided in Table 3-10 for the updated 1972 Skeena flows. This improved the difference between observed and simulated WEL, but the simulated WEL was still generally higher.

Table 3-9: Estimated High-water Marks June 12, 1972 (Skeena 6202 m³/s; Bulkley 1702 m³/s)

Location (approximate coordinates UTM Z9)	Observed WEL (m)	Simulated WEL (m)	Difference (m) (Simulated – Observed)
School Field (583935 m East, 6123850 m North)	215.2 – 215.3*	216.58 – 216.61	1.31 – 1.38
Ferry Rd (583870 m East, 6123885 m North)	215.30*	216.64	1.34
'Ksan Parking Lot (584105 m East, 6123360 m North)	214.50*	215.16	0.66
		Average Absolute Difference	1.17

* taken from RDKS 1974 report

Table 3-10: Estimated High-water Marks June 12, 1972 (Skeena 5537 m^3/s; Bulkley 1702 m^3/s)

Location (approximate coordinates UTM Z9)	Observed WEL (m)	Simulated WEL (m)	Difference (m) (Simulated – Observed)
School Field (583935 m East, 6123850 m North)	215.2 – 215.3*	216.05 – 216.07	0.77 – 0.85
Ferry Rd (583870 m East, 6123885 m North)	215.30*	216.08	0.78
‘Ksan Parking Lot (584105 m East, 6123360 m North)	214.50*	214.85	0.35
Average Absolute Difference			0.69

* taken from RDKS 1974 report

For both 1936 and 1972, the simulated WELs are higher than the observed WELs. Despite these over estimations, the Manning’s *n* roughness was not reduced because:

- A more recent flood (2007) had simulated and observed WEL that matched well;
- The flood in 2007 was only about 6% lower than the flood in 1972 (5209 m^3/s versus 5537 m^3/s) and should have similar roughness characteristics;
- Historic differences to the terrain generated for this study (2019/2020) (other than the existing dike) are likely since the area has been developing over the past 80 years. Terrain differences that could affect flood water elevations include things such as the development of roadways or buildings, adjustments to floodplain elevations (e.g. campground development), and changes to the channel geomorphology (e.g., bank erosion); and
- Over-estimation is a conservative estimate of the flood WEL.

3.3.4 Design Flow Model Simulation

The design flow peak discharges for Skeena River and Bulkley River were run in the model to simulate WELs in the study reach and had the following characteristics:

- The 200-year instantaneous peak flow for the Skeena River;
- The 200-year instantaneous peak flow for the Bulkley River;
- The instantaneous flows have been increased to account for climate change;
- The 200-year flood events on Skeena River and Bulkley River occur simultaneously;
- Channel morphology was considered constant (e.g., no scour, erosion, degradation, etc.); and
- Open water conditions (i.e., no ice).

The simulated design flood profiles are plotted in Figure 3-7 (Skeena River) and Figure 3-8 (Bulkley River).

Figure 3-7: Skeena River Profile – 200-year (plus Climate Change) Simulated WEL.

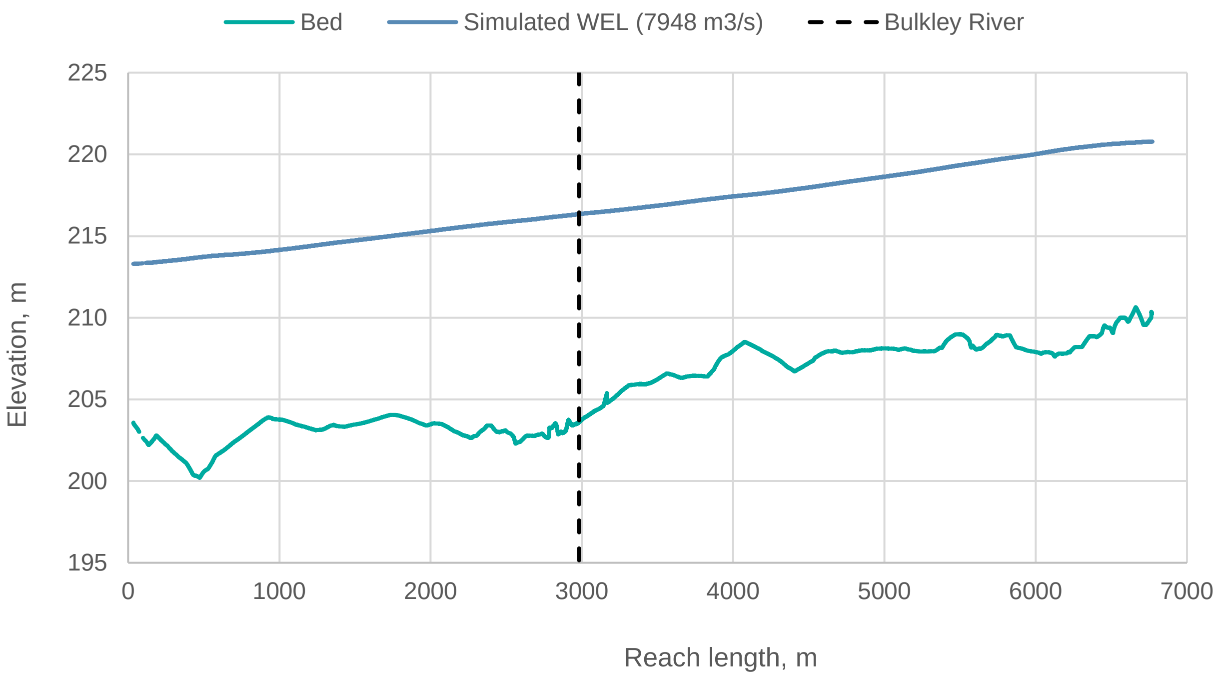
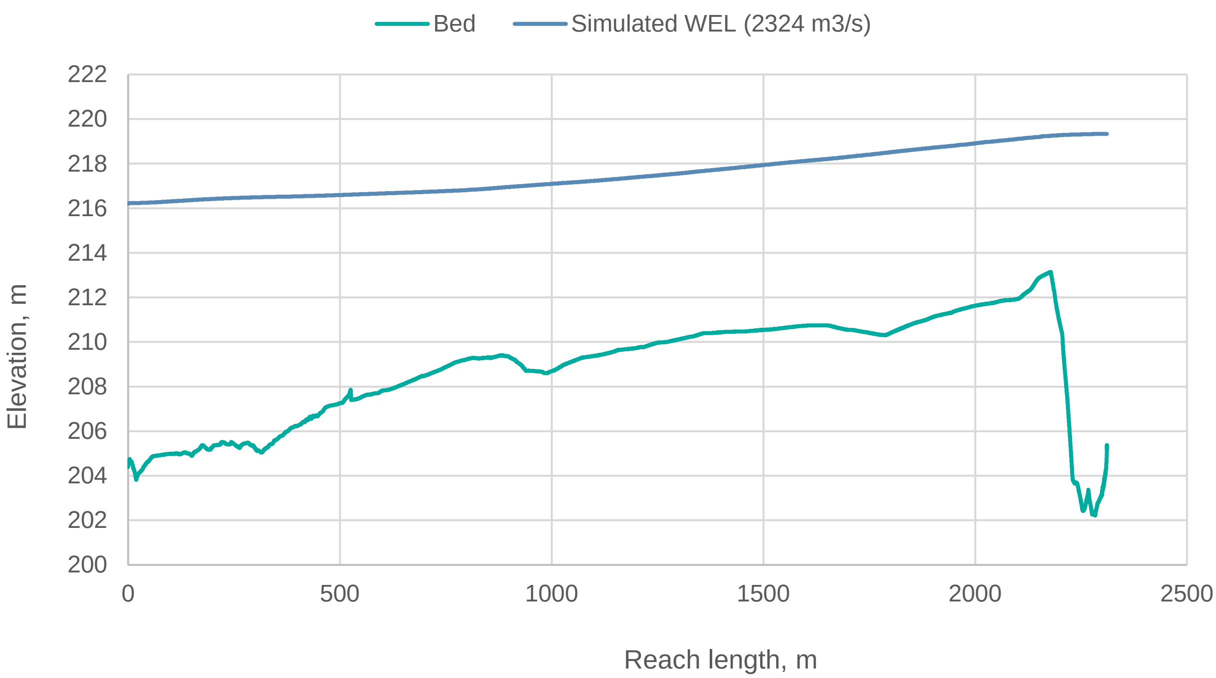


Figure 3-8: Bulkley River Profile – 200-year (plus climate change) Simulated WEL.



3.3.5 Sensitivity Analysis

A sensitivity analysis was conducted to evaluate the effect of changing various model parameters on simulated WELs. The climate change affected 200-year flood was used as a base case. The sensitivity analysis was used to quantify the level of uncertainty related to the simulated flood levels.

The following model parameters were varied within a credible range:

- Downstream boundary condition;
- Inflow boundary conditions (upstream);
- Channel roughness values; and
- Overbank roughness values.

3.3.5.1 Downstream Boundary Condition

The downstream boundary condition in the model was normal depth, which is based on the friction slope and estimated from the water surface slope. The friction slope was modified to identify how much the simulated WELs would be affected. The friction slope was increased from 0.0009 (obtained from surveyed WEL near the downstream end) to 0.0013 (calculated from all surveyed WELs in the study reach).

The difference in simulated WEL is shown in Figure 3-9 (Skeena River) and Figure 3-10 (Bulkley River) and summarised in Table 3-11. The steeper downstream boundary condition (0.0013) produces lower WELs, which are most prominent at the downstream end of the model (difference of 1.00 m). However, WEL differences closer to the village of Hazelton and Gitanmaax are less (average -0.15 m and maximum -0.23 m). Bulkley River WEL differences were greatest near the confluence as the Skeena River WEL is the downstream boundary condition and control (average of -0.27 m and maximum of -0.31 m).

As a check, the slope along the Skeena River was measured over a longer reach using Canadian Digital Elevation Data, which is based on National Topographic database. While much less accurate than LiDAR data, the data can provide a good estimate of slope over a longer distance. A ~ 5 km reach downstream of the study area was measured to have a slope of 0.0011 m/m, which agreed well with the surveyed WEL slopes. Therefore, it was assumed that the normal depth condition should not be lower than 0.0009 and will likely be less than 0.0013; 0.0009 is conservative as it produces a higher WEL.

Table 3-11: Difference in Simulated WELs using Normal Depth = 0.0009 and Normal Depth = 0.0013

Reach	Average Difference (m)	Maximum Difference (m)
Skeena River – entire model (~0 – 7000 m)	-0.32	-1.00
Skeena River – ‘Ksan campground to upstream of Hazelton (~3500 – 5200m)	-0.15	-0.23
Bulkley River – entire model (~0 – 2500m)	-0.16	-0.31
Bulkley River – from confluence to upstream of ‘Ksan Village (~0 – 600m)	-0.27	-0.31

Figure 3-9: Skeena River Downstream Boundary Sensitivity Analysis.

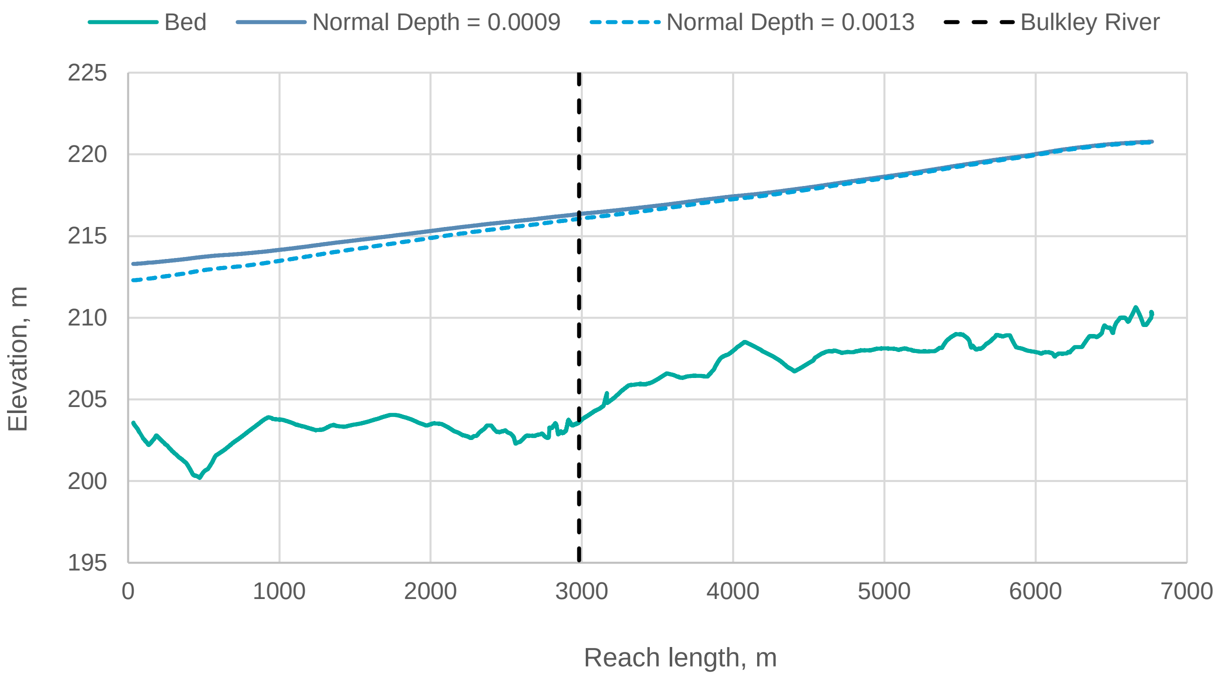
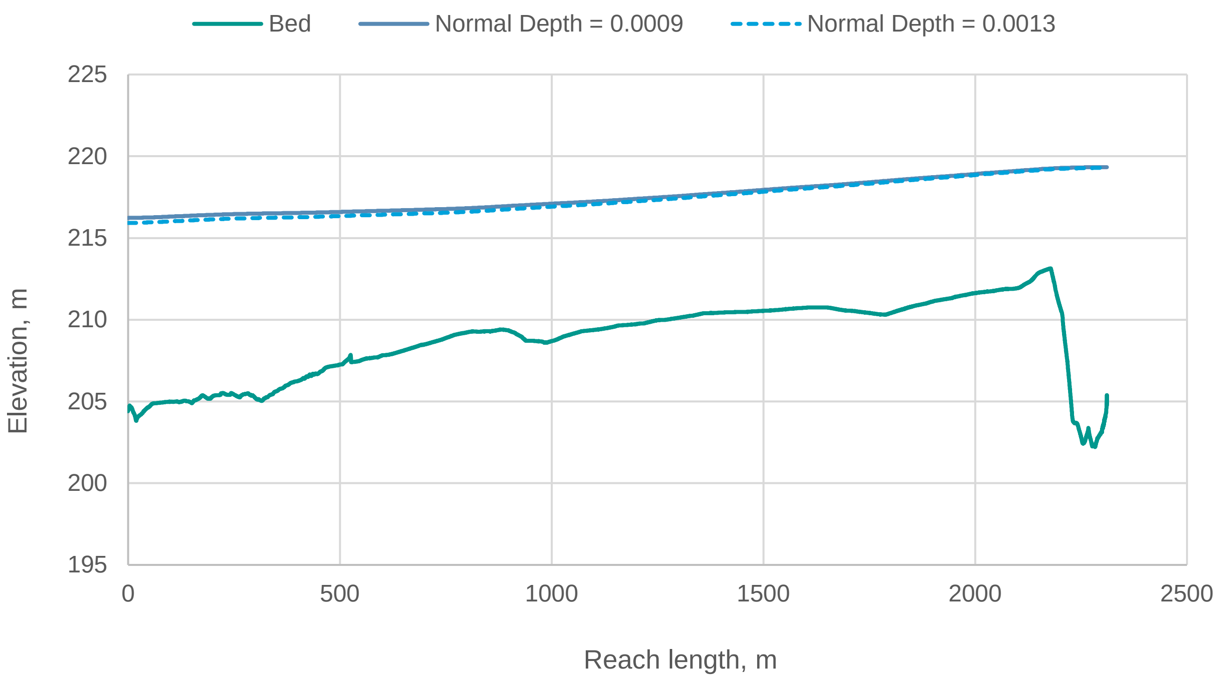


Figure 3-10: Bulkley River Downstream Boundary Sensitivity Analysis.



3.3.5.2 Inflow Boundary Condition

The inflow boundary conditions are the design flows for Skeena River and Bulkley River. The instantaneous peak flows (with climate change) were varied by +/- 10% to identify how much the simulated WEL would be affected.

The difference in simulated WEL is summarised in Table 3-12 shown in Figure 3-11 (Skeena River) and Figure 3-12 (Bulkley River). The increased inflow boundary condition (+10%) produces a somewhat consistent increase of about 0.5 m in WELs over the entire study area (about 5% increase in depth). The decreased inflow boundary condition (-10%) also produces a somewhat consistent decrease of about -0.6 m in WEL's over the entire study area (about 6% increase in depth).

Table 3-12: Difference in Simulated WELs using 10% Higher and Lower Flows

	+10% Q =8743 m^3/s vs 7948 m^3/s		-10% Q =7153 m^3/s vs 7948 m^3/s	
Reach	Average Difference (m)	Maximum Difference (m)	Average Difference (m)	Maximum Difference (m)
Skeena River – entire model (~0 – 7000 m)	0.49	0.52	-0.58	-0.63
Skeena River – 'Ksan campground to upstream of Hazelton (~3500 – 5200m)	0.46	0.50	-0.54	-0.59
Bulkley River – entire model (~0 – 2500m)	0.46	0.56	-0.48	-0.58
Bulkley River – from confluence to upstream of 'Ksan Village (~0 – 600m)	0.55	0.56	-0.57	-0.58

Figure 3-11: Skeena River Inflow Boundary Condition Sensitivity Analysis.

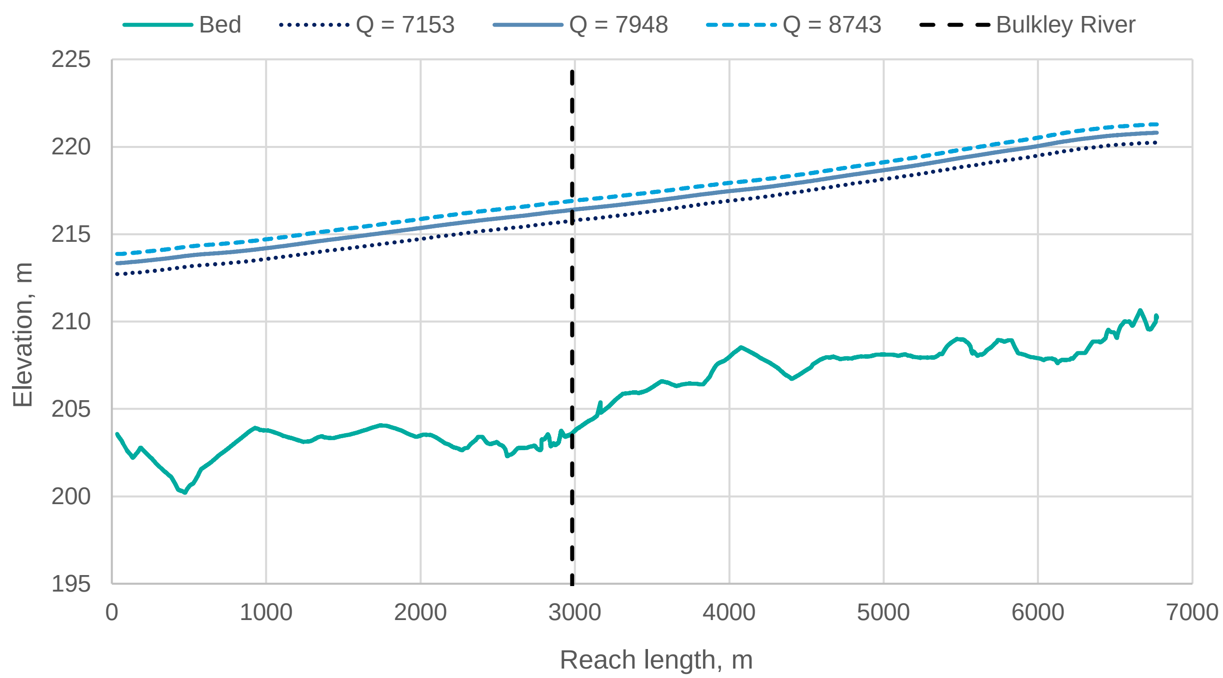
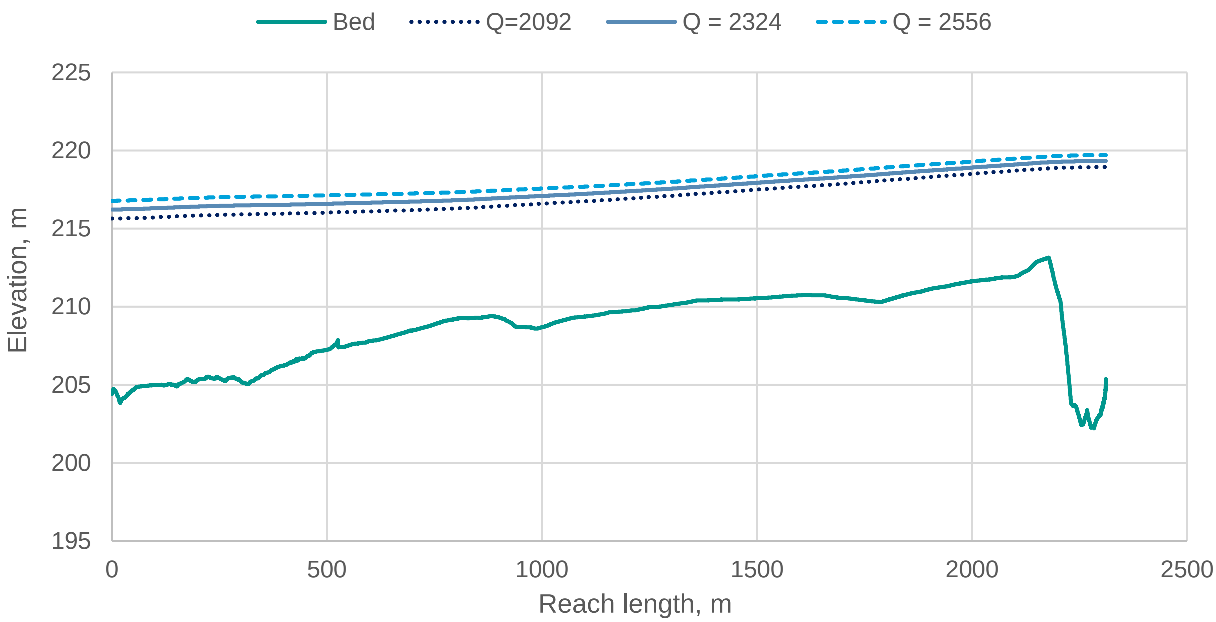


Figure 3-12: Bulkley River Inflow Boundary Condition Sensitivity Analysis.



3.3.5.3 Channel Roughness

The channel roughness coefficients (Manning *n*) were varied by +/-10% to identify how much the simulated WEL would be affected. The difference in simulated WEL is summarised in Table 3-13 and shown in Figure 3-13 (Skeena River) and Figure 3-14 (Bulkley River). The increased channel roughness coefficient (+10%) produces a somewhat consistent increase of about 0.5 m in WELs over the entire study area, which equates to about a 5% increase in flow depth. The decreased channel roughness coefficient (-10%) also produces a somewhat consistent decrease of about -0.6 m in WEL's over the entire study area, which equates to about a 6% decrease in flow depth.

Table 3-13: Difference in Simulated WELs using 10% Higher and Lower Channel Manning n's.

	+10% Channel Manning n		-10% Channel Manning n	
Reach	Average Difference (m)	Maximum Difference (m)	Average Difference (m)	Maximum Difference (m)
Skeena River – entire model (~0 – 7000 m)	0.47	0.52	-0.57	-0.63
Skeena River – 'Ksan campground to upstream of Hazelton (~3500 – 5200 m)	0.43	0.47	-0.52	-0.58
Bulkley River – entire model (~0 – 2500 m)	0.44	0.55	-0.47	-0.58
Bulkley River – from confluence to upstream of 'Ksan Village (~0 – 600 m)	0.53	0.55	-0.56	-0.58

Figure 3-13: Skeena River Channel Manning n Sensitivity Analysis.

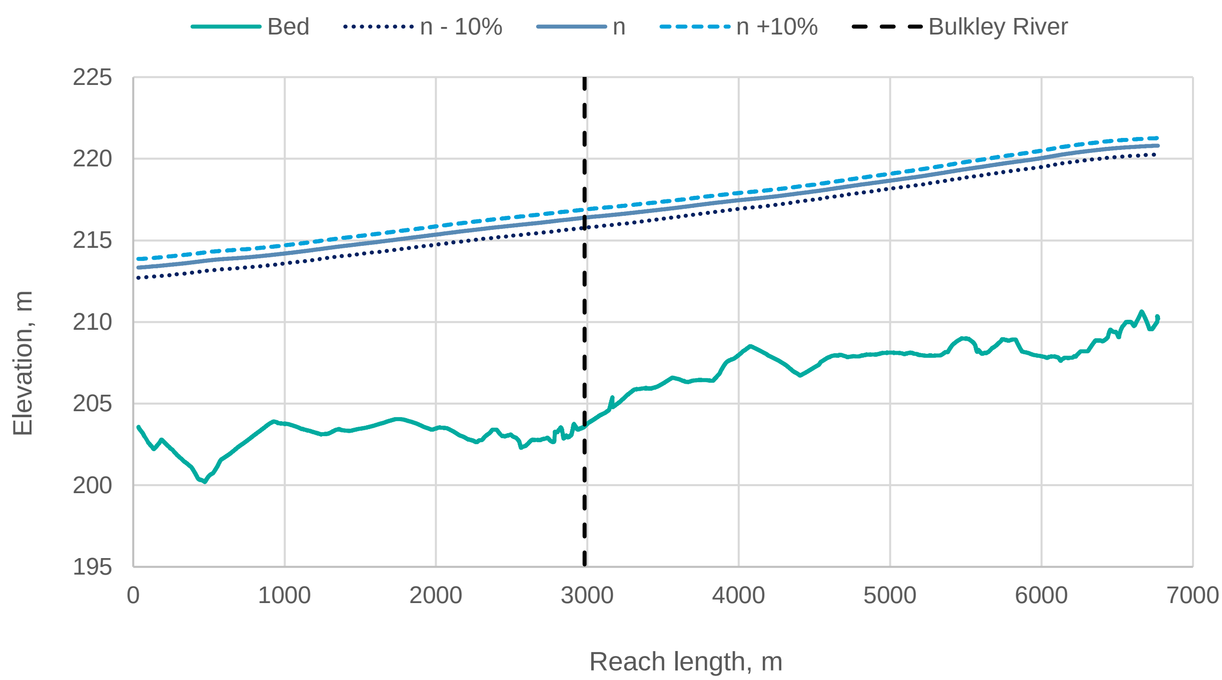
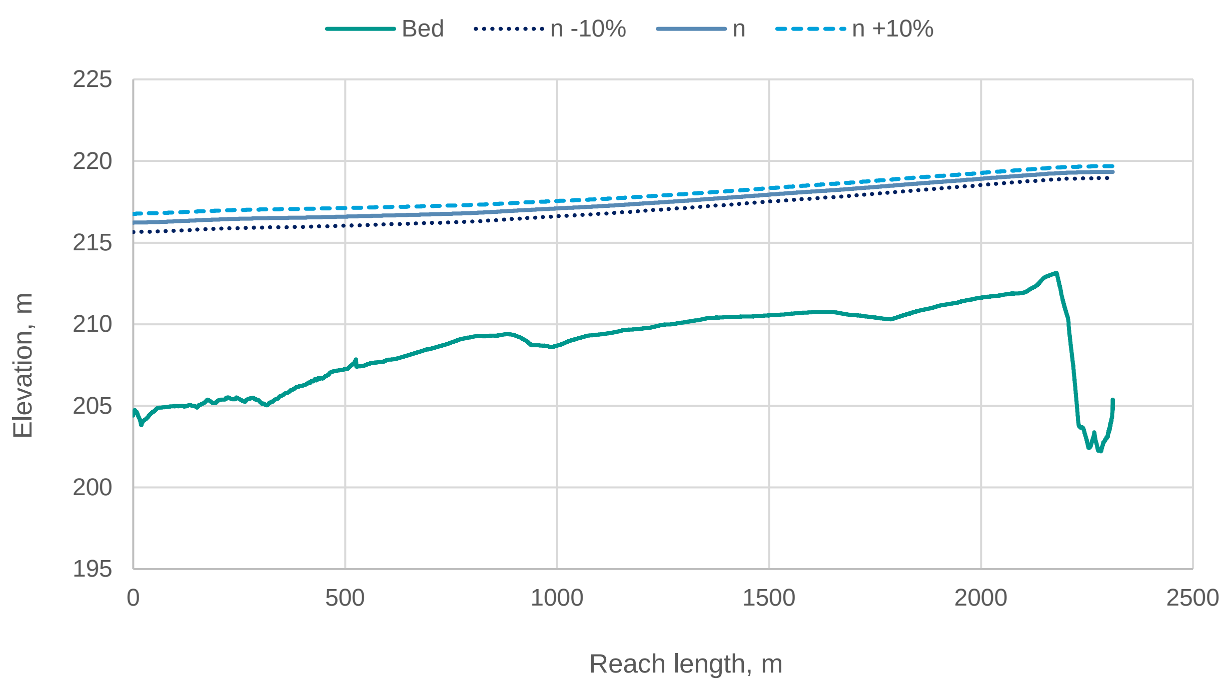


Figure 3-14: Bulkley River Channel Manning n Sensitivity Analysis.



3.3.5.4 Overbank Roughness

The overbank roughness coefficients (Manning *n*) were varied by +/-15% to identify how much the simulated WEL would be affected. The difference in simulated WEL is summarised in Table 3-14 and shown in Figure 3-15 (Skeena River) and Figure 3-16 (Bulkley River). The increased and decreased overbank roughness coefficients only changed the WEL by a few centimeters, less than 0.5% of flow depth.

Table 3-14: Difference in Simulated Wels using 15% Higher and Lower Overbank Manning *n*'s.

	+15% Overbank Manning n		-15% Overbank Manning *n*	
Reach	Average Difference (m)	Maximum Difference (m)	Average Difference (m)	Maximum Difference (m)
Skeena River – entire model (~0 – 7000 m)	0.01	0.03	-0.02	-0.04
Skeena River – 'Ksan campground to upstream of Hazelton (~3500 – 5200m)	0.03	0.03	-0.03	-0.04
Bulkley River – entire model (~0 – 2500m)	0.01	0.02	-0.02	-0.03
Bulkley River – from confluence to upstream of 'Ksan Village (~0 – 600m)	0.01	0.01	-0.01	-0.01

Figure 3-15: Skeena River Overbank Manning *n* Sensitivity Analysis.

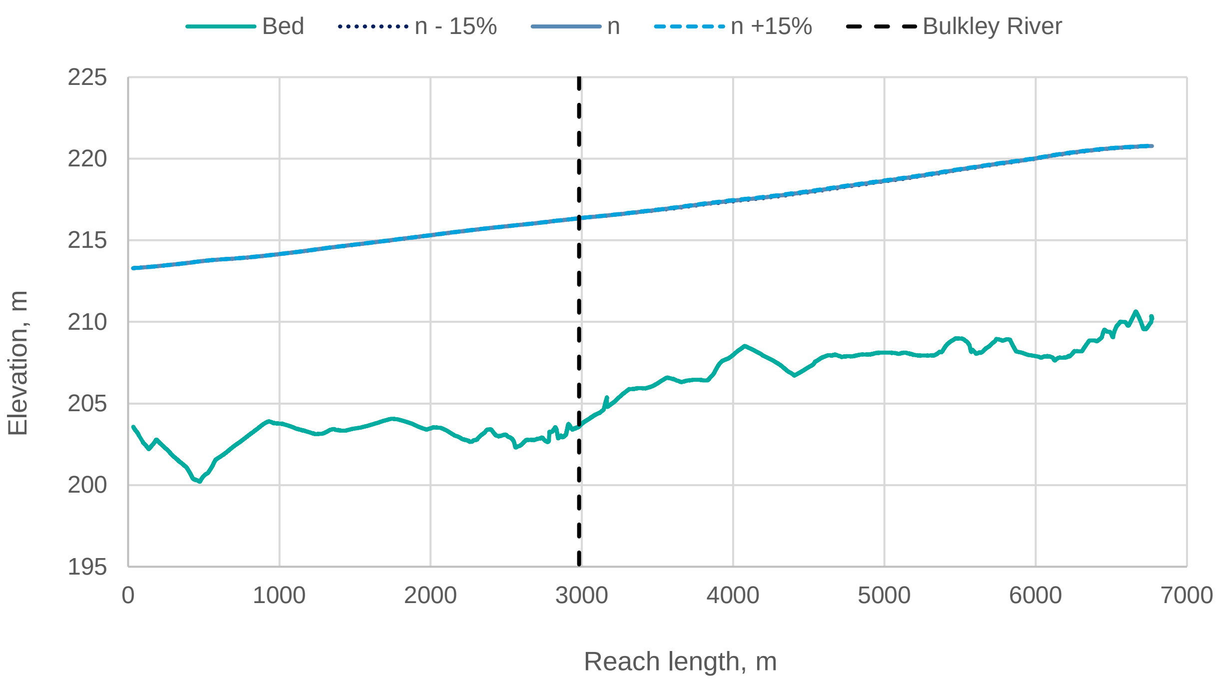
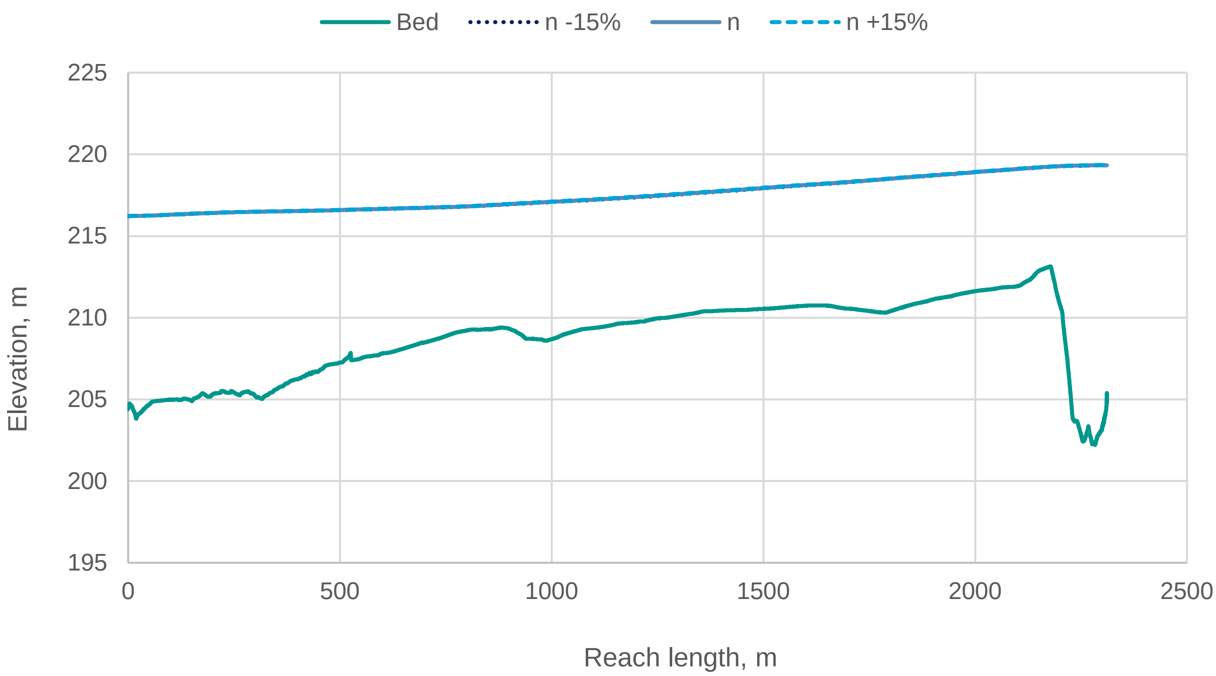


Figure 3-16: Bulkley River Overbank Manning *n* Sensitivity Analysis.



3.3.6 Summary and Freeboard

The model and simulated WEL are not very sensitive to the overbank Manning's *n* roughness. The simulated WEL is somewhat sensitive to the downstream boundary condition (friction flow) but becomes less sensitive further away from the boundary (e.g., near the village of Hazelton and Gitanmaax). The simulated WEL is most sensitive to the inflow boundary (discharge) and channel Manning's *n* roughness coefficient. This is similar to the sensitivity analysis from the MOELP 1993 flood study. The model was sensitive to both inflow and roughness and it was thought to be a result of the confining 'U" shaped valley in the area; meaning that instead of water spreading out (as with a flat floodplain), WEL's rise and maintain a similar footprint.

Due to this sensitivity in the model parameters, it was decided to add 0.6 m of freeboard to the simulated WEL for the 200-year climate change affected flood.

3.4 Flood Inundation Mapping

Flood inundation maps are powerful tools for emergency response planning and preparation. They help communities and authorities to visualize the probable areas of inundation, the depth of the water within these areas, and provide a tool for risk management and emergency response.

Results from the 2D hydraulic modelling were used to produce open water flood inundation maps for three climate change affected scenarios within the study area. The 200-year climate change affected inundation maps include a freeboard of 0.6 m and are presented in Appendix A. The 2-year and 25-year climate change affected inundation maps (no freeboard) were also produced and are presented in Appendix B and Appendix C, respectively.

SNC·LAVALIN

3.4.1 Base Map Preparation

APEGBC Professional Practice Guidelines for Flood Mapping in BC (2017) were followed to produce the maps. Base maps (11"x17") included:

- Topographic contour lines created from the merged ground survey, bathymetry, and LiDAR data;
- Same mapping scale (1:3,200) and orientation for each scenario;
- Orthophoto imagery from August 2019 as a map background;
- Local government boundaries, parcels, and roadways; and
- Streamlines and approximate extents of existing flood and erosion control structure (riprap and dike).

3.4.2 Skeena River 200-year

The 200-year flood inundation boundary with climate change allowance and 0.6 m freeboard for Skeena River is plotted in Sheet 1 to Sheet 5 of the Skeena River and Bulkley River Floodplain Map (Appendix A). The flood overtops the existing dike structure and inundates much of Government Street, extending to several residences on the southeast side. The sewer lift station at the end of Ferry Road is completely inundated, along with the school playing field. Residents along Cunningham Street are completely inundated, and some residents along River Road are also inundated. The 'Ksan campground is also inundated.

3.4.3 Bulkley River 200-year

The 200-year flood inundation boundary with climate change allowance and 0.6 m freeboard for Bulkley River is plotted in the Skeena River and Bulkley River Floodplain Map (Sheet 6 and Sheet 7). The flood inundates 'Ksan historical village and much of the Anderson Flats Provincial Park.

3.4.4 Limitations

Current industry best practices were used to develop the floodplain maps; however, actual flood levels and inundation boundaries may vary. Variation in channel conditions from those modelled, such as debris/ice jams, bank erosion, channel degradation or aggradation, and channel scour can cause flood levels to differ from those mapped. As well, additions to inflows such as tributary flow, groundwater flow, and local storm water can cause flood levels to exceed those mapped.

The flood and erosion protection structures (dike and riprap bank) were not inspected or evaluated during this study. Their ability to protect or withstand floods was not assessed.

The maps do not provide erosion or scour hazard information. Site-specific engineering designs must consult a Qualified Professional to determine the specific hazards associated with the design.

4 Summary

This report outlined the flood modelling assessments for the 200-year climate change affected flood for Skeena River and Bulkley River in the village of Hazelton, BC and Gitanmaax. Analyses included:

- Flow frequency analyses for Skeena River and Bulkley River;
- Climate change assessment;
- 2D hydraulic model development and analysis;
- Calibration and validation of model; and
- Model parameter sensitivity analysis.

Flood inundation boundaries were mapped to show locations where the rivers were expected to overtop banks. This report should be reviewed in conjunction with our *Skeena River and Bulkley River Flood Study - Flood Mitigation Plan Report* (SNC-Lavalin 2021), which is provided under separate cover. The Flood Mitigation Plan report includes the assessment of flood hazards (namely water depth and water velocity), a qualitative risk assessment, and proposed mitigation options (structural and non-structural) to manage the flooding risks identified.

5 Notice to Reader

This report has been prepared and the work referred to in this report have been undertaken by SNC-Lavalin Inc. (SNC-Lavalin) for the exclusive use of Corporation of the Village of Hazelton (the Village) and Gitanmaax Band (Band), who has been party to the development of the scope of work and understands its limitations. The methodology, findings, conclusions, and recommendations in this report are based solely upon the scope of work and subject to the time and budgetary considerations described in the proposal and/or contract pursuant to which this report was issued. Any use, reliance on, or decision made by a third party based on this report is the sole responsibility of such third party. SNC-Lavalin accepts no liability or responsibility for any damages that may be suffered or incurred by any third party as a result of the use of, reliance on, or any decision made based on this report. Should this report be submitted to the BC Ministry of Environment & Climate Change Strategy (ENV) by the Village and Band, ENV is authorized to rely on the results in the report, subject to the limitations set out herein, for the sole purpose of determining whether Village and Band have fulfilled its obligations with respect to meeting the regulatory requirements of ENV.

The findings, conclusions and recommendations in this report (i) have been developed in a manner consistent with the level of skill normally exercised by professionals currently practicing under similar conditions in the area, and (ii) reflect SNC-Lavalin's best judgment based on information available at the time of preparation of this report. No other warranties, either expressed or implied, are made as to the professional services provided under the terms of our original contract and included in this report. The findings and conclusions contained in this report are valid only as of the date of this report and may be based, in part, upon information provided by others. If any of the information is inaccurate, new information is discovered, site conditions change or standards are amended, modifications to this report may be necessary. The results of this assessment should in no way be construed as a warranty that the subject site is free from any and all environmental impact.

This report must be read as a whole, as sections taken out of context may be misleading. If discrepancies occur between the preliminary (draft) and final version of this report, it is the final version that takes precedence. Nothing in this report is intended to constitute or provide a legal opinion.

The contents of this report are confidential and proprietary. Other than by the Village and Band, copying or distribution of this report or use of or reliance on the information contained herein, in whole or in part, is not permitted without the express written permission of the Village and Band and SNC-Lavalin.

6 References

AMEC Environment and Infrastructure. 2014. Frequency analysis procedure for stormwater design. Report prepared for City of Calgary, 145 p.

Arcement, G.J. and Schneider, V.R. 1983. *Guide for selecting Manning's roughness coefficients for natural channels and flood plains*. U.S. Geological Survey, Water-Supply Paper 2339, 44 p.

Association of Professional Engineers and Geoscientists of British Columbia (APEGBC). 2017. Professional Practice Guidelines – Flood Mapping in BC, 54p.

BC Ministry of Environment Lands and Parks (MOELP). 1993. *Floodplain mapping study Skeena and Bulkley Rivers at Hazelton*. Province of British Columbia, MOELP, Water Management Division Floodplain Management Branch, 23p.

BC Ministry of Forests, Lands, Natural Resources Operations and Rural Development GeoBC (MFLNRO). 2020. Specifications for Airborne LiDAR for the Province of British Columbia, 54 p.

BC Ministry of Land, Water, and Air Protection (MWLAP). 2004. Flood Hazard Area Land Use Management Guidelines, 73 p.

Chow, V.T. 1959. Open-channel hydraulics: New York, McGraw-Hill, 680 p.

Engineers and Geoscientists British Columbia (EGBC). 2018. Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC, 192 p.

Earth Resources Observation and Science (EROS). 2016. National Land Cover Database. U.S. Geological Survey. Available at: https://www.usgs.gov/centers/eros/science/national-land-cover-database?qt-science_center_objects=0#qt-science_center_objects (accessed January 2021).

Friend, A. and McBroom, M. 2018. Smooth transition – adjusting Manning's n values for 2D modeling [PowerPoint Presentation]. Available at: http://dnrc.mt.gov/divisions/water/operations/floodplain-management/training/2018-amfm-conference/Friend_ManningsNValuesFor2DModeling.pdf (Accessed January 2021).

Interior News – Blackpress. 2011. Bulkley River continues to rise with rainfall. Article date 27 May 2011, available at: https://www.interior-news.com/news/bulkley-river-continues-to-rise-with-rainfall/. (Accessed February 2021).

Interior News – Blackpress. 2007. Bulkley flood eclipses all records. Article date 13 June 2007, provided by Interior News.

Regional District of Kitimat-Stikine (RDKS). 1974. Flood plain study. Hazelton, p 3 – 13.

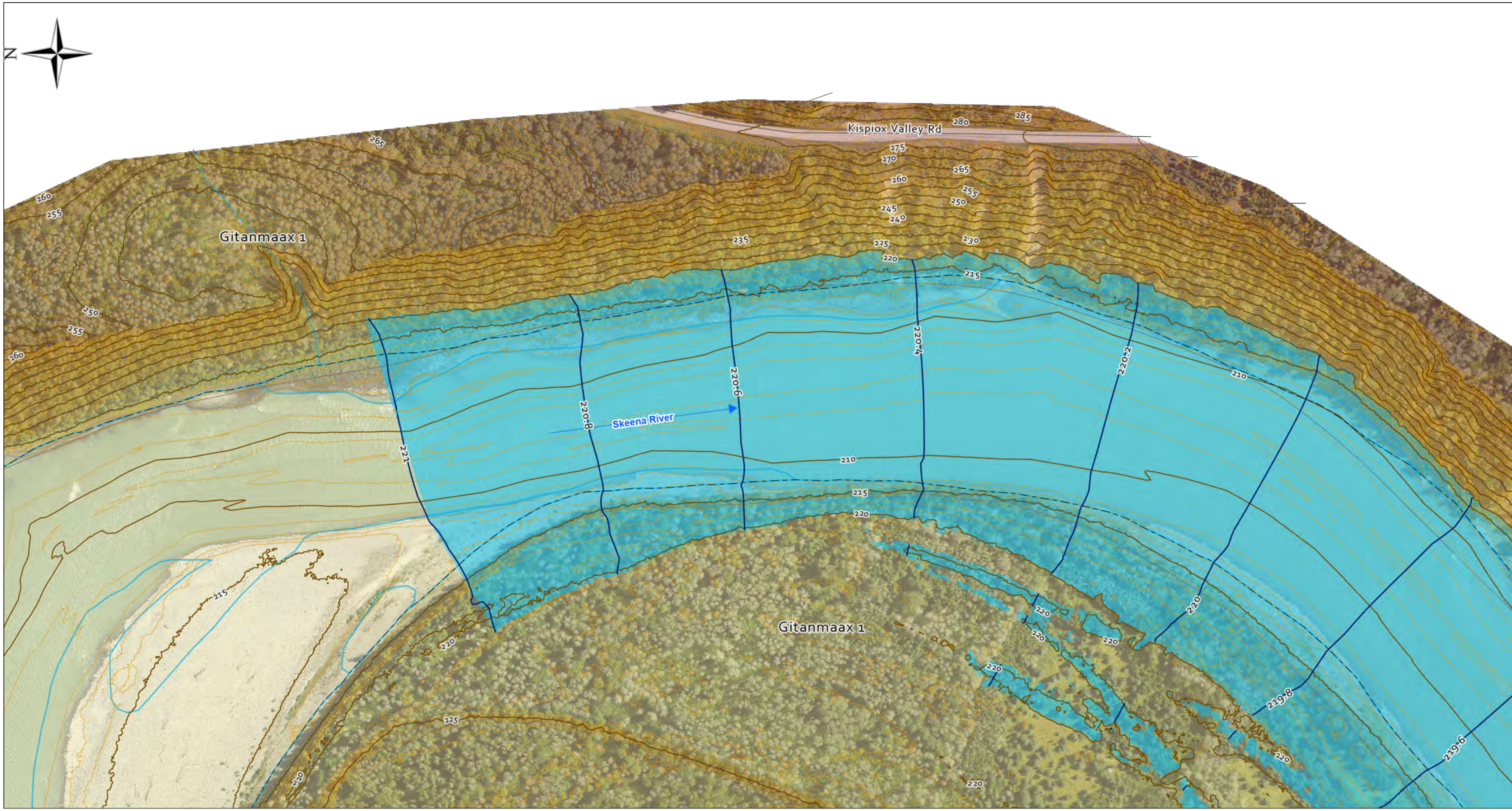
Septer, D. 2006. *Flooding and landslide events northern British Columbia 1820 – 2006*. Province of British Columbia, Ministry of Environment, 216 p.

SNC-Lavalin Inc. (SNC-Lavalin). 2021. *Skeena River and Bulkley River Flood Study - Flood Mitigation Plan. Prepared for Village of Hazelton and Gitanmaax Band*.

Turner, R.J.W., Van Heek, B., and Dodd, S. 2010. GeoTour guide for the Hazeltons, British Columbia. Geological Survey of Canada, Open File 5560, 22p.

Appendix A

Flood Inundation Map – 200-Year Flow with Climate Change Allowance and 0.6 m Freeboard

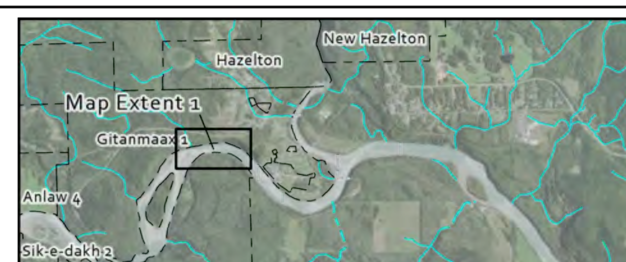


LEGEND

- Contours (5m)
- Contours (1m)
- Local Government Boundaries
- Parcels
- Roads
- River or Stream - Definite
- River or Stream - Dry

Flood Extent with Freeboard

- 200-year Flood
- Water Surface Contours (0.2m)



REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Skeena River and Bulkley River Flood Study - Floodplain Inundation Mapping Report prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 200-year return period events with an allowance for climate change plus 0.6 m of freeboard.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.

Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m

3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc., Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

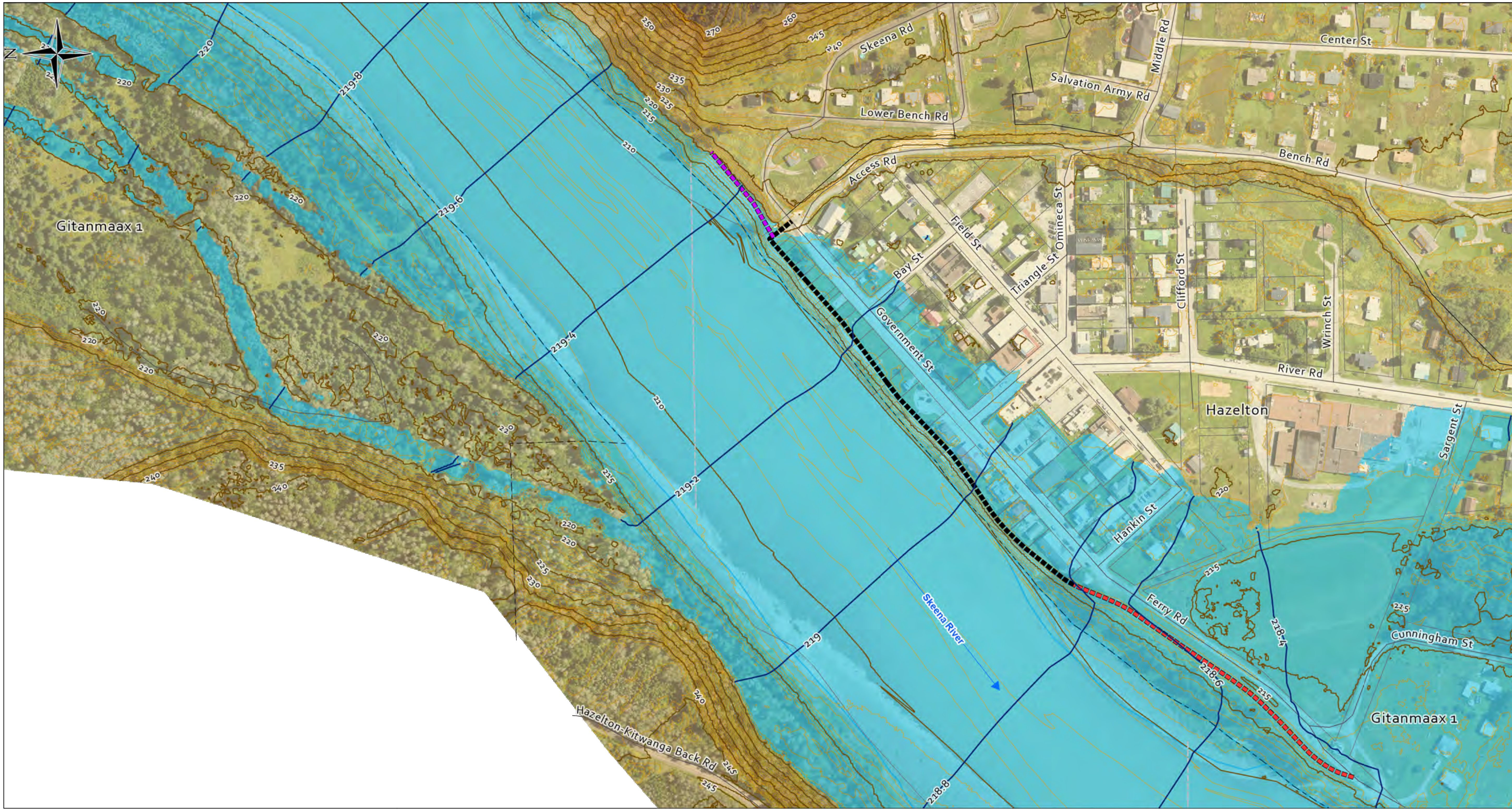
SNC·LAVALIN

CLIENT NAME: Village of Hazelton	PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River 200 Year Floodplain Map (Sheet 1 of 9)

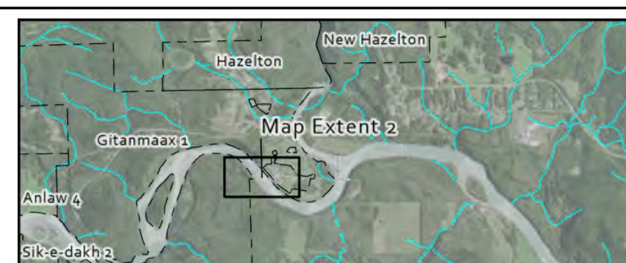
BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No: REV: 0
CHK'D: BR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-007-1

MXD Path: \\Sil2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx



LEGEND

- Contours (5m)
- Contours (1m)
- Local Government Boundaries
- Parcels
- Roads
- Flood and Erosion Protection Works (Approximate Locations)
  - Dike
  - Dike and Riverbank Protection
  - Riverbank Protection
- River or Stream - Definite
- River or Stream - Dry
- Flood Extent with Freeboard
  - 200-year Flood
- Water Surface Contours (0.2m)



REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Skeena River and Bulkley River Flood Study - Floodplain Inundation Mapping Report prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 200-year return period events with an allowance for climate change plus 0.6 m of freeboard.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.

Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m

3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc., Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

SNC·LAVALIN

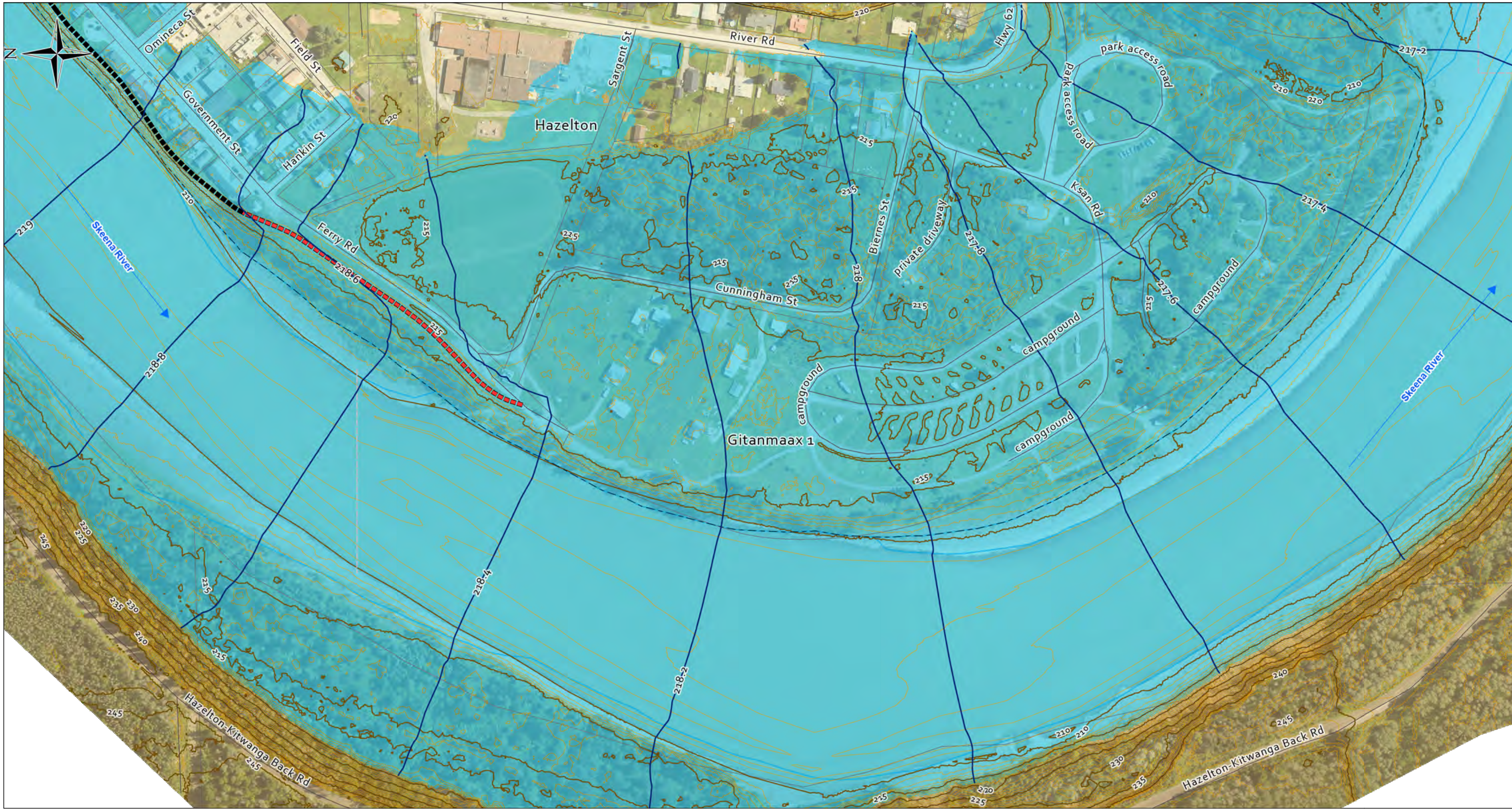
CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River 200 Year Floodplain Map (Sheet 2 of 9)

BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No:	REV: 0
CHK'D: BR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-007-2	

MXD Path: \\Sil2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx



LEGEND

Contours (5m)

Contours (1m)

Local Government Boundaries

Parcels

Roads

Flood and Erosion Protection Works (Approximate Locations)

Dike

Dike and Riverbank Protection

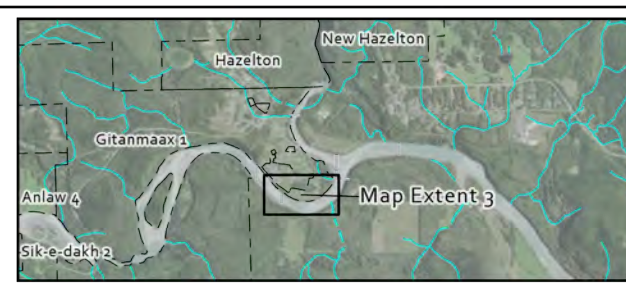
River or Stream - Definite

River or Stream - Dry

Flood Extent with Freeboard

200-year Flood

Water Surface Contours (0.2m)



REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Skeena River and Bulkley River Flood Study - Floodplain Inundation Mapping Report prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 200-year return period events with an allowance for climate change plus 0.6 m of freeboard.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.

Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m

3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc., Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

SNC·LAVALIN

CLIENT NAME: Village of Hazelton

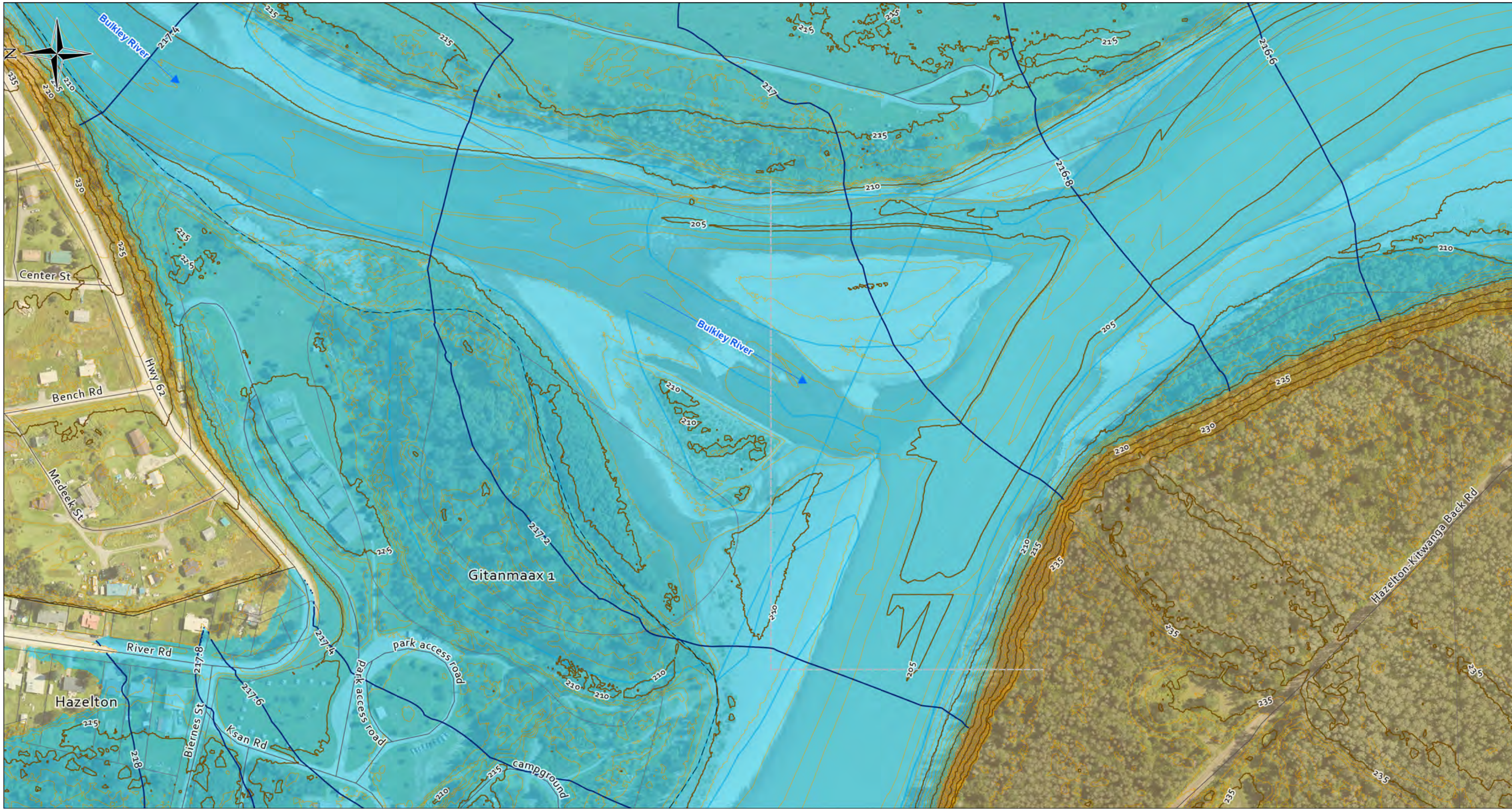
PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River
200 Year Floodplain Map (Sheet 3 of 9)

BY: ECH | SCALE: 1:3,200 | DATE: 2021-03-18 | REF No: 675878-007-3 | REV: 0

CHK'D: BR | PROJ COORD SYS: UTM Zone 9N NAD83

MXD Path: \\Sli2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx

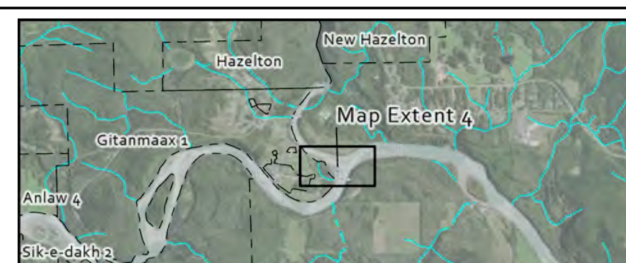


LEGEND

- Contours (5m)
- Contours (1m)
- Local Government Boundaries
- Parcels
- Roads
- River or Stream - Definite
- River or Stream - Dry

Flood Extent with Freeboard

- 200-year Flood
- Water Surface Contours (0.2m)



REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Skeena River and Bulkley River Flood Study - Floodplain Inundation Mapping Report prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 200-year return period events with an allowance for climate change plus 0.6 m of freeboard.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.

Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m

3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc., Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

SNC·LAVALIN

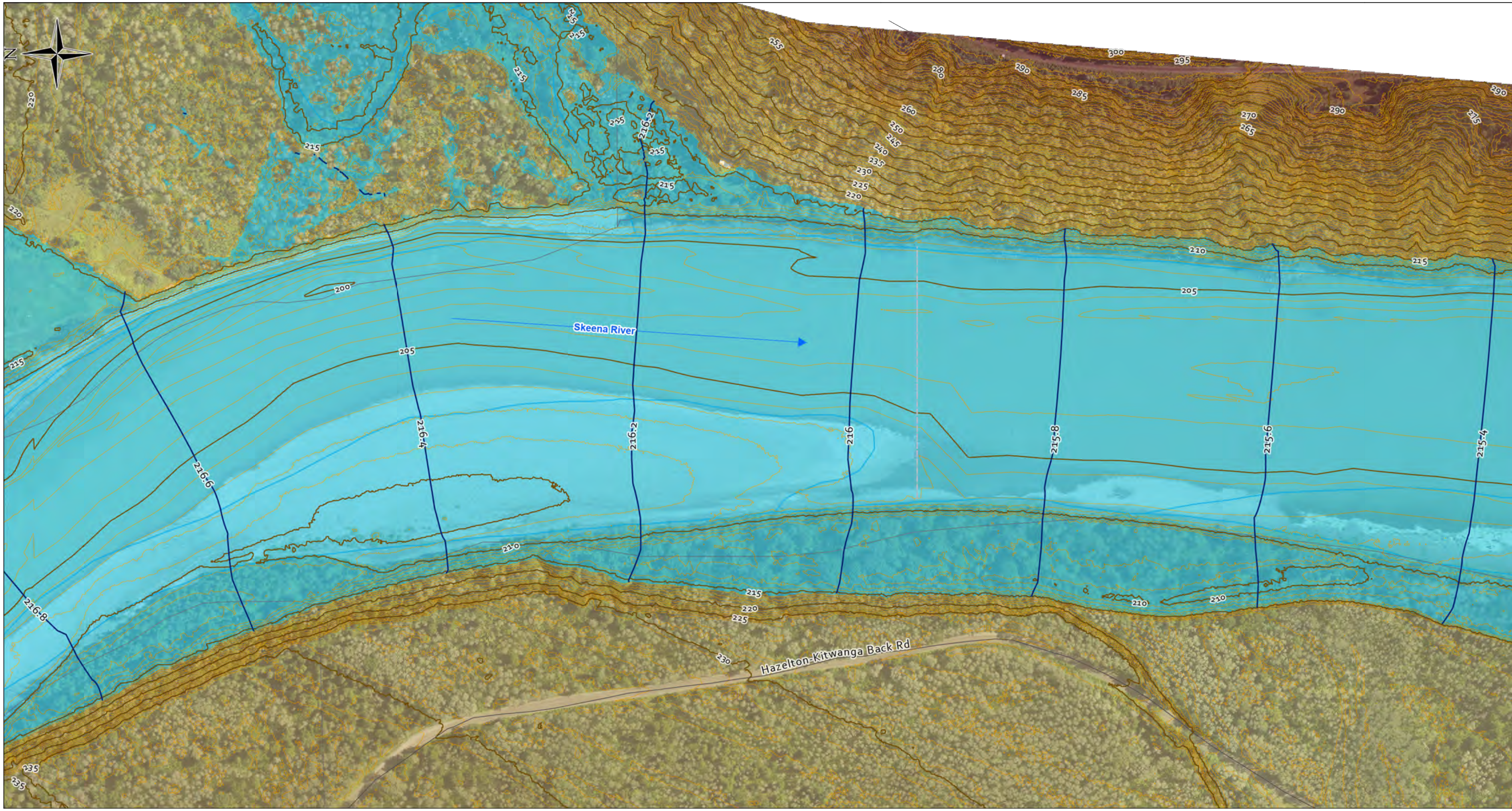
CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River 200 Year Floodplain Map (Sheet 4 of 9)

BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No:	REV: 0
CHK'D: BR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-007-4	

MXD Path: \\Sl2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx



LEGEND

Contours (5m)

Contours (1m)

Parcels

Roads

River or Stream - Definite

River or Stream - Dry

Flood Extent with Freeboard

200-year Flood

Water Surface Contours (0.2m)

REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Skeena River and Bulkley River Flood Study - Floodplain Inundation Mapping Report prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 200-year return period events with an allowance for climate change plus 0.6 m of freeboard.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.

Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m

3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc., Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

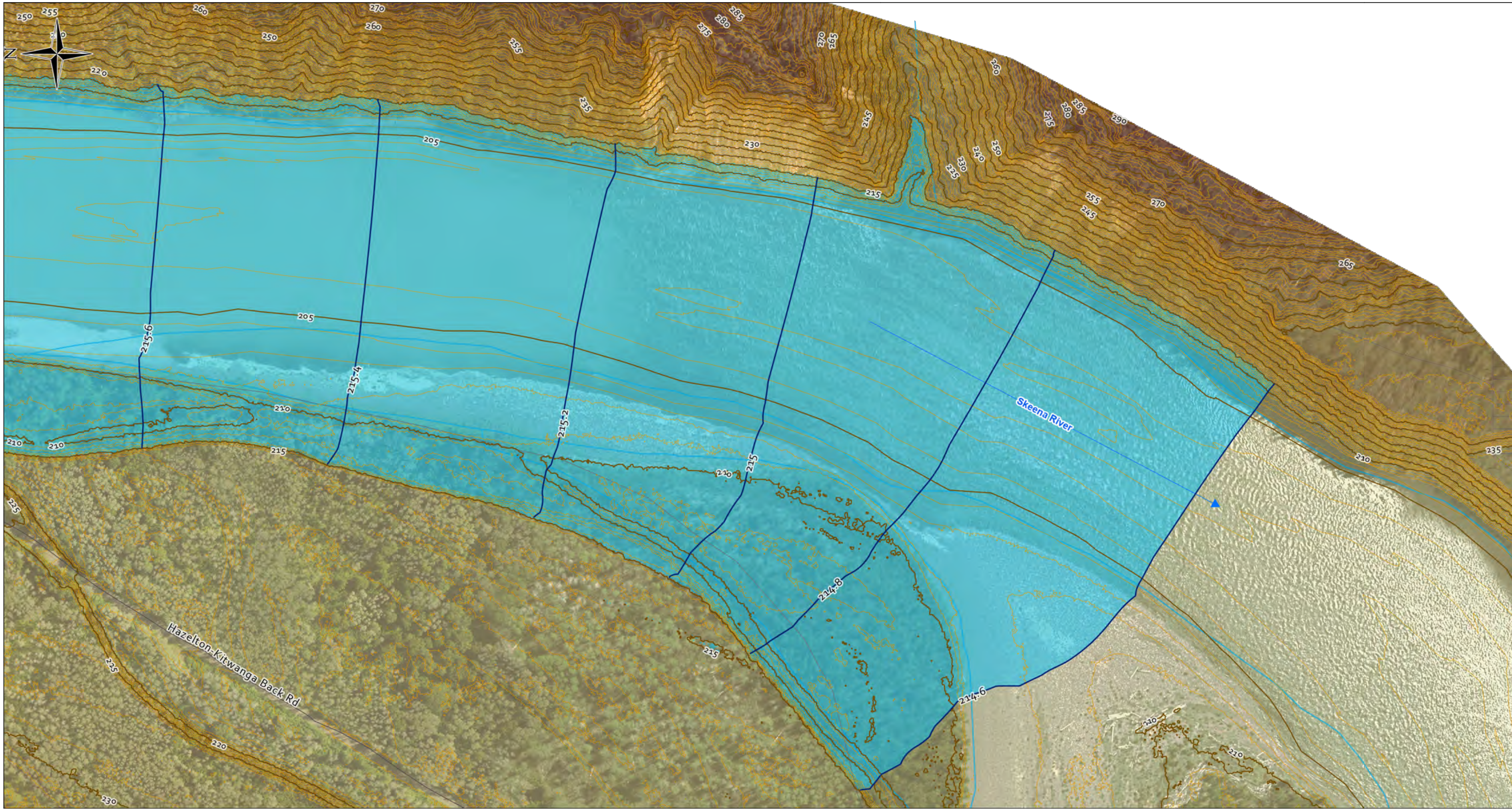
SNC • LAVALIN

CLIENT NAME: Village of Hazelton	PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River
200 Year Floodplain Map (Sheet 5 of 9)

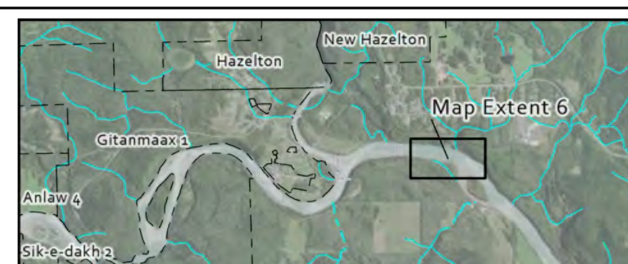
BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No: REV: 0
CHK'D: BR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-007-5

MXD Path: \\Sil2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx



LEGEND

Contours (5m)
Contours (1m)
Parcels
Roads
River or Stream - Definite
River or Stream - Dry
Flood Extent with Freeboard
200-year Flood
Water Surface Contours (0.2m)



REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Skeena River and Bulkley River Flood Study - Floodplain Inundation Mapping Report prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 200-year return period events with an allowance for climate change plus 0.6 m of freeboard.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.
Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m
3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc., Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

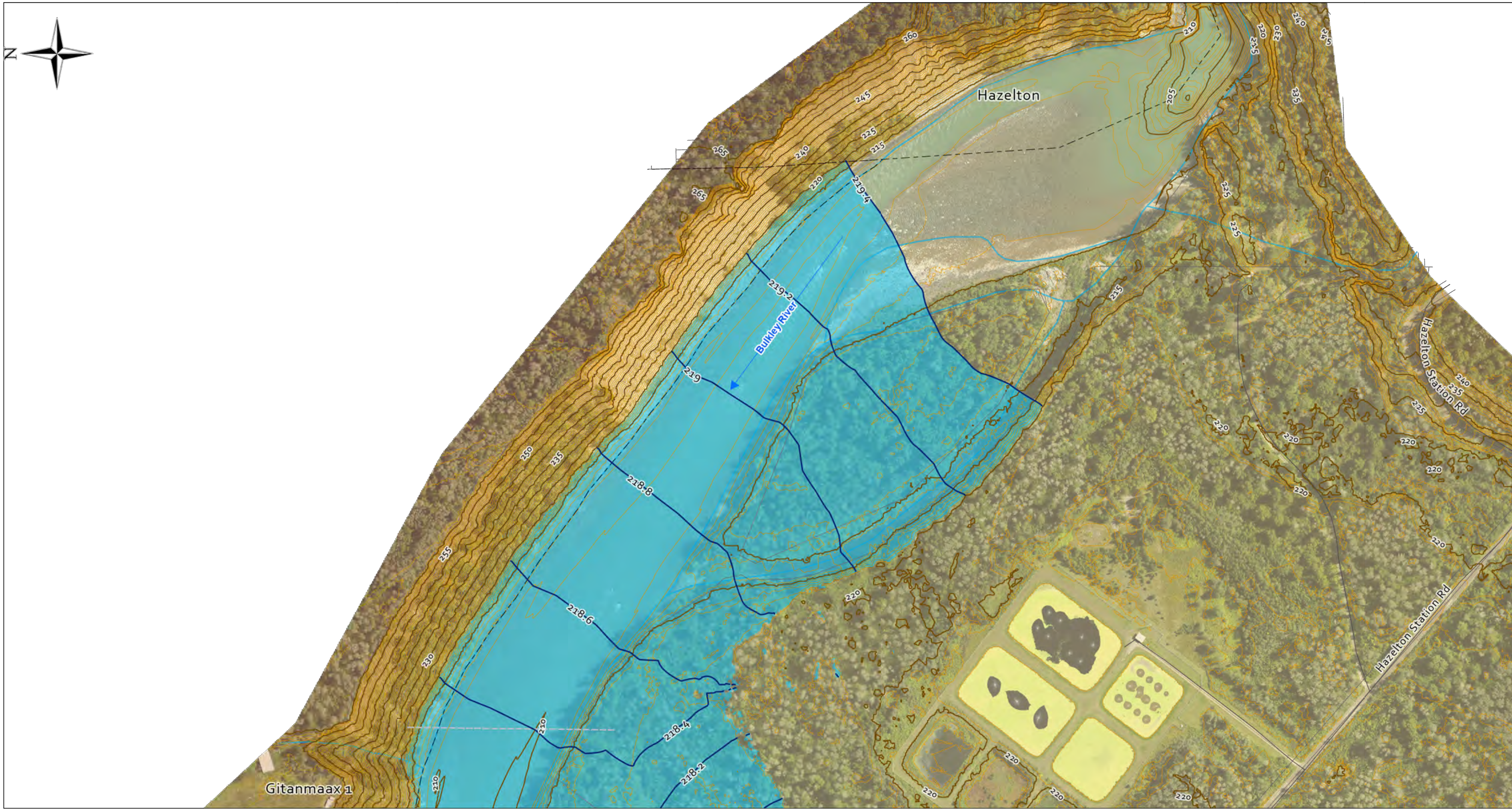
SNC·LAVALIN

CLIENT NAME: Village of Hazelton	PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River
200 Year Floodplain Map (Sheet 6 of 9)

BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No: REV: 0
CHK'D: BR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-007-6

MXD Path: \\SI2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx



LEGEND

- Contours (5m)
- Contours (1m)
- Local Government Boundaries
- Parcels
- Roads
- River or Stream - Definite
- River or Stream - Dry
- Flood Extent with Freeboard
- 200-year Flood
- Water Surface Contours (0.2m)

REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Skeena River and Bulkley River Flood Study - Floodplain Inundation Mapping Report prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 200-year return period events with an allowance for climate change plus 0.6 m of freeboard.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.

Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m

3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc., Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

SNC • LAVALIN

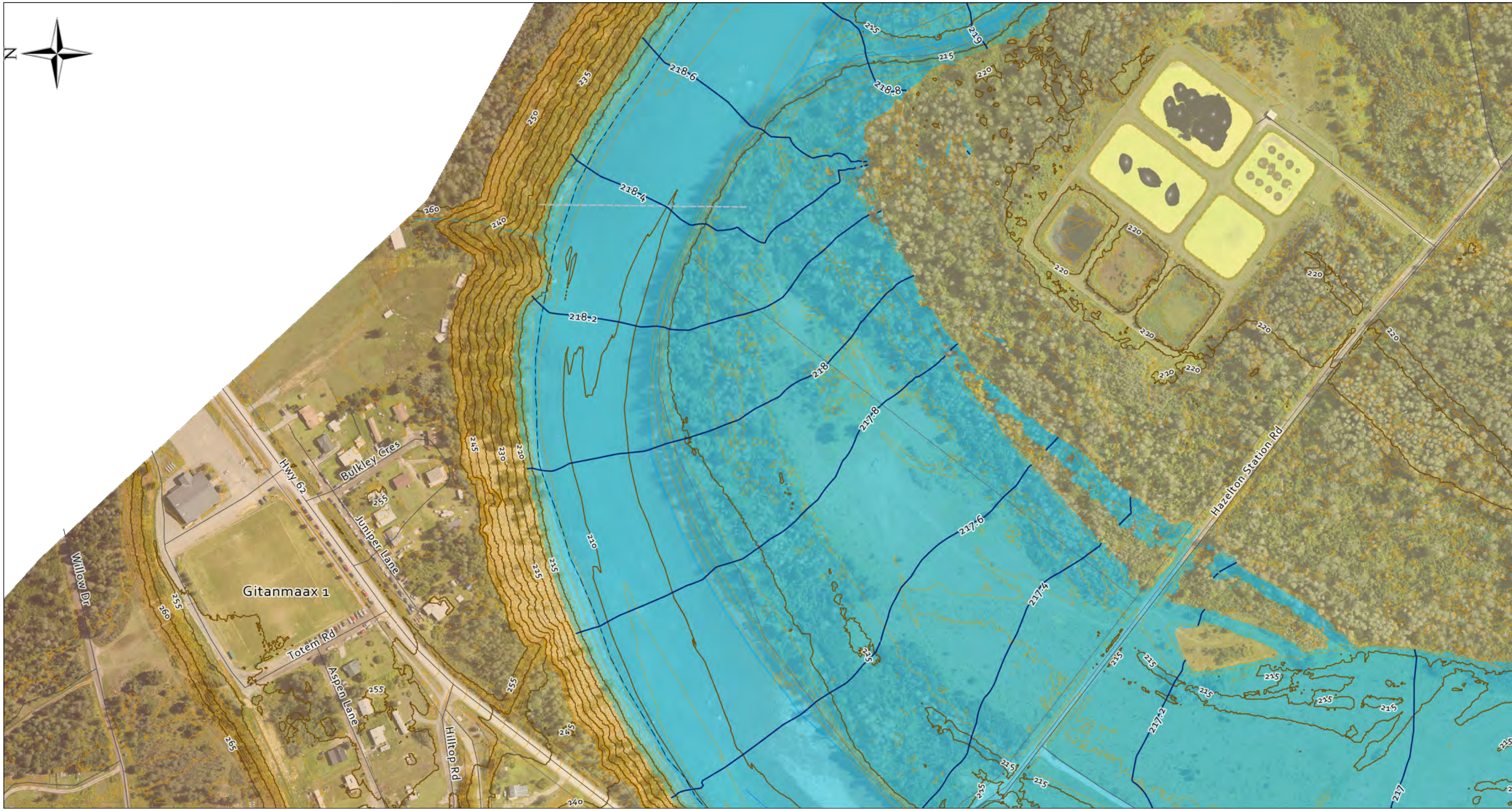
CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River 200 Year Floodplain Map (Sheet 7 of 9)

BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No:	REV: 0
CHK'D: BR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-007-7	

MXD Path: \\Sl2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx



LEGEND

Contours (5m)
Contours (1m)
Local Government Boundaries
Parcels
Roads
River or Stream - Definite
River or Stream - Dry
Flood Extent with Freeboard
200-year Flood
Water Surface Contours (0.2m)

REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Skeena River and Bulkley River Flood Study - Floodplain Inundation Mapping Report prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 200-year return period events with an allowance for climate change plus 0.6 m of freeboard.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.
Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m
3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc., Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

SNC·LAVALIN

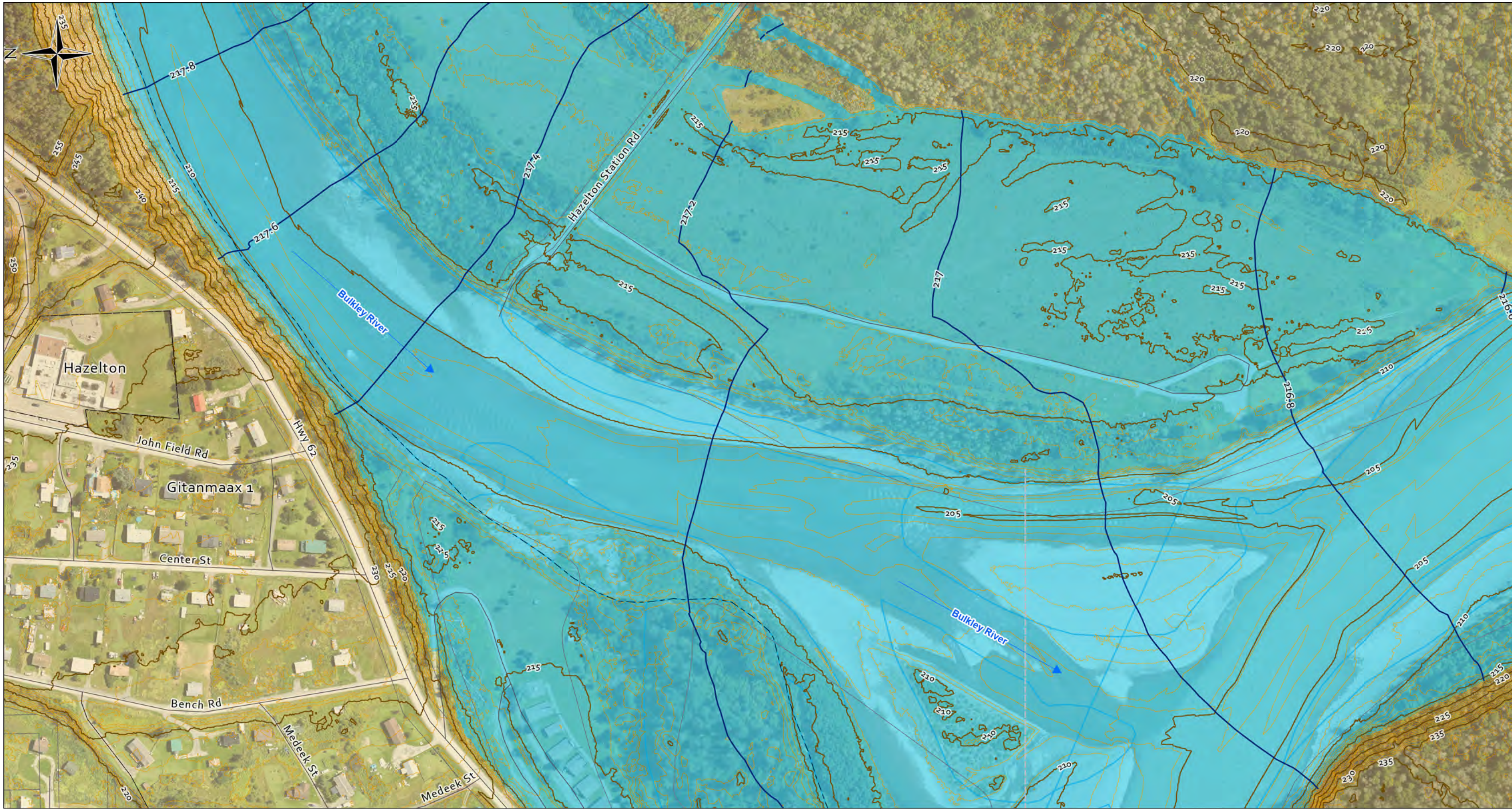
CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River 200 Year Floodplain Map (Sheet 8 of 9)

BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No:	REV: 0
CHK'D: BR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-007-8	

MXD Path: \\Sil2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx

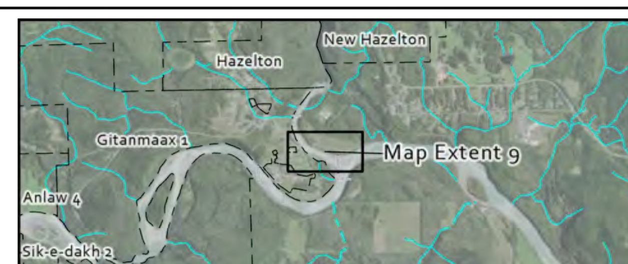


LEGEND

- Contours (5m)
- Contours (1m)
- Local Government Boundaries
- Parcels
- Roads
- River or Stream - Definite
- River or Stream - Dry

Flood Extent with Freeboard

- 200-year Flood
- Water Surface Contours (0.2m)



REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Skeena River and Bulkley River Flood Study - Floodplain Inundation Mapping Report prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 200-year return period events with an allowance for climate change plus 0.6 m of freeboard.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.

Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m

3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc., Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

SNC·LAVALIN

CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

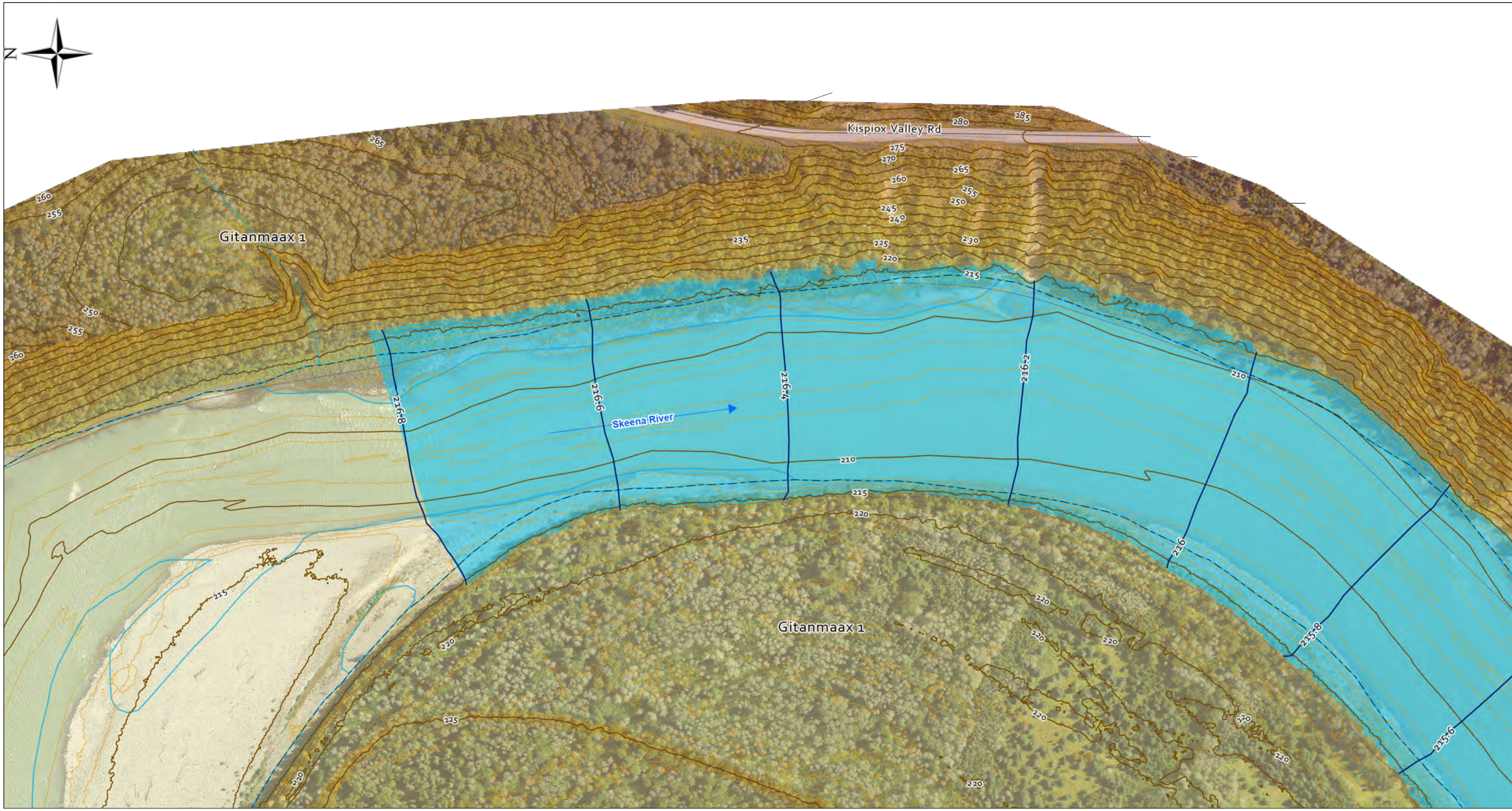
Skeena River and Bulkley River
200 Year Floodplain Map (Sheet 9 of 9)

BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No:	REV: 0
CHK'D: BR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-007-9	

MXD Path: \\Sil2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx

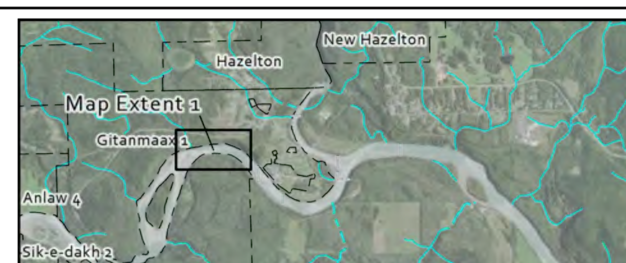
Appendix B

Flood Inundation Map – 2-Year Flow with Climate Change Allowance



LEGEND

- Contours (1m)
- Contours (5m)
- Local Government Boundaries
- Parcels
- River or Stream - Definite
- River or Stream - Dry
- Roads
- Flood Extent with Freeboard
- 2-year Flood
- Water Surface Contours (0.2m)



REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Skeena River and Bulkley River Flood Study - Floodplain Inundation Mapping Report prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 2-year return period events with an allowance for climate change.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.

Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m

3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc., Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

SNC • LAVALIN

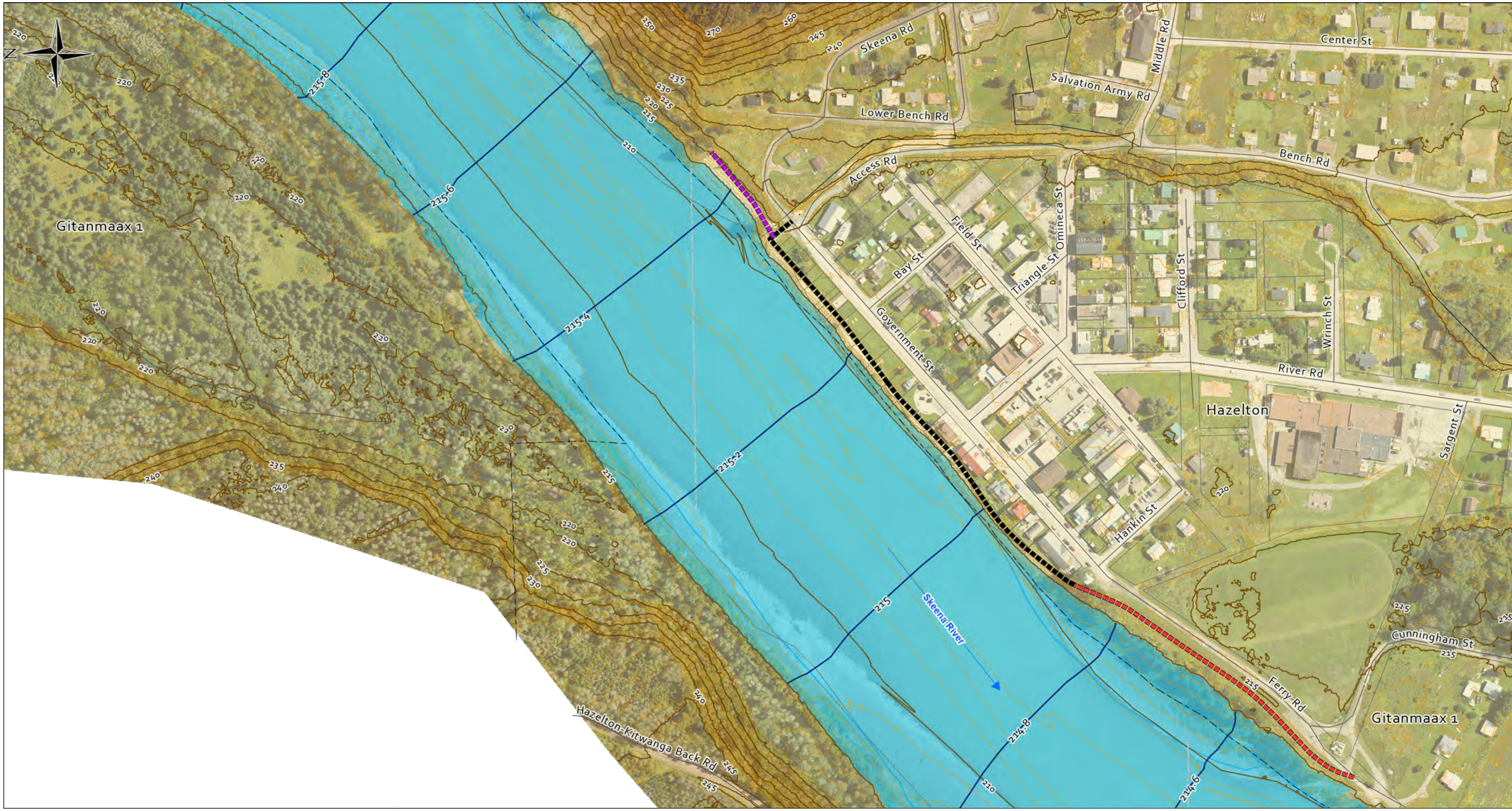
CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River 2 Year Floodplain Map (Sheet 1 of 9)

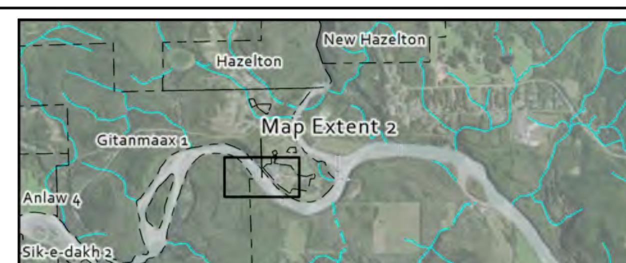
BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No:	REV: 0
CHK'D: CBR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-002-1	

MXD Path: \\Sl2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx



LEGEND

- Contours (1m)
- Contours (5m)
- Local Government Boundaries
- Parcels
- Flood and Erosion Protection Works (Approximate Locations)
  - Dike
  - Dike and Riverbank Protection
  - Riverbank Protection
- River or Stream - Definite
- River or Stream - Dry
- Roads
- Flood Extent with Freeboard
  - 2-year Flood
- Water Surface Contours (0.2m)



REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Skeena River and Bulkley River Flood Study - Floodplain Inundation Mapping Report prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 2-year return period events with an allowance for climate change.

Data Sources
1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.
Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m
3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations
1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc., Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

SNC·LAVALIN

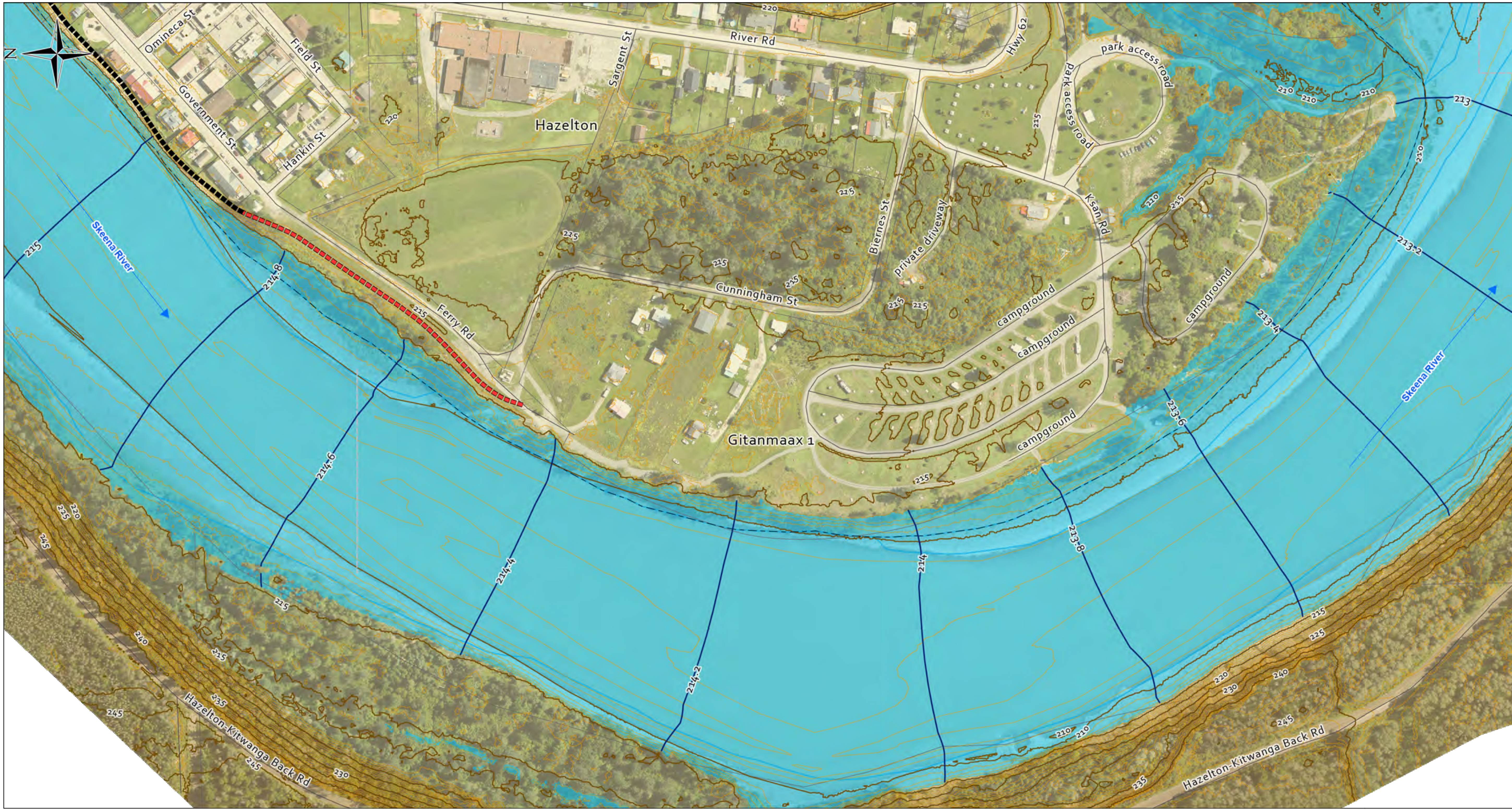
CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River 2 Year Floodplain Map (Sheet 2 of 9)

BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No: 675878-002-2 REV: 0
CHK'D: CBR	PROJ COORD SYS: UTM Zone 9N NAD83		

MXD Path: \\Sli2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx



LEGEND

Contours (1m)

Contours (5m)

Local Government Boundaries

Parcels

Flood and Erosion Protection Works (Approximate Locations)

Dike

Dike and Riverbank Protection

River or Stream - Definite

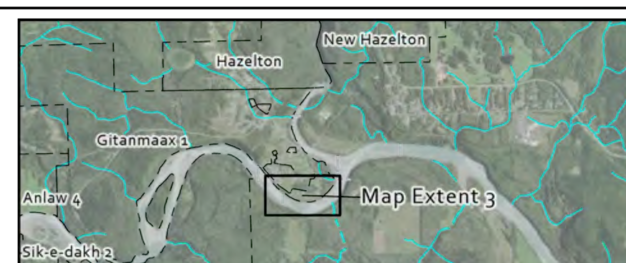
River or Stream - Dry

Roads

Flood Extent with Freeboard

2-year Flood

Water Surface Contours (0.2m)



REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Skeena River and Bulkley River Flood Study - Floodplain Inundation Mapping Report prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 2-year return period events with an allowance for climate change.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.

Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m

3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc., Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

SNC·LAVALIN

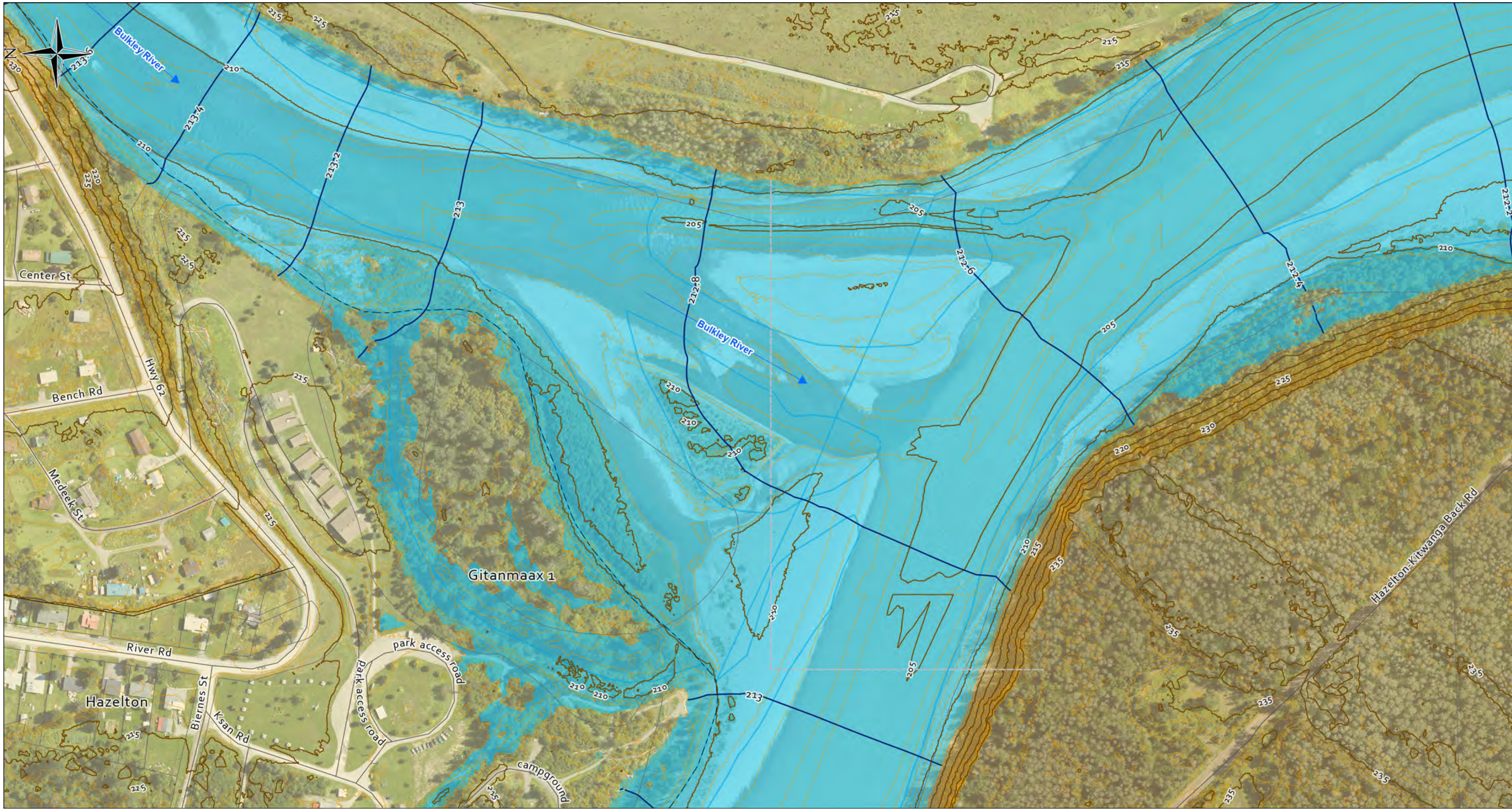
CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River 2 Year Floodplain Map (Sheet 3 of 9)

BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No:	REV: 0
CHK'D: CBR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-002-3	

MXD Path: \\Sl2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx



LEGEND

Contours (1m)

Contours (5m)

Local Government Boundaries

Parcels

River or Stream - Definite

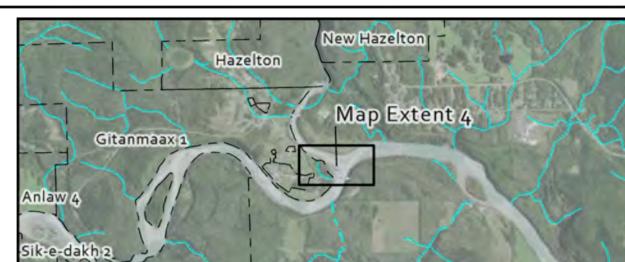
River or Stream - Dry

Roads

Flood Extent with Freeboard

2-year Flood

Water Surface Contours (0.2m)



REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Skeena River and Bulkley River Flood Study - Floodplain Inundation Mapping Report prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 2-year return period events with an allowance for climate change.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.
Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m
3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc., Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

SNC · LAVALIN

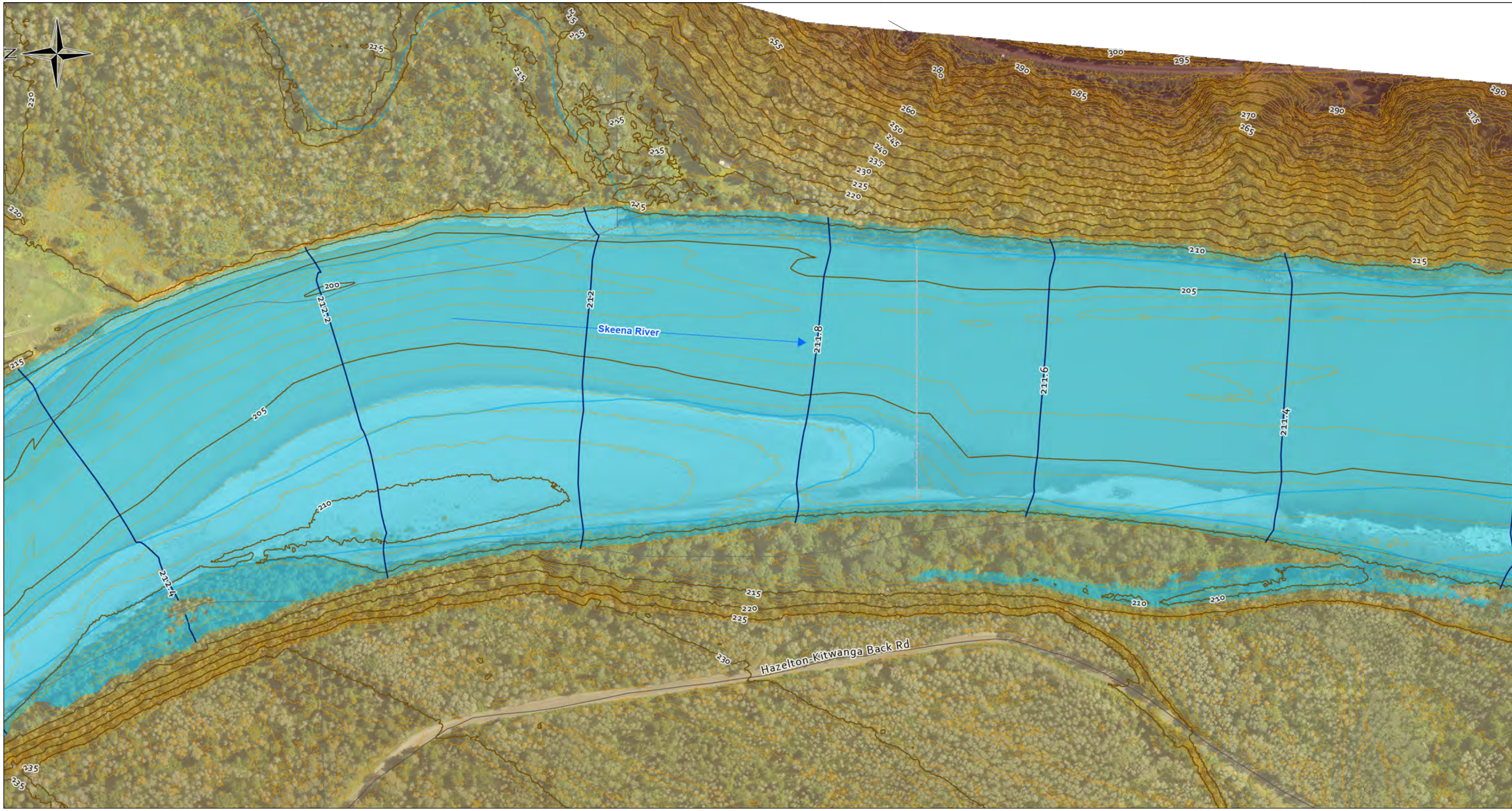
CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River
2 Year Floodplain Map (Sheet 4 of 9)

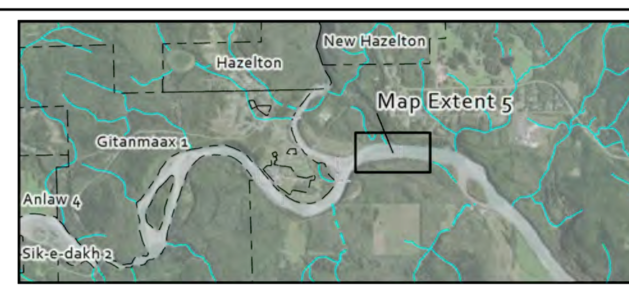
BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No: REV: 0
CHK'D: CBR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-002-4

MXD Path: \\Sil2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx



LEGEND

- Contours (1m)
- Contours (5m)
- Parcels
- River or Stream - Definite
- River or Stream - Dry
- Roads
- Flood Extent with Freeboard
  - 2-year Flood
- Water Surface Contours (0.2m)



REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Skeena River and Bulkley River Flood Study - Floodplain Inundation Mapping Report prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 2-year return period events with an allowance for climate change.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.

Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m

3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc., Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

SNC·LAVALIN

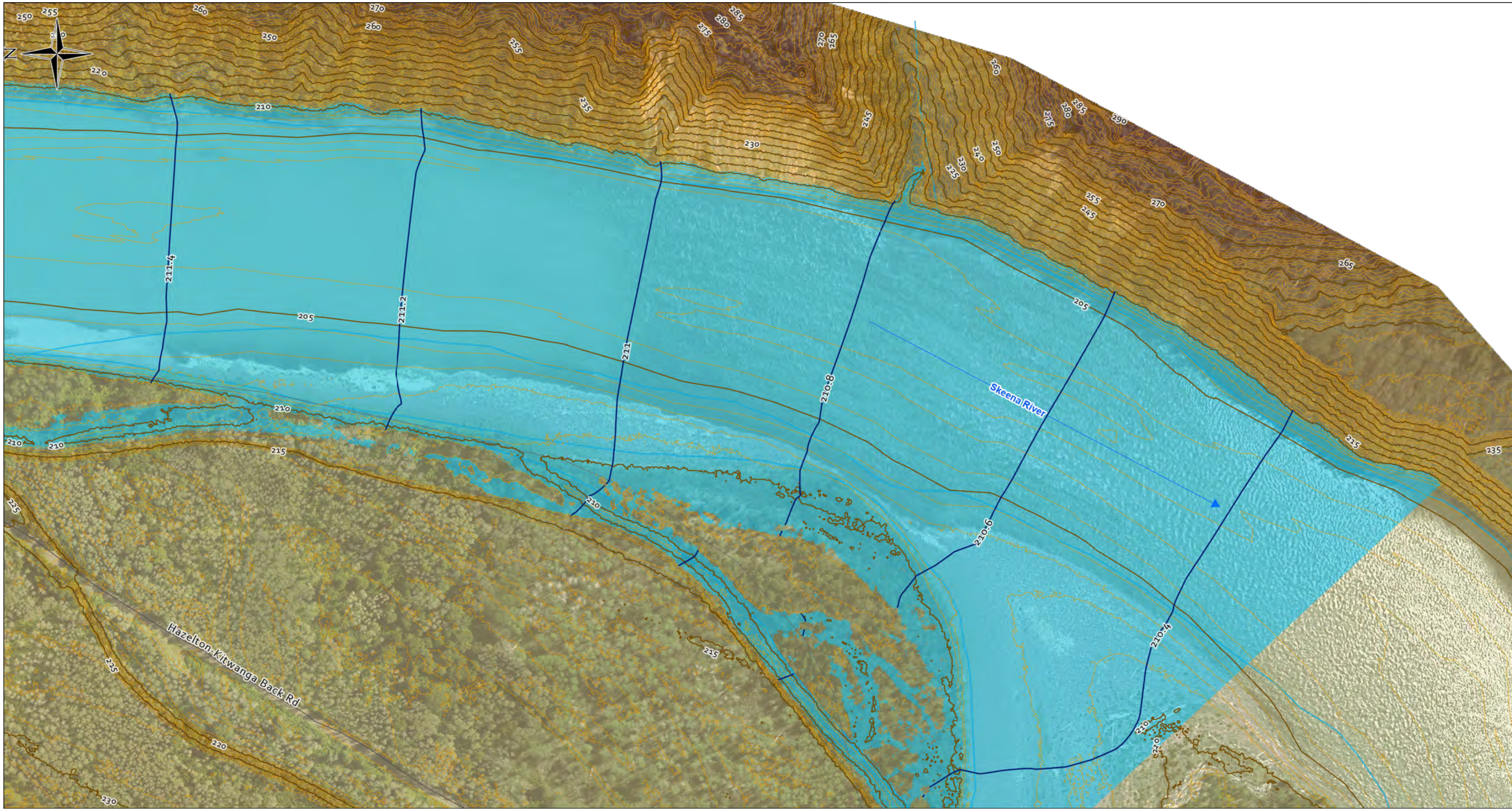
CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River 2 Year Floodplain Map (Sheet 5 of 9)

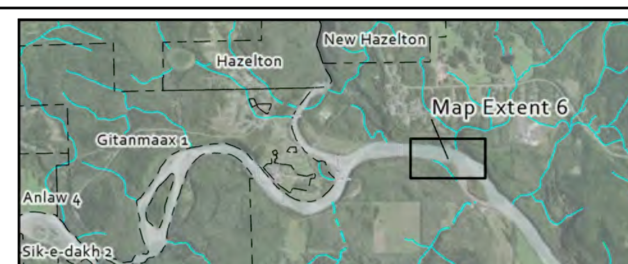
BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No: REV: 0
CHK'D: CBR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-002-5

MXD Path: \\Sil2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx



LEGEND

- Contours (1m)
- Contours (5m)
- Parcels
- River or Stream - Definite
- River or Stream - Dry
- Roads
- Flood Extent with Freeboard
  - 2-year Flood
- Water Surface Contours (0.2m)



REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Skeena River and Bulkley River Flood Study - Floodplain Inundation Mapping Report prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 2-year return period events with an allowance for climate change.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.

Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m

3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc., Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

SNC · LAVALIN

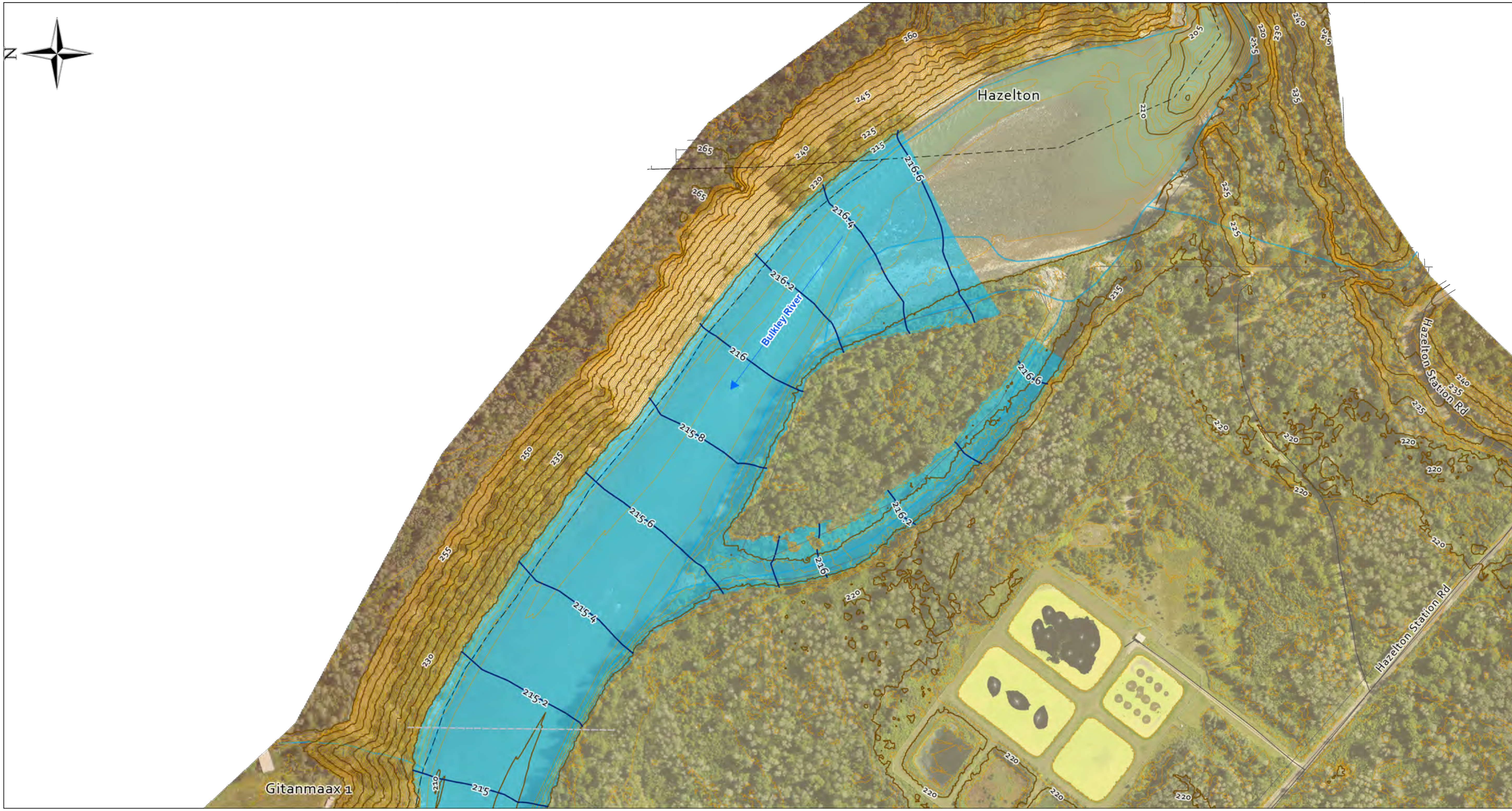
CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River
2 Year Floodplain Map (Sheet 6 of 9)

BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No:	REV: 0
CHK'D: CBR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-002-6	

MXD Path: \\Sli2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx



LEGEND

- Contours (1m)
- Contours (5m)
- Local Government Boundaries
- Parcels
- River or Stream - Definite
- River or Stream - Dry
- Roads
- Flood Extent with Freeboard
- 2-year Flood
- Water Surface Contours (0.2m)

REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Skeena River and Bulkley River Flood Study - Floodplain Inundation Mapping Report prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 2-year return period events with an allowance for climate change.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.
Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m
3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc., Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

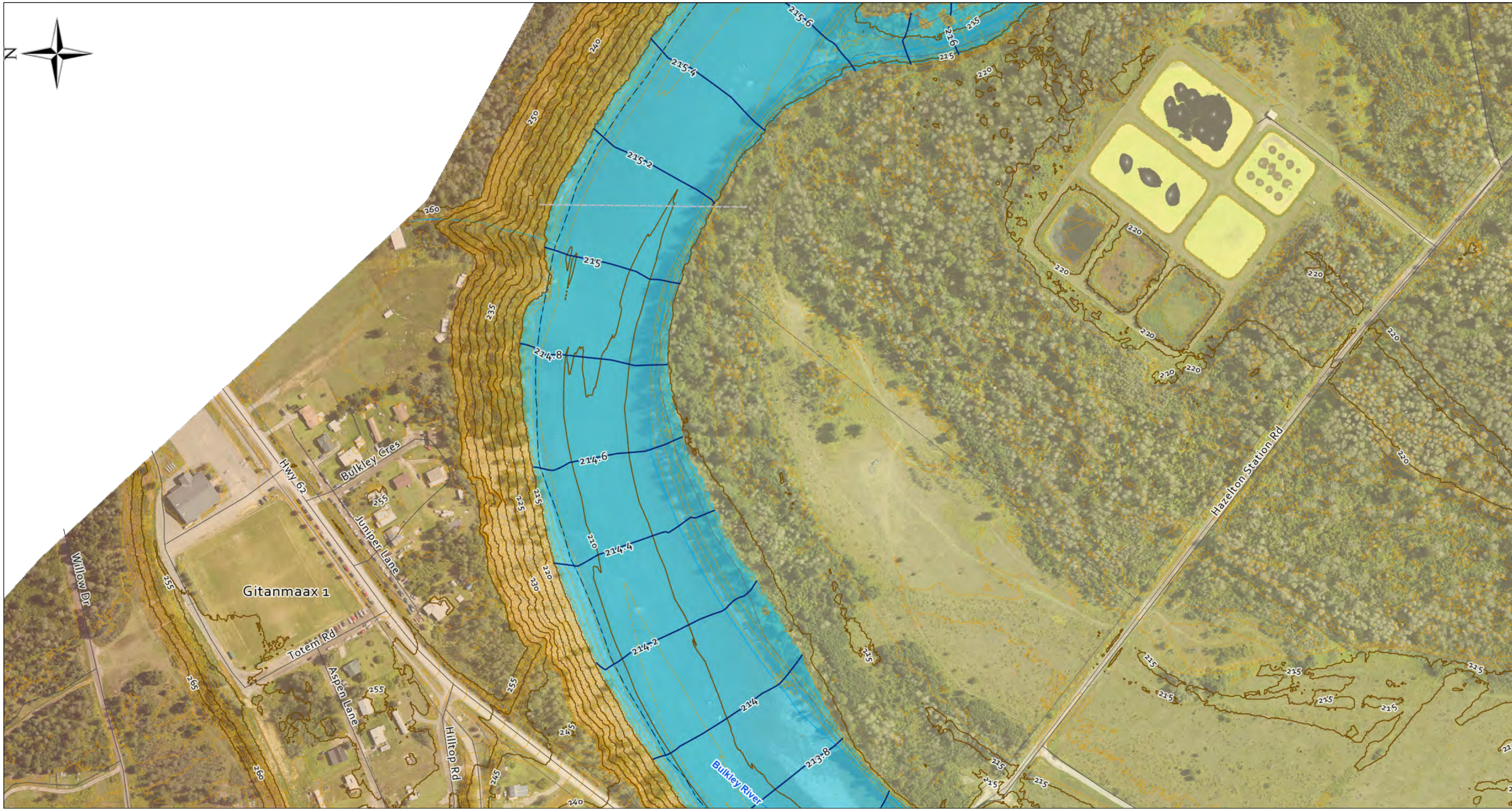
SNC·LAVALIN

CLIENT NAME: Village of Hazelton	PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River 2 Year Floodplain Map (Sheet 7 of 9)

BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No: REV: 0
CHK'D: CBR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-002-7

MXD Path: \\Sil2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx



LEGEND

Contours (1m)	Parcels
Contours (5m)	River or Stream - Definite
Local Government Boundaries	River or Stream - Dry
	Roads

Flood Extent with Freeboard

- 2-year Flood
- Water Surface Contours (0.2m)

REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Skeena River and Bulkley River Flood Study - Floodplain Inundation Mapping Report prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 2-year return period events with an allowance for climate change.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.

Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m

3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc., Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

SNC·LAVALIN

CLIENT NAME: Village of Hazelton

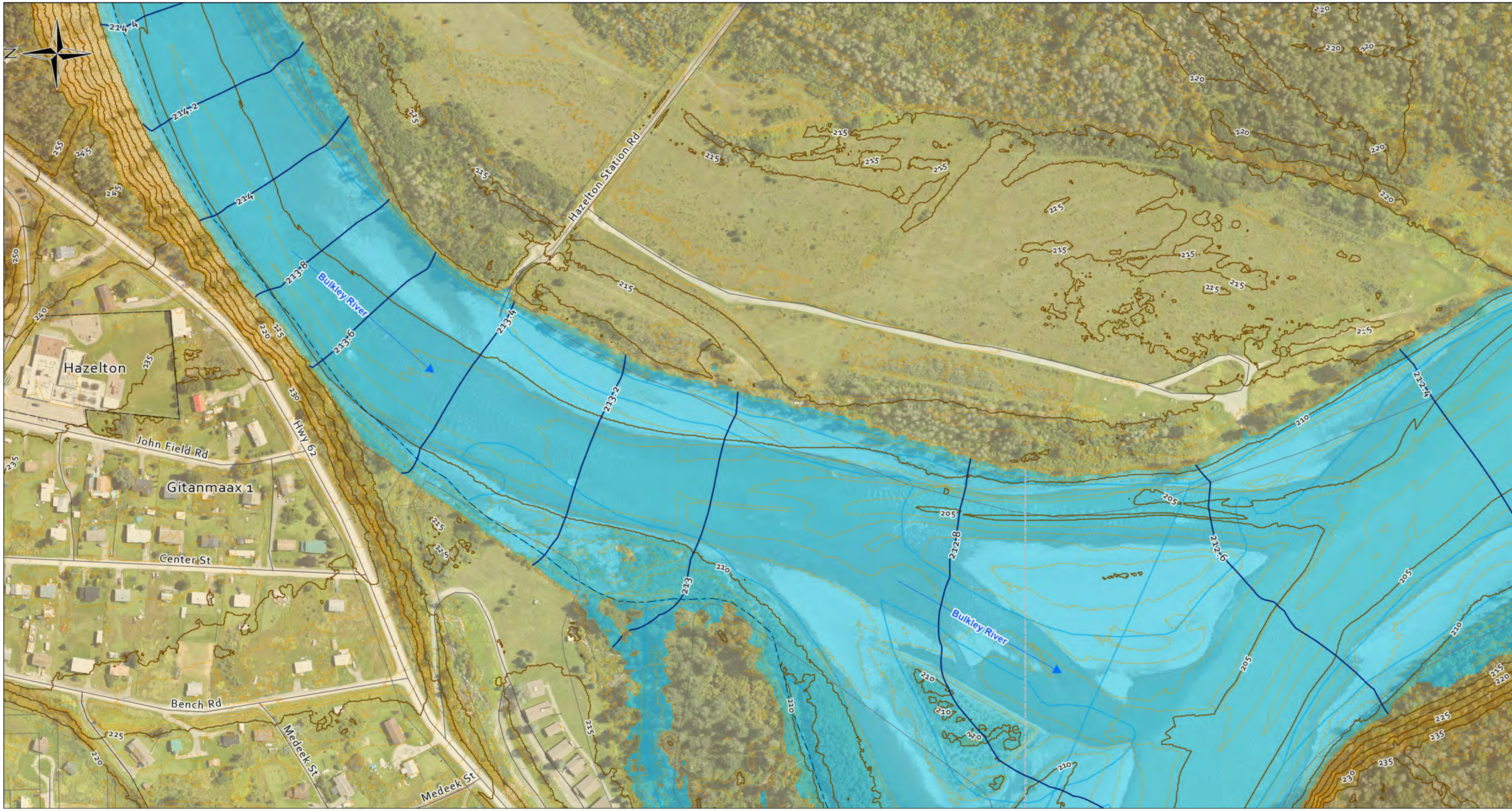
PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River 2 Year Floodplain Map (Sheet 8 of 9)

BY: ECH | SCALE: 1:3,200 | DATE: 2021-03-18 | REF No: 675878-002-8 | REV: 0

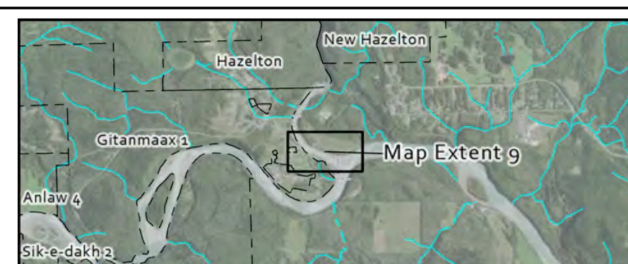
CHK'D: CBR | PROJ COORD SYS: UTM Zone 9N NAD83

MXD Path: \\Sil2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx



LEGEND

Contours (1m)
Contours (5m)
Local Government Boundaries
Parcels
River or Stream - Definite
River or Stream - Dry
Roads
Flood Extent with Freeboard
2-year Flood
Water Surface Contours (0.2m)



REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Skeena River and Bulkley River Flood Study - Floodplain Inundation Mapping Report prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 2-year return period events with an allowance for climate change.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.
Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m
3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc., Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

SNC·LAVALIN

CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

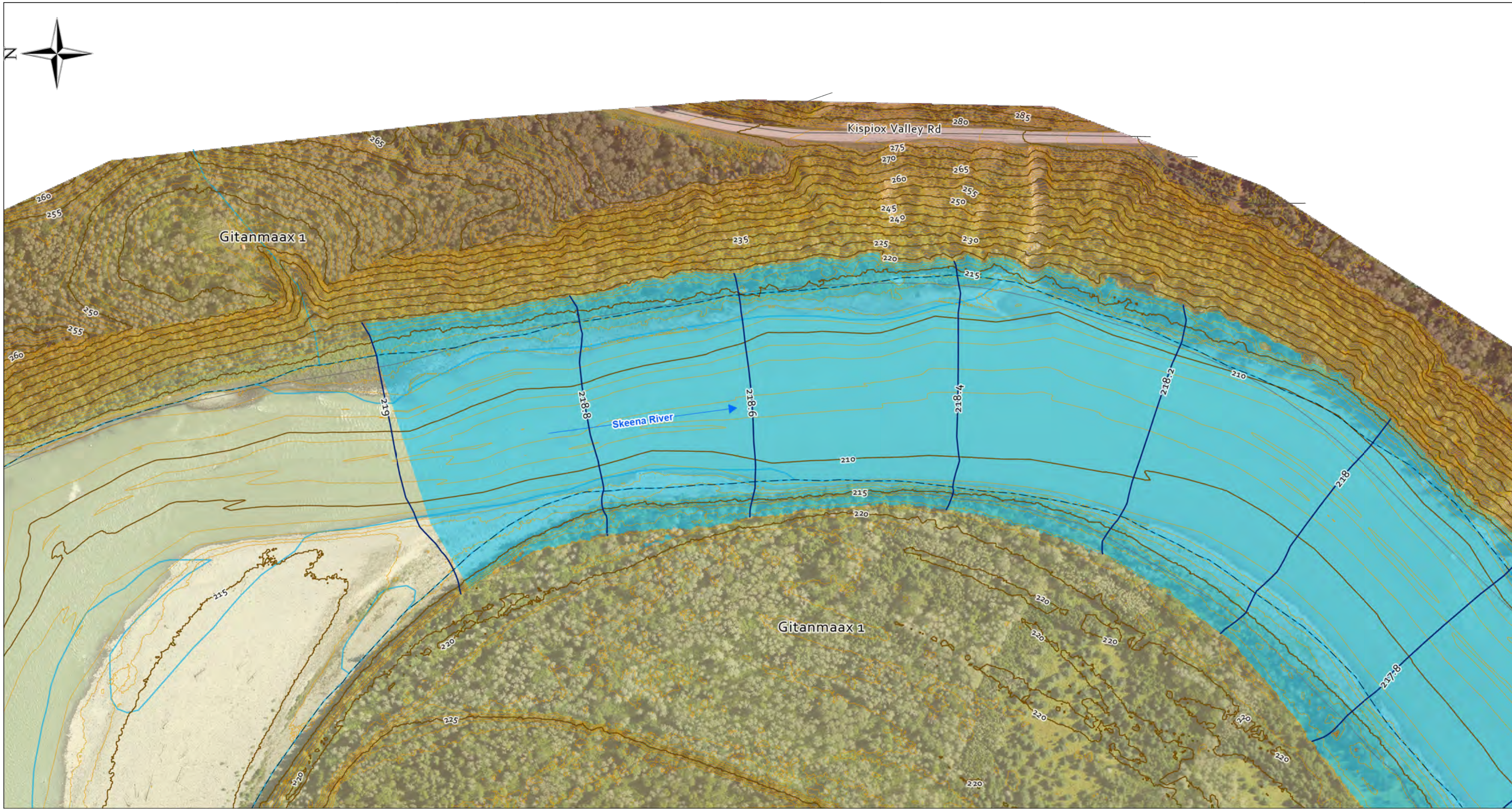
Skeena River and Bulkley River 2 Year Floodplain Map (Sheet 9 of 9)

BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No: REV: 0
CHK'D: CBR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-002-9

MXD Path: \\Sl2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx

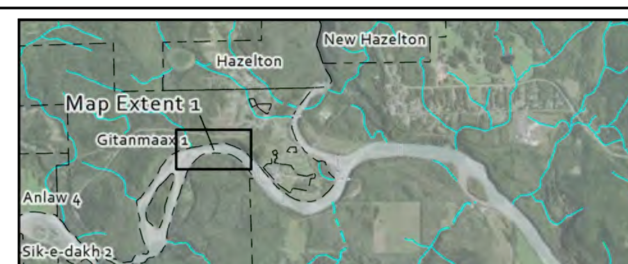
Appendix C

Flood Inundation Map – 25-Year Flow with Climate Change Allowance



LEGEND

- Contours (1m)
- Contours (5m)
- Local Government Boundaries
- Parcels
- Roads
- River or Stream - Definite
- River or Stream - Dry
- Flood Extent with Freeboard
- 25-year Flood
- Water Surface Contours (0.2m)



REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Floodplain Mapping Study prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 25-year return period events with an allowance for climate change.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.

Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m

3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc. (SNC-Lavalin), Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

SNC·LAVALIN

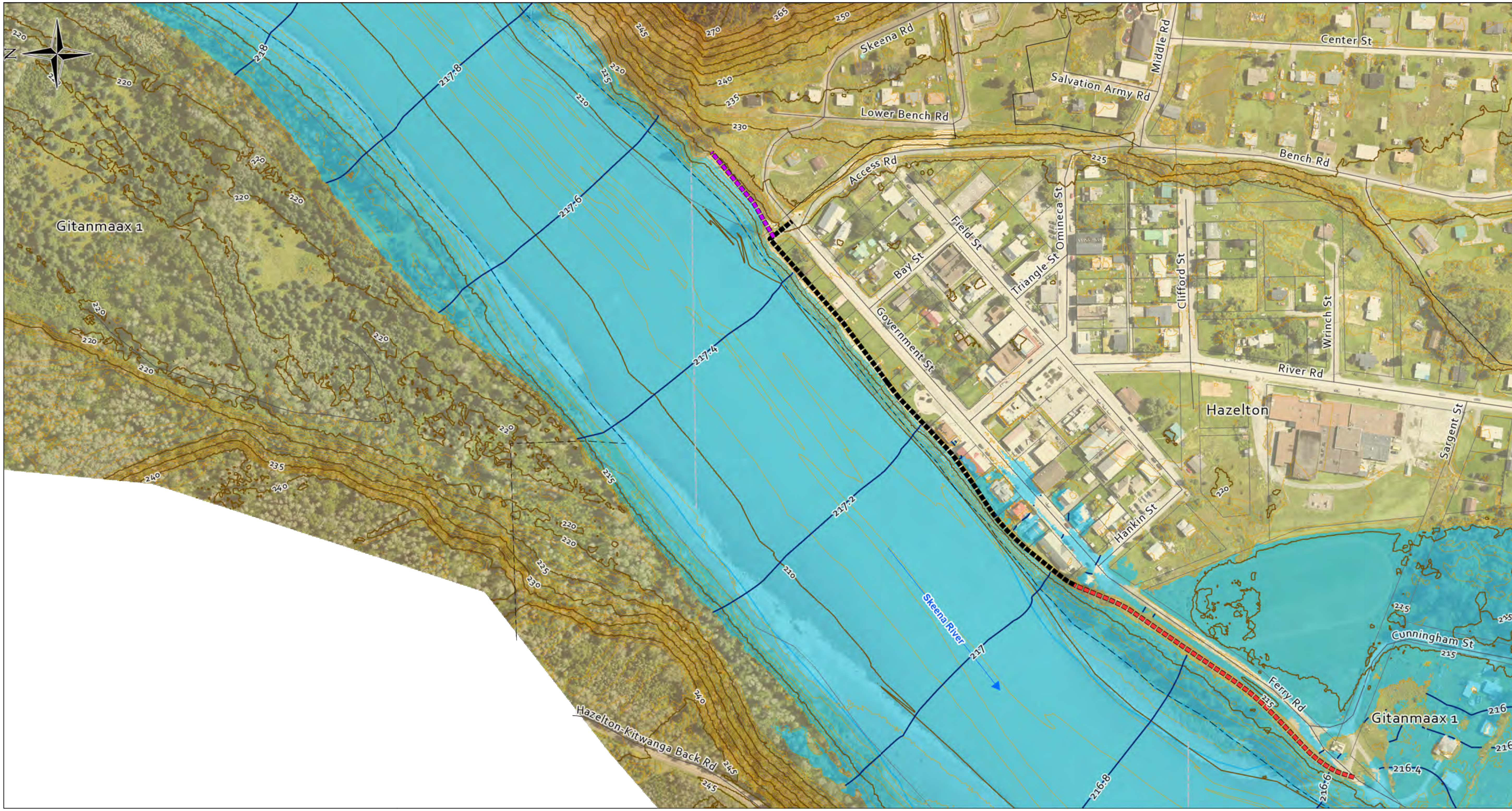
CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River 25 Year Floodplain Map (Sheet 1 of 9)

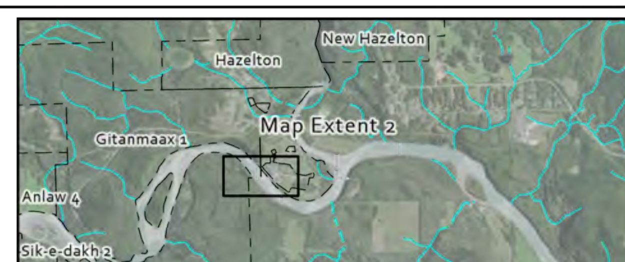
BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No: REV: 0
CHK'D: BR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-006-1

MXD Path: \\Sl2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx



LEGEND

- Contours (1m)
- Contours (5m)
- Local Government Boundaries
- Parcels
- Flood and Erosion Protection Works (Approximate Locations)
  - Dike
  - Dike and Riverbank Protection
  - Riverbank Protection
- Roads
- River or Stream - Definite
- River or Stream - Dry
- Flood Extent with Freeboard
  - 25-year Flood
- Water Surface Contours (0.2m)



REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Floodplain Mapping Study prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 25-year return period events with an allowance for climate change.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.

Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m

3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc. (SNC-Lavalin), Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

SNC·LAVALIN

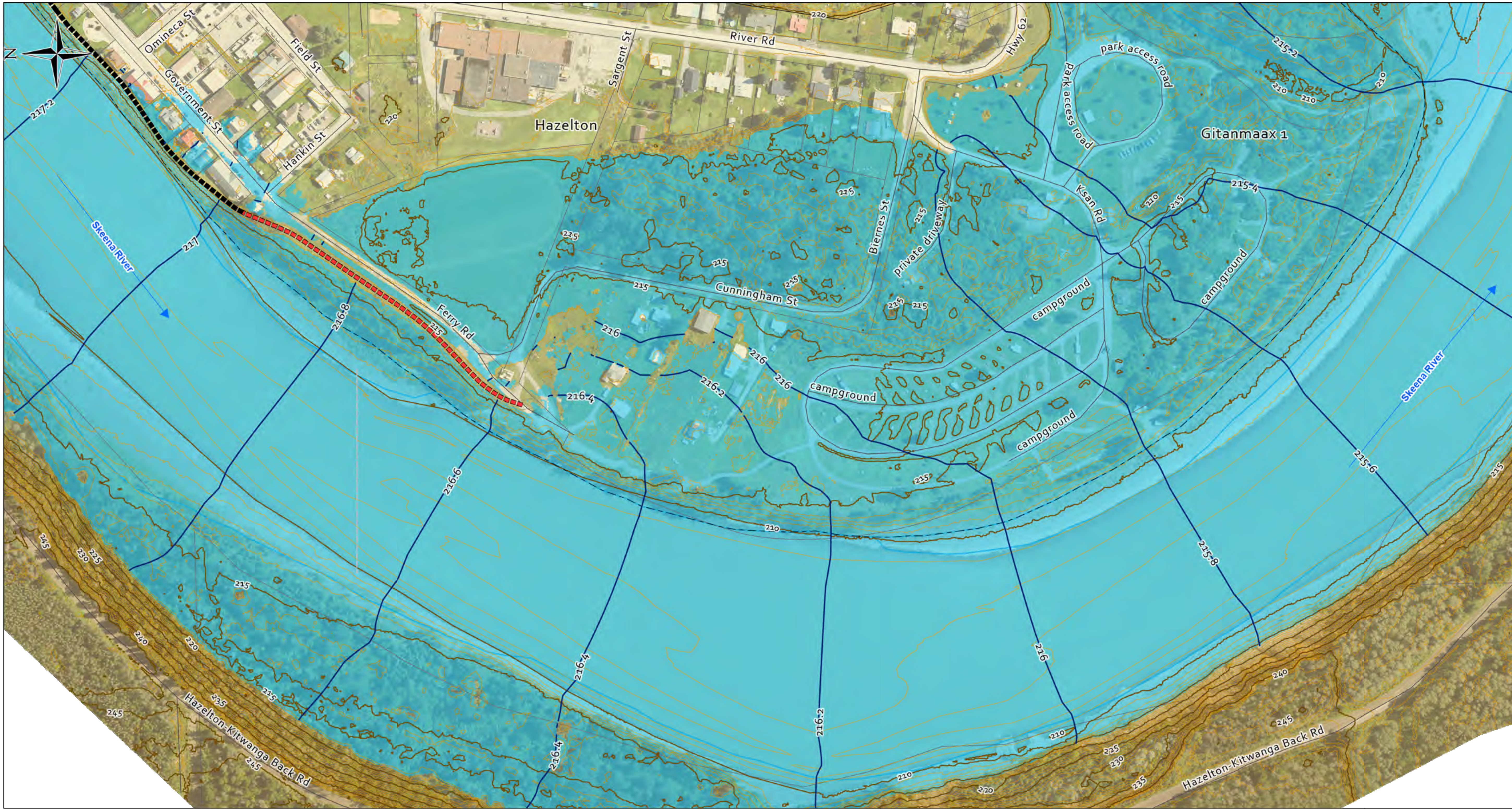
CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River 25 Year Floodplain Map (Sheet 2 of 9)

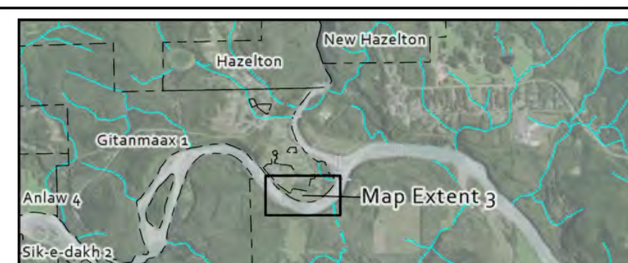
BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No:	REV: 0
CHK'D: BR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-006-2	

MXD Path: \\Sl2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx



LEGEND

- Contours (1m)
- Contours (5m)
- Local Government Boundaries
- Parcels
- Flood and Erosion Protection Works (Approximate Locations)
  - Dike
  - Dike and Riverbank Protection
- Roads
- River or Stream - Definite
- River or Stream - Dry
- Flood Extent with Freeboard
  - 25-year Flood
- Water Surface Contours (0.2m)



REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Floodplain Mapping Study prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 25-year return period events with an allowance for climate change.

Data Sources
1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.
Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m
3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations
1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc. (SNC-Lavalin), Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

SNC·LAVALIN

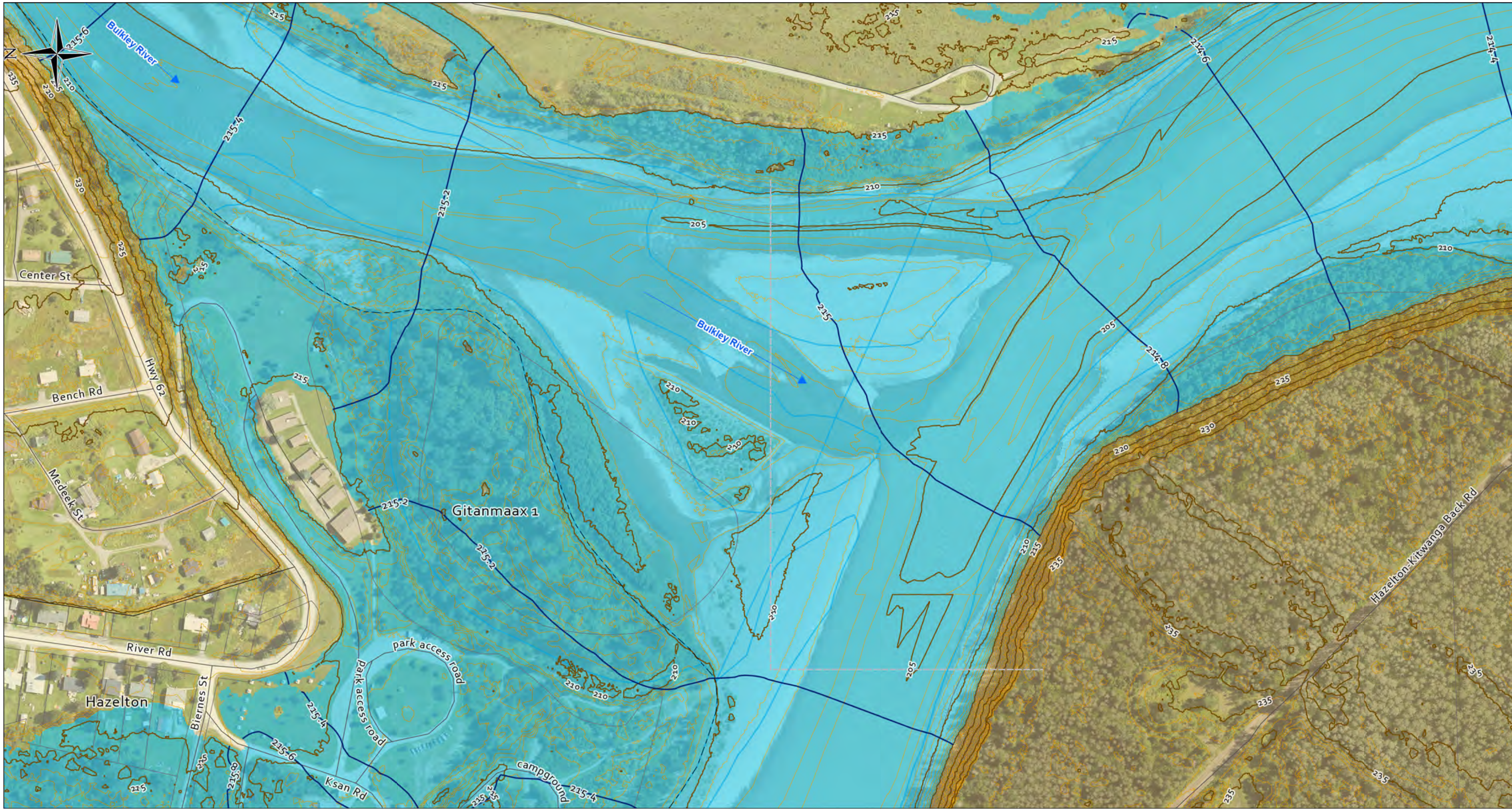
CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River 25 Year Floodplain Map (Sheet 3 of 9)

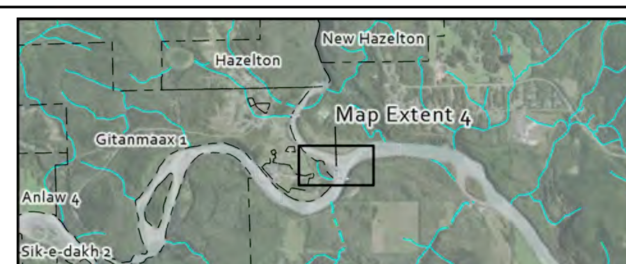
BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No: 675878-006-3	REV: 0
CHK'D: BR	PROJ COORD SYS: UTM Zone 9N NAD83			

MXD Path: \\Sli2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx



LEGEND

- Contours (1m)
- Contours (5m)
- Local Government Boundaries
- Parcels
- Roads
- River or Stream - Definite
- River or Stream - Dry
- Flood Extent with Freeboard
  - 25-year Flood
- Water Surface Contours (0.2m)



REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Floodplain Mapping Study prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 25-year return period events with an allowance for climate change.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.

Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m

3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc. (SNC-Lavalin), Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

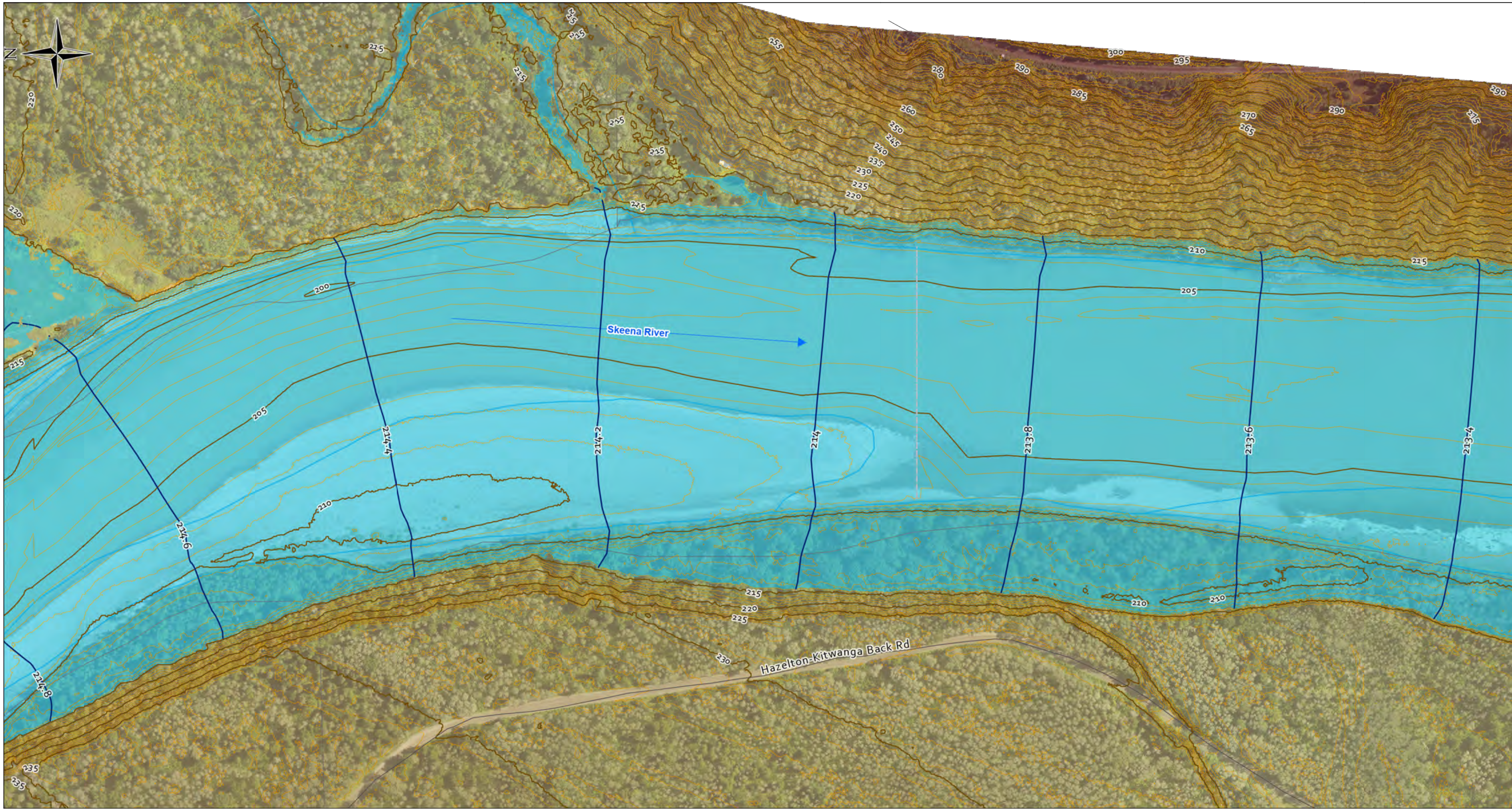
SNC·LAVALIN

CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

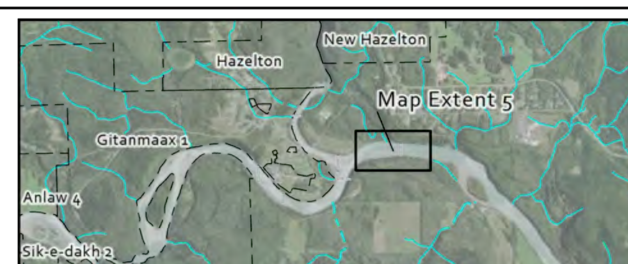
Skeena River and Bulkley River
25 Year Floodplain Map (Sheet 4 of 9)

BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No:	REV: 0
CHK'D: BR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-006-4	



LEGEND

- Contours (1m)
- Contours (5m)
- Parcels
- Roads
- River or Stream - Definite
- River or Stream - Dry
- Flood Extent with Freeboard
- 25-year Flood
- Water Surface Contours (0.2m)



REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Floodplain Mapping Study prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 25-year return period events with an allowance for climate change.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.

Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m

3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc. (SNC-Lavalin), Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

SNC·LAVALIN

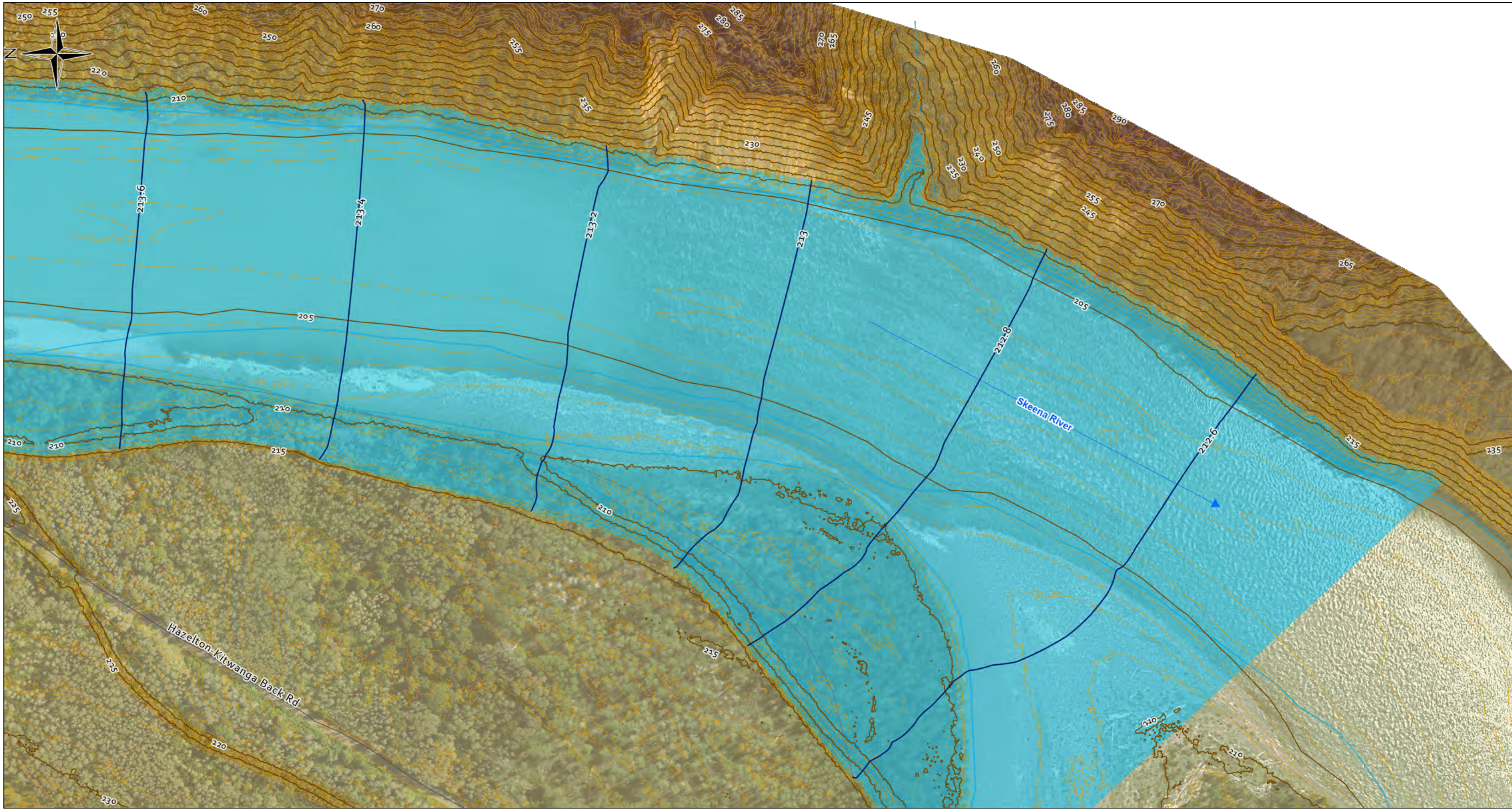
CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River 25 Year Floodplain Map (Sheet 5 of 9)

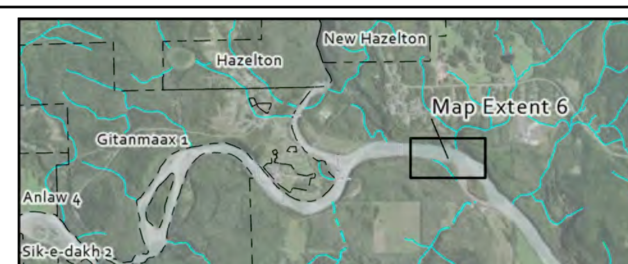
BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No:	REV: 0
CHK'D: BR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-006-5	

MXD Path: \\Sl2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx



LEGEND

- Contours (1m)
- Contours (5m)
- Parcels
- Roads
- River or Stream - Definite
- River or Stream - Dry
- Flood Extent with Freeboard
- 25-year Flood
- Water Surface Contours (0.2m)



REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Floodplain Mapping Study prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 25-year return period events with an allowance for climate change.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.

Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m

3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc. (SNC-Lavalin), Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

SNC · LAVALIN

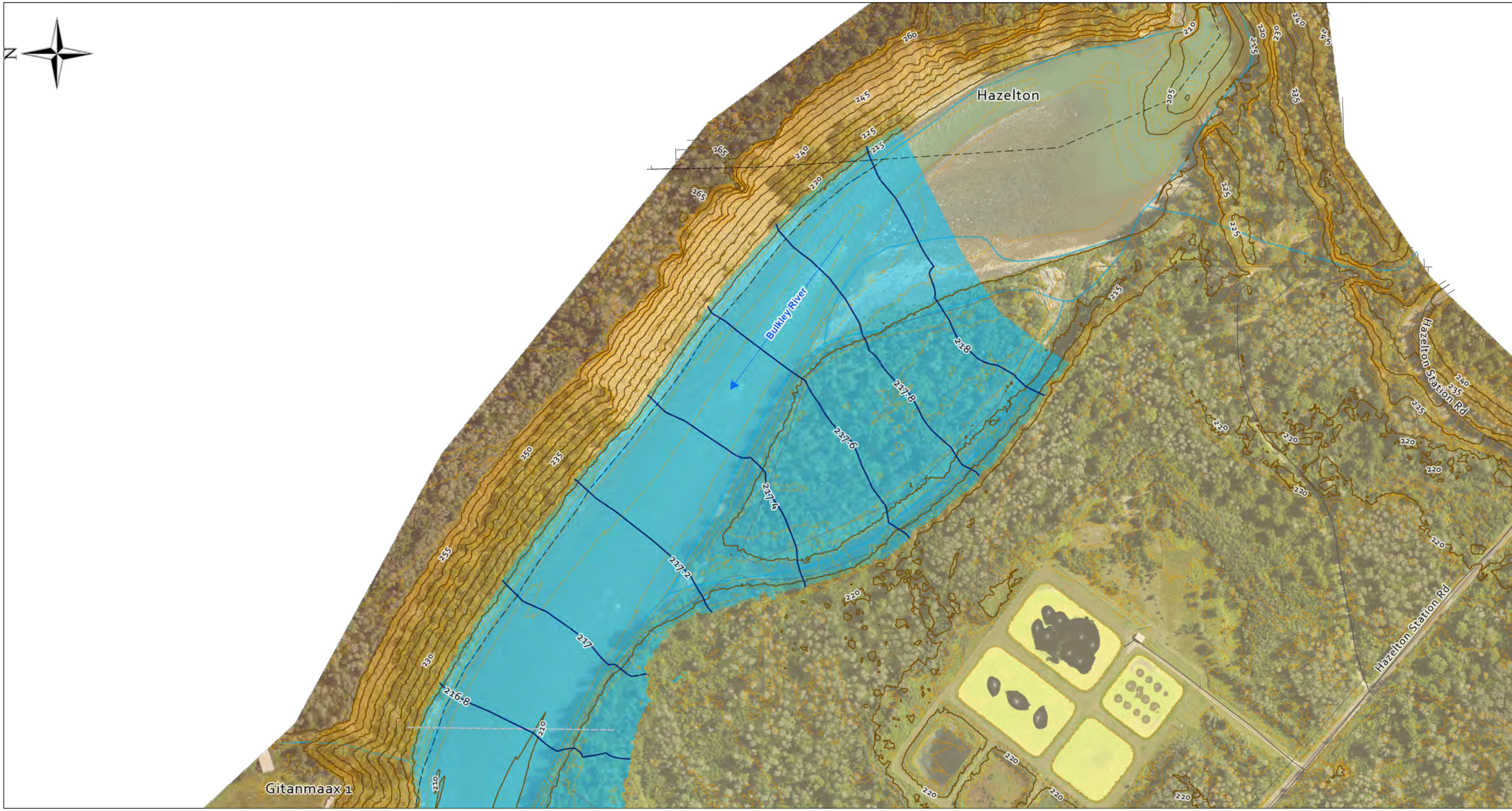
CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River 25 Year Floodplain Map (Sheet 6 of 9)

BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No: REV: 0
CHK'D: BR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-006-6

MXD Path: \\Sli2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx



LEGEND

- Contours (1m)
- Contours (5m)
- Local Government Boundaries
- Parcels
- Roads
- River or Stream - Definite
- River or Stream - Dry
- Flood Extent with Freeboard
- 25-year Flood
- Water Surface Contours (0.2m)

REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Floodplain Mapping Study prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 25-year return period events with an allowance for climate change.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.
Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m
3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc. (SNC-Lavalin), Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

SNC·LAVALIN

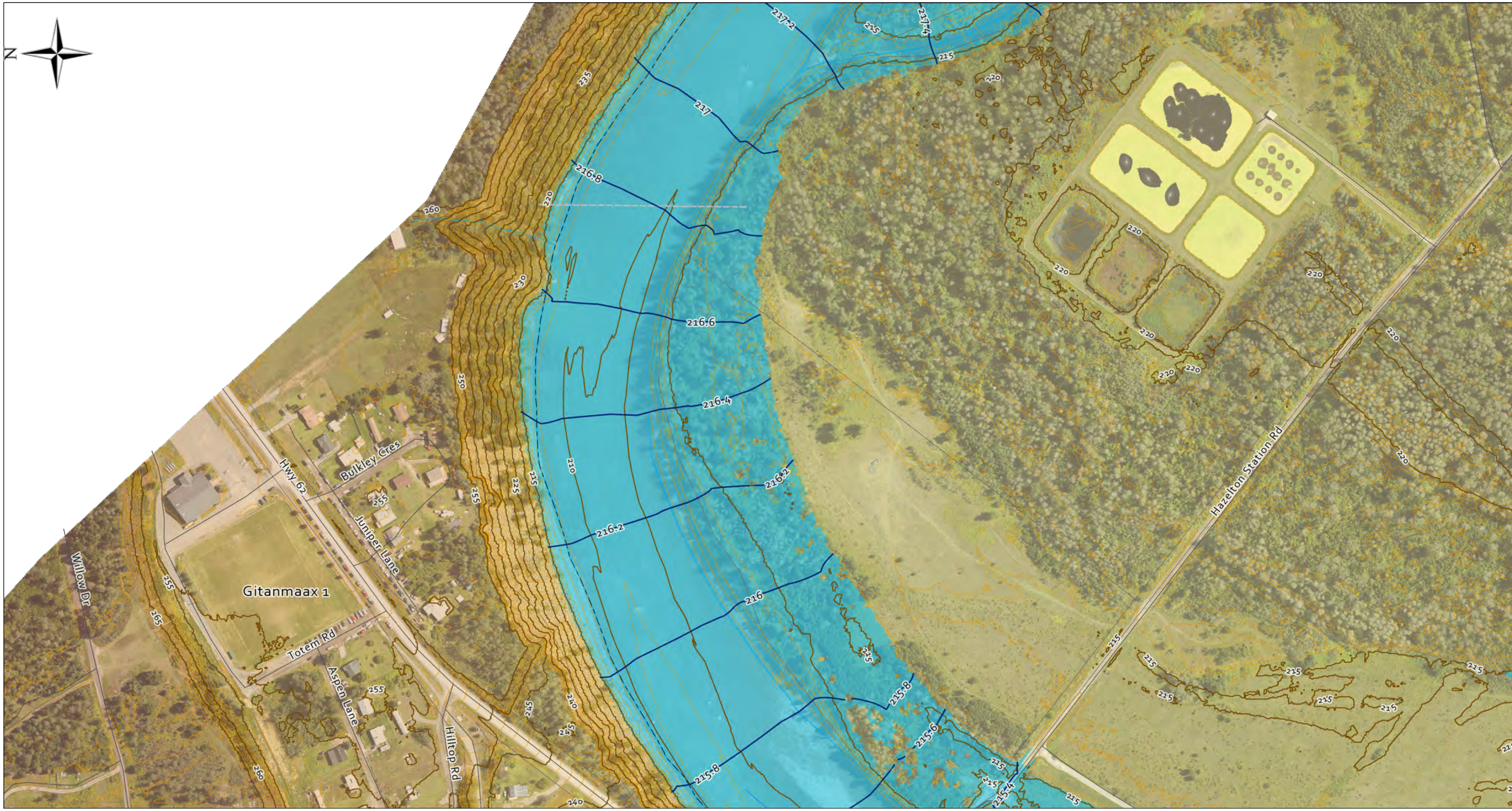
CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River
25 Year Floodplain Map (Sheet 7 of 9)

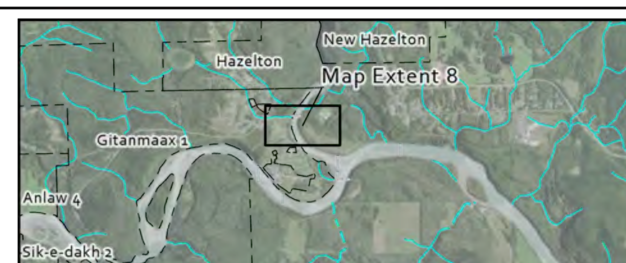
BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No:	REV: 0
CHK'D: BR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-006-7	

MXD Path: \\Sli2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx



LEGEND

Contours (1m)	Parcels	Flood Extent with Freeboard
Contours (5m)	Roads	25-year Flood
Local Government Boundaries	River or Stream - Definite	Water Surface Contours (0.2m)
	River or Stream - Dry	



REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Floodplain Mapping Study prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 25-year return period events with an allowance for climate change.

Data Sources
1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.
Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m
3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations
1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc. (SNC-Lavalin), Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

SNC·LAVALIN

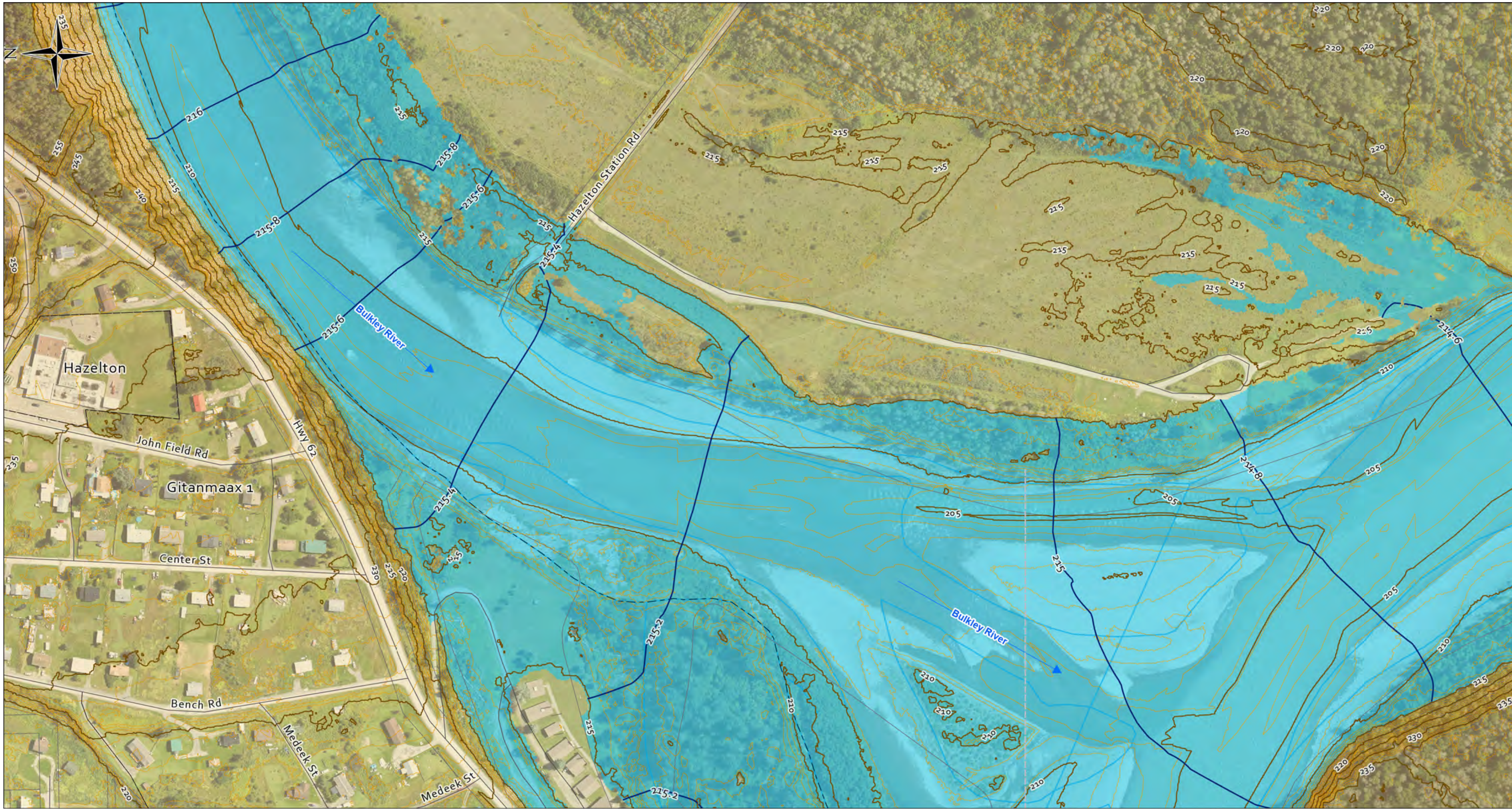
CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River
25 Year Floodplain Map (Sheet 8 of 9)

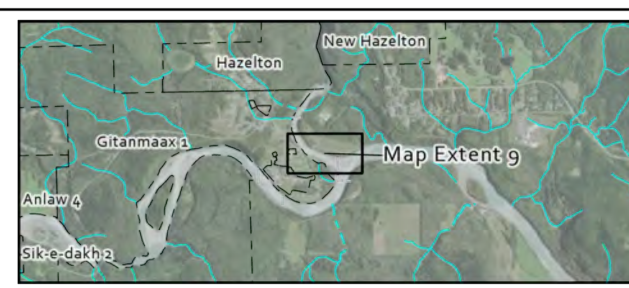
BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No:	REV: 0
CHK'D: BR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-006-8	

MXD Path: \\Sl2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx



LEGEND

- Contours (1m)
- Contours (5m)
- Local Government Boundaries
- Parcels
- Roads
- River or Stream - Definite
- River or Stream - Dry
- Flood Extent with Freeboard
- 25-year Flood
- Water Surface Contours (0.2m)



REFERENCES

0 20 40 80 120 160 Meters

1. This map is based on the 2021 Floodplain Mapping Study prepared for the Village of Hazelton by SNC-Lavalin Inc. and should be consulted when utilizing this map.
2. This map delineates potential flooding from simultaneous Skeena River and Bulkley River 25-year return period events with an allowance for climate change.

Data Sources

1. Flood water levels based on 2D hydraulic modelling by SNC-Lavalin Inc.
2. Contours based on LiDAR data flown August 2019 and survey data collected August 2020.
3. Survey data coordinates were derived from static GPS observations at control points 101 and 102. They are referred to NAD83, Zone 9.

Point 101 - 583839.35 m E, 6123806.24 m N, Elv. 215.49 m Point 102 - 583839.35 m E, 6123806.26 m N, Elv. 215.48 m

3. Orthophoto background from August 2019.
4. Local government boundaries, parcels, and roads based on DataBC.

Limitations

1. Current industry best practices were used to develop the floodplain maps. Actual flood levels and inundation boundaries may vary; SNC-Lavalin Inc. (SNC-Lavalin), Village of Hazelton, and Gitanmaax Band do not assume any liability for such variations.
2. Maps do not indicate erosion, scour, channel migration hazards. A Qualified Professional must be consulted to determine site-specific hazards.

SNC·LAVALIN

CLIENT NAME: Village of Hazelton

PROJECT LOCATION: Hazelton and Gitanmaax, Kitimat-Stikine, BC

Skeena River and Bulkley River
25 Year Floodplain Map (Sheet 9 of 9)

BY: ECH	SCALE: 1:3,200	DATE: 2021-03-18	REF No: REV: 0
CHK'D: BR	PROJ COORD SYS: UTM Zone 9N NAD83		675878-006-9

MXD Path: \\Sl2606\projects\Current Projects\Village of Hazelton\675878\40_Execution\45_GIS_Dwgs\GIS\675878_Pro\675878_Pro.aprx

SNC·LAVALIN

SNC-Lavalin Inc.
8648 Commerce Court
Burnaby, British Columbia, Canada V5A 4N6
604.515.5151 604.515.5150
www.snclavalin.com