Flood Mapping and Flood Hazard Mapping for the Skeena River and the Lower Kitsumkalum River near Terrace

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Submitted to: Regional District of Kitimat Stikine
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Our Passion.

The preparation of this study was carried out with assistance from the Government of Canada and the Federation of Canadian Municipalities. Notwithstanding this support, views expressed are the personal views of the authors, and the Federation of Municipalities and the Government of Canada accept no responsibility for them.

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Executive Summary

Flooding in communities has significant consequences to the people who live there. Damage to public and private property and infrastructure results in economic, social, and environmental losses that can take a community years to recover. However, these damages can be prevented and/or mitigated through proactive flood planning. McElhanney was retained by the Regional District of Kitimat Stikine (RDKS) to complete a flood hazard assessment and mapping for the Skeena River from Kitselas canyon to the Zymagotitz (locally known as the Zymacord) River confluence, and the Kitsumkalum River from Deep Creek to the Skeena River. The project area was modestly expanded to include the Copper Estates subdivision, located near the Skeena River-Zymoetz (locally known as the Copper) River confluence, and the community of New Remo which is adjacent to the Skeena River at the Zymagotitz River confluence.

The project included:

- The acquisition of LiDAR and bathymetric channel survey information;
- A review of existing information;
- A hydrologic analysis of climate and flow information to estimate flows, for various return periods, that were used in the hydraulic analysis;
- Consideration of the effect of climate change on extreme flows in the watercourses of interest;
- The development of a 2-dimension (2-D) computational hydraulic model for the study area that, based on flow estimates, LiDAR and bathymetric survey, and additional physical parameters, predicted the water surface elevation, water velocity, and direction of flow in the study area;
- Translation of the hydraulic modeling results into a series of flood hazard maps for the study area;
- Identification of areas that maybe prone to flooding under current and future climate conditions; and
- Provide recommendations for future work related to flood mitigation planning and works, protection of public infrastructure, and erosion protection work.

Hydrologic Analysis

The 200-year peak instantaneous flow was employed as the design flood for the flood hazard assessment. To estimate the flow in the Skeena River, the Zymoetz River, and the Kitsumkalum River, flood frequency analysis was performed on Water Survey of Canada (WSC) information. A regional hydrologic analysis was completed for the study area. Flows were increased by 10% to account for the potential effects of climate change on extreme events. *Table 1* highlights the flows, for various return periods, in the three watercourses assessed.

Table 1: Annual Peak Instantaneous Flows (m^3/s) for the Major Watercourses under Existing and Future Climate Conditions.

Watercourse	Return Period							
	200-yr		100-yr		10-yr		2-yr	
	Existing	with C.C.	Existing	with C.C.	Existing	with C.C.	Existing	with C.C.
Skeena River	8725	9598	8287	9116	6537	7191	4775	5253
Zymoetz River	5328	5861	3875	4263	1393	1532	684	752
Kitsumkalum River	1192	1311	1059	1165	684	752	449	494
Zymagotitz River	783	861	709	780	535	589	457	503

Flow Timing

The four main rivers in the study area do not necessarily experience peak flows at the same time of year or experience the same magnitude of peak flow (return period) in a given same year. Predicting how the timing and magnitude of the flow in each watercourse occurs will have significant effect on flows throughout the study area. The flow between the Zymoetz River and the Kitsumkalum River/New Remo is the combination of the Skeena River (at Usk) and the Zymoetz River. Flow in the Skeena adjacent to New Remo and Old Remo includes flow the Skeena (at Usk), the Zymoetz, and the Kitsumkalum.

Annual and seasonal flow records were examined. The largest combined flows were derived for the spring freshet driven floods, and the autumn flood seasons. Two design flows have been identified and were used for flood mapping. Most of the study area will consider the **Fall 200-year peak instantaneous flow with climate change.** The results of this scenario will be applied to the Skeena River downstream of the Zymoetz River to the downstream boundary of the study area.

The section from the upstream boundary (Kitselas Canyon) to the Zymoetz River will consider the **Spring 200-year peak instantaneous flow with climate change**. The Kitsumkalum River will also consider this scenario, however the area surrounding the confluence of the Skeena River will be compared to the Fall scenario with the one producing the highest water elevation being adopted.

Hydraulic Modeling

A 2-D computational hydraulic model was developed for the study area. The model covered a domain of 64 km^2 and represented 41.6 km of the Skeena, Zymoetz, Kitsumkalum, and Zymagotitz Rivers. A digital elevation model (DEM) at a 0.5x0.5 m grid size served as the basis for the model. The DEM combined the LiDAR and bathymetric survey information. The model included four upstream boundaries where inflow hydrographs were specified: the Skeena River at Kitselas Canyon; the Zymoetz River 1.6 km upstream of the Skeena River; the Kitsumkalum River upstream of Deep Creek, and the Zymagotitz River 2.6 km upstream of the Skeena River. The downstream boundary of the model was immediately downstream of the Zymagotitz River - Skeena River confluence.

The design flow scenarios considering both current and future climate conditions were input into the hydraulic model. The results of the hydraulic model, including water surface elevations, depths, and velocities, provided the basis for the flood hazard mapping, and flood mapping. These results will provide design parameters for future flood mitigation and erosion protection work.

Flood Hazard Mapping

Flood Hazard Mapping combines the water depth, water velocity, and the potential for mobile debris to develop a flood hazard rating. Flood waters that are deeper, faster moving, and have more debris pose a high hazard than shallow, slow moving flood water that transport little debris.

The main channel of watercourses will always have an extreme hazard rating: this is were most of flow is conveyed. Focusing on areas outside of the main channels, the following areas were highlighted:

Skeena River

- Upstream of Terrace, isolated properties immediately adjacent to the Skeena River are at risk under current conditions. It appears that most structures are either above the water surface elevation (based on LiDAR) or are indicated as low hazard, which suggests minor inundation as opposed to deep, fast moving flood waters. The hazard for some properties increases to extreme under the future climate scenario. A 1200 m section of Highway 16 between Kitselas and the Copper River Estates also is in a high to extreme hazard zone under the future climate scenario.
- There are properties in the Queensway subdivision, located between Thornhill Creek and Bobsein Slough that are at risk, including areas that are in high to extreme hazard areas under current conditions, and most are under extreme hazard under future climate conditions.
- The RDKS sewage lagoons located downstream of the Queensway subdivision will not be inundated under current conditions. They will be overtopped under the future climate conditions scenario.
- The flood plain south of Graham Avenue in the City of Terrace is subject to some flooding under the current scenario. Flood waters gain access this area through sloughs and back channels. The slough around Brauns Island is an area of extreme hazard, primarily due to predicted water depth. Under future climate scenarios, the inundated area and hazard increases.
- The City of Terrace sewage lagoons are not overtopped under current or future climate scenarios.
- Properties in New Remo are not inundated under the current climate scenario. Under the future climate scenario, significant inundation is predicted.
- Building structures in the Kitsumkalum community are not subject to inundation from the Skeena River under current or future climate scenarios.

Kitsumkalum River

- Low lying properties in Dutch Valley are subject to inundation, primarily identified as low to moderate hazard, under current climate conditions. Under the future climate scenario, the flood hazard and area of inundation increases in the same area.
- Building structures in the Kitsumkalum community are not inundated under current or future climate scenarios. The flood hazard maps reflect surface flooding from major watercourses. Inundation due to groundwater seepage, minor tributaries, or ditch lines with small culverts were not considered in this scope of work and may be a contributing factor to flooding and inundation during extreme flows.

Recommendations

We have identified the following locations that should receive focussed attention for flood mitigation in order to reduce the current and future flood hazard:

- Properties immediately adjacent to the Skeena River in the Queensway subdivision between Thornhill Creek and Bobsein Slough. This area is identified as under moderate to high flood hazard under current conditions. Under future conditions, the hazard increased to extreme.

- Examine the Skeena River floodplain from Highway 16/Ferry Island to Brauns Island. The food hazard is currently considered low to moderate (apart from the sloughs and back-channels). The risk and extent of flooding is predicted to increase under future climate scenarios. Developing a staged approach to improved flood protection primarily by increasing ground elevations at specific locations along the riverbank can provide a reduction in future flood hazard.

- Inundation and flood hazard are predicted to increase in the Dutch Valley area adjacent to the Kitsumkalum/Kalum River under future climate scenarios. The most effective approach to reduce flood hazard in this location is to work with individual properties owns to reduce flood hazard on a very localized level.

Design parameters for potential erosion protection and mitigation are available from the hydraulic models. This includes the predicted water surface elevation and water velocity at the erosion sites. The large slope failure south of Bohler Road/Spring Creek is suspected to be a larger geotechnical problem, however fluvial erosion and forces are available from the model.

1. Introduction

Flooding in communities has significant consequences to the people who live there. Damage to public and private property and infrastructure results in economic, social, and environmental losses that can take a community years to recover from. However, these damages can be prevented and/or mitigated through proactive flood planning.

McElhanney has been requested by the Regional District of Kitimat Stikine (RDKS) to provide Inundation and Flood Hazard Mapping for the Skeena River and Kitsumkalum/Kalum River near Terrace. This assignment makes up Phase II of the Skeena Channel Management Program. Phase I was initiated in 2008 to identify erosion and flood concerns while optimizing mitigation strategies; Phase II involves data gathering and analysis for integration into future floodplain maps, and the evaluation of options for ongoing erosion control.

Flood hazard assessment and mapping provides addition information to traditional flood (inundation) mapping. Hazard ratings consider flood water depth, water velocity and mobile debris loads. The deep, faster moving, and larger potential for mobile debris, the greater the flood hazard.

The RDKS requires inundation and flood hazard maps to identify and assess potential priority areas for the flood mitigation and protection, and erosion protection. Special focus has been given to assessing the City and District infrastructure, and areas of concern identified by the surrounding First Nations communities that are at risk. The most recent flood event in the Skeena River that occurred in 2007 provided a baseline understanding of where flood risks are in the study area.

A considerable portion of the lands within the Kitsumkalum First Nation (KFN), the Kitselas Indian Band (KIB), and the City of Terrace (COT) are on the floodplains of the Skeena and Kitsumkalum/Kalum Rivers. These lands are mainly used for residential and agricultural purposes may be at risk of flooding.

Stakeholders identified additional concerns relating flooding and/or erosion within the study area:

- On-going erosion on the banks of the Kitsumkalum River in the vicinity of Dutch Valley and along approximately 172 meters of bank north of the Kalum River Bridge;
- Deposition of bedload and sediments at the Zymoetz River-Skeena River confluence;
- Log-jams within the Kitsumkalum/Kalum River;
- CN Rail Bridge Abutment affecting the natural movement of water at the Kitsumkalum/Kalum-Skeena confluence, and
- Slope instability south of Dutch Valley attributed to undercutting by a meandering channel from the Kitsumkalum/Kalum River.

1.1. PROJECT STUDY AREA

The study area for this assignment encompasses the Skeena River from Kitselas Canyon to the Zymagotitz River confluence, the Kitsumkalum River from Deep Creek to the Skeena River confluence, the lower 1.6 km of the Zymoetz River, and the lower 2.6 km of Zymagotitz River. *Figure 1-1* shows the project location and highlights the major watercourses considered in this assignment. The study area is presented in *Figure 5-1* and is discussed in more detail in Section 5 of this report.

1.1.1. Major Watersheds

Four major watersheds were considered as part of this assignment including the Skeena River upstream of Kitselas canyon, the Zymoetz River, the Kitsumkalum River, and the Zymagotitz River.

Skeena River

The Skeena River is the second largest river in British Columbia, draining approximately 54,000 km^2 in north central British Columbia. Upstream of the study area, the Skeena River watershed comprises 42,300 km^2. Major tributaries include the Babine River and the Bulkley River. The Skeena River is a nival watershed with peak flows generally occurring in late May to late June as a result of snowmelt. *Figure 1-2* shows the annual hydrograph for the Skeena River immediately upstream of the study area.

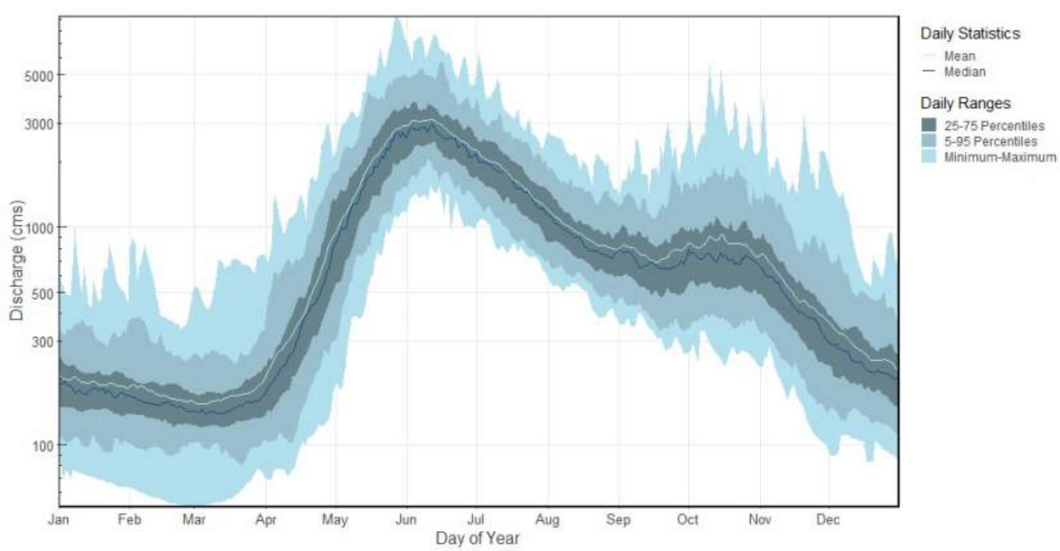
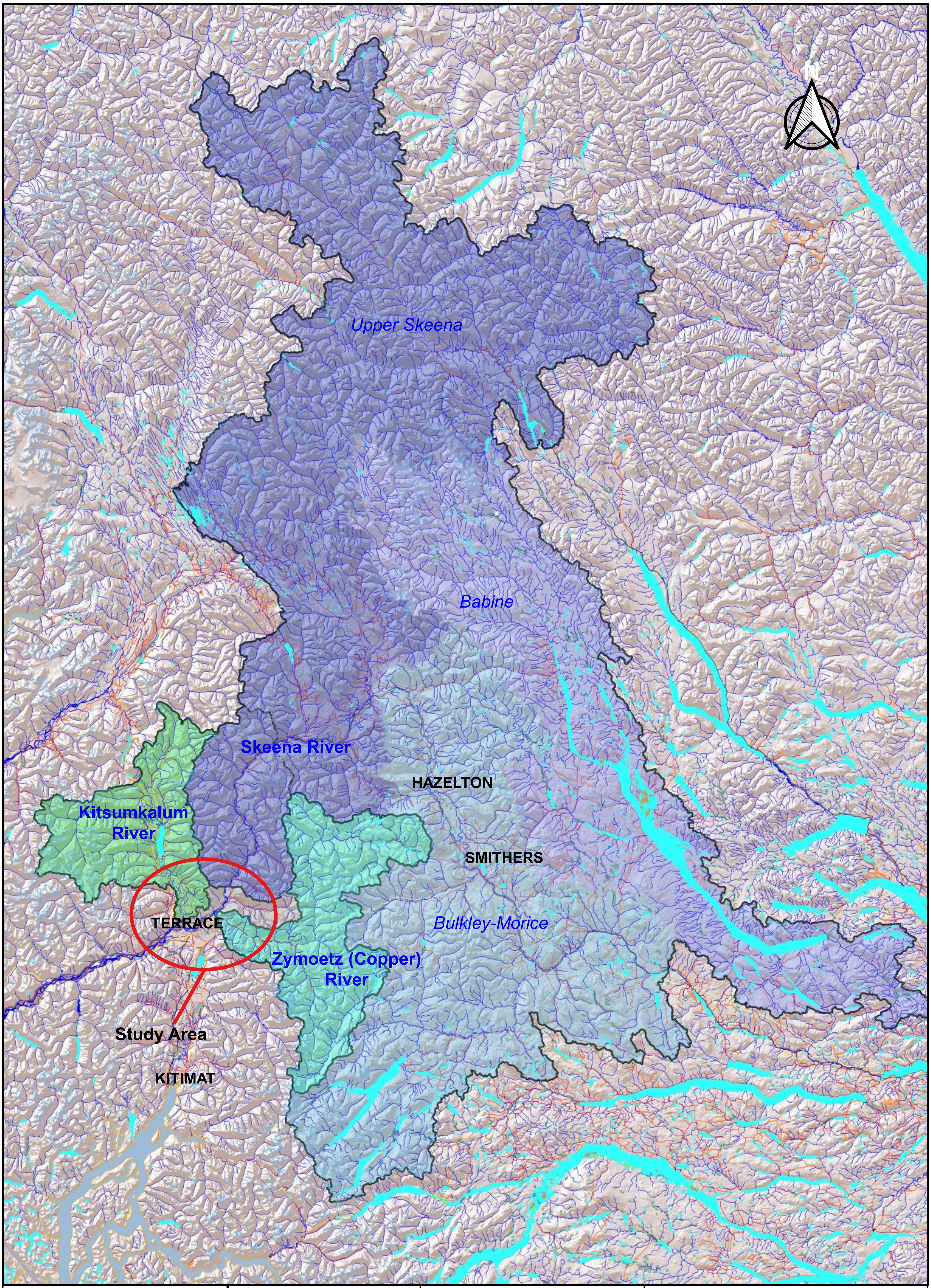


Figure 1-2: Annual hydrographs for the Skeena River at Usk - 1928-2018

Zymoetz River

The Zymoetz River is a tributary of the Skeena River, discharging into the Skeena River approximately 6 km upstream of the City of Terrace. The Zymoetz River drains an area of 3025 km^2. Major tributaries include the Clore River, the Kitnayakwa River, and Mulwain Creek. The Zymoetz River is a nival-pluvial watershed, with annual peak flows generally occurring between mid-May and late June due to snowmelt, or between late September to mid November, due to rain-on-snow events. *Figure 1-3* presents the annual hydrographs for the Zymoetz/Copper River.



Regional District of Kitimat-Stikine

McElhanney

Scale=1:1,250,000

Projection: BC Albers
Datum: NAD83

Project No.	Date
2321-01515-01	June 2021

LEGEND

Watersheds

- Upper Skeena
- Babine
- Bulkley-Morice
- Zymoetz (Copper) River
- Kitsumkalum River

Figure 1-1

Project Location and Watersheds of Interest

Skeena-Kitsumkalum Flood Hazard Assessment

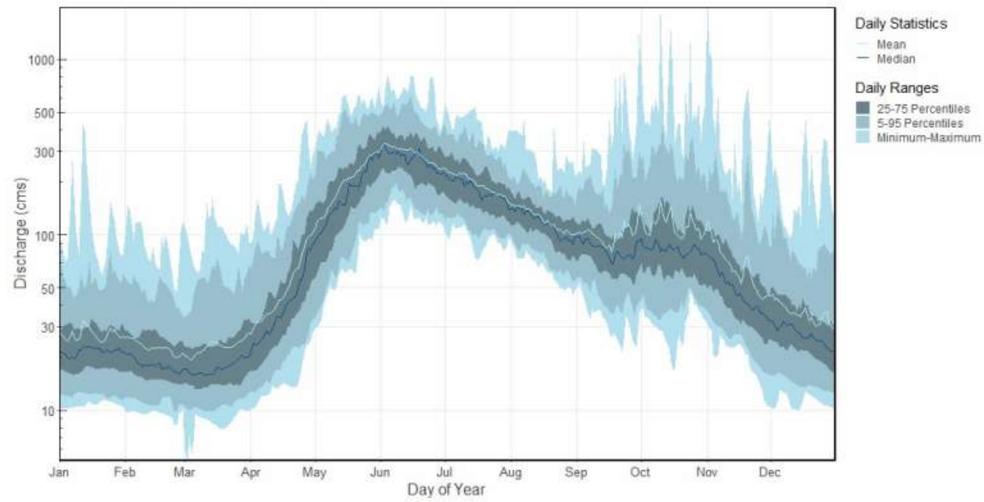


Figure 1-3: Annual hydrographs for the Zymoetz River above OK Creek - 1963-2015

Kitsumkalum River

The Kitsumkalum River is a tributary to the Skeena River, flowing into the Skeena River west of the City of Terrace. The Kitsumkalum River has a watershed area of 2290 km^2. Major tributaries include the Cedar River, the Nelson River, Mayo Creek, Goat Creek, and Deep Creek. Kitsumkalum Lake is situated in the heart of the watershed. 85% of the watershed is upstream of the lake. This waterbody provides attenuation to peak flow within the watershed. The Kitsumkalum River is a nival-pluvial watershed with annual peak flows occurring late May to early June as a result of snowmelt, or late September to mid November from rain and/or rain on snow events. *Figure 1-4* shows the annual hydrographs for the Kitsumkalum River.

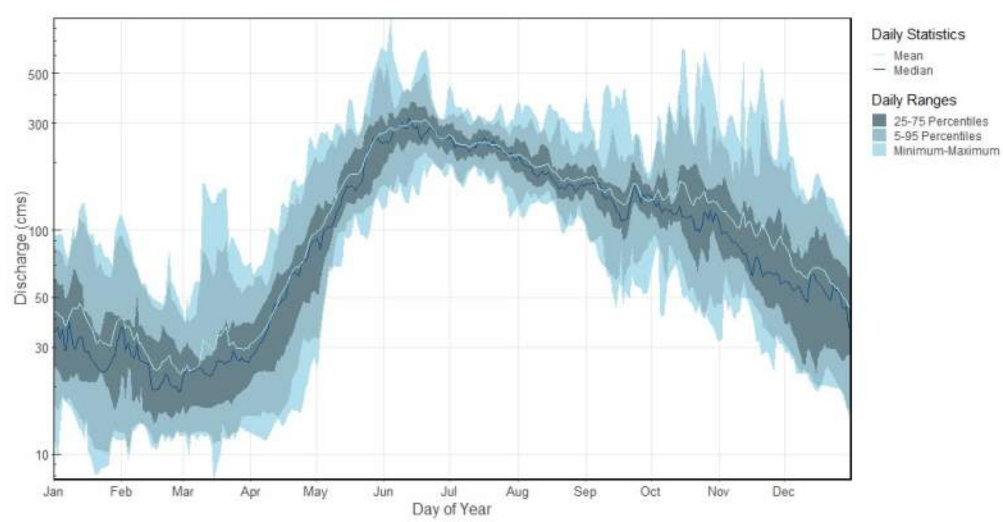


Figure 1-4: Annual Hydrographs for the Kitsumkalum River - 1929-1950

Zymagotitz River

The Zymagotitz (locally known as the Zymacord) River is a tributary to the Skeena River, flowing south into the Skeena River at the community of New Remo. The Zymagotitz River has a watershed area of 386 km^2. Its major tributary is Erlandsen Creek. The watershed is characterized by steep, rugged terrain with glaciers situated in high elevations. The Zymagotitz River nival-pluvial watershed with annual peak flows generally occurring late in late September to mid December from rain and/or rain on snow events. *Figure 1-5* shows the annual hydrographs for the Zymagotitz River.

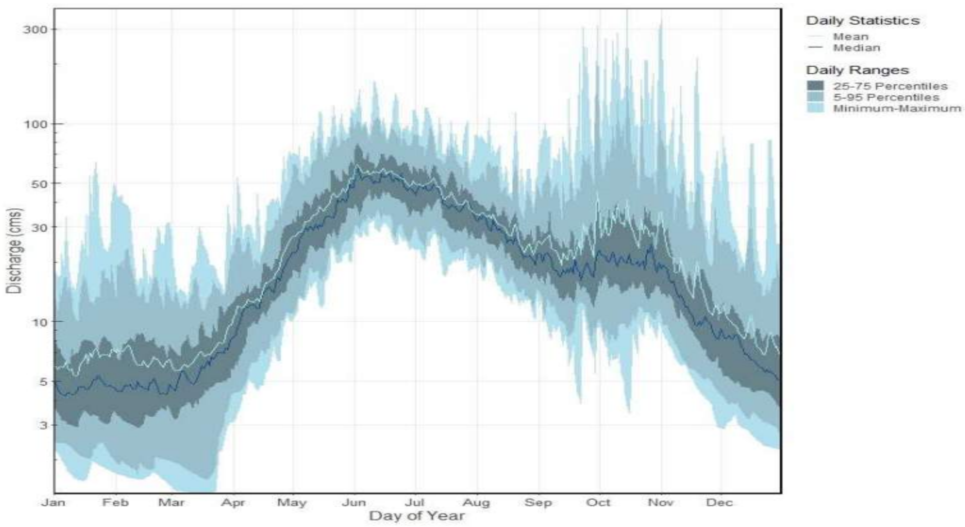


Figure 1-5: Annual Hydrographs for the Zymagotitz River - 1960-1994

2. Methodology

The flood hazard and inundation mapping project was completed as per our proposal submitted in September 2018. The methodology selected was a logical sequence involving the collection and review of existing LiDAR information and background data plus the acquisition of bathymetry information. Subsequently, LiDAR and bathymetry were combined into a single digital elevation model (DEM) at sufficient resolution to support the detailed analysis required to develop the flood mapping. The analysis included a hydrologic assessment and a 2-dimensional (2-D) hydraulic model of the Skeena River and Kitsumkalum River within the study area. These analyses were then interpreted into flood hazard maps and flood inundation maps for the area. Local knowledge was combined with these maps to isolate potential priority areas for erosion and flood protection. A brief description of each task is provided below. Detailed descriptions of the methods used are provided in the appropriate sections of this report.

2.1. COLLECTION AND REVIEW OF BACKGROUND INFORMATION

Available relevant information was obtained and reviewed by the project team. This included previous geomorphological reports completed for the area, GIS information, Water Survey of Canada (WSC) information, previous (1982) flood mapping, historic aerial imagery, and photographs. To develop a comprehensive digital elevation model (DEM), aerial LiDAR was obtained in July 2018. Channel survey cross-sections were obtained in November 2018 for the Skeena and Kitsumkalum Rivers. This information was then developed into a complete surface that reflected the ground and channel bathymetry.

Site visits of identified areas along the watercourses were completed on July 3rd and 4th, 2019 by members of the project team, including Doug Johnston, P.Eng., Chris Houston, P.Eng., and Adeola Oyefiade. A meeting with representatives from the RDKS and local stakeholders took place on July 3rd, 2019, after which a walk around with representatives from the COT, KFN, and KIN occurred to gain an understanding of past flood events and identify areas of the most concern.

2.2. HYDROLOGIC ANALYSIS

A hydrologic analysis was completed to estimate flows, for various return periods, for the Skeena, Kitsumkalum and Zymoetz River within the study area. A hydrologic analysis for the Zymagotitz River was completed when the community of New Remo was included in the study area. Water Survey of Canada (WSC) operates hydrometric stations across Canada. These stations measure water stage (elevation) and flow in watercourses. The Skeena, Kitsumkalum, and Zymoetz Rivers have active hydrometric stations located near the upstream boundaries of the study area. The Zymagotitz River was gauged by WSC from 1960 to 1994, however the station was discontinued.

A statistical flood frequency analysis was performed on data from these stations and flows for various return periods, including the 200-year, 100-year, 20-year, 10-year, and 2-year return periods were estimated. Flood mapping must consider the potential effect of climate change on extreme flows. Climate change conditions anticipated in 2080 were estimated using the Plan2Adapt tool developed and maintained by the Pacific Climate Impacts Consortium (PCIC). The flows were adjusted based on the climate change analysis.

2.3. HYDRAULIC MODELING

A 2-D hydraulic model was developed for the study area. The DEM surface of the channel and surrounding ground along with flow information from the hydrologic analysis were input into the model. Water surface elevation, depths, velocities, and direction of flow were predicted for the Skeena, Kitsumkalum, and Zymoetz Rivers within the study area.

2.4. FLOOD HAZARD MAPPING

Flood hazard mapping translates the water depth, water velocity, and potential for debris into a hazard rating. The deeper the water and the faster the water is moving, the greater the hazard to life and property. The results of the hydraulic modeling were used to develop flood hazard maps for the study area.

2.5. FLOOD (INNUNDATION) MAPPING

Flood mapping refers to the classic flood maps produced in the province of British Columbia. They display the *Flood Construction Level* (FCL), which represent the predicted 200-year return period water surface elevations with and allowance (addition) for freeboard, along the watercourses. The FCL is depicted with isolines at 0.5 m intervals, and the corresponding extent of the FCL based on terrain. The extent of inundation of the 20-year return period is also highlighted. Flood maps for the area were produced. They relied on the results from the hydraulic model.

3. Background Information Collection and Review

Available relevant information was obtained and reviewed by the project team. This included previous reports completed for the area and historic aerial imagery.

3.1. INFORMATION REVIEWED

The project began with a data review of information that was currently held by the RDKS, COT, and KFN on hydrology, floodplain mapping, and channel stability issues. *Table 3-1* identifies the overall information that was reviewed.

Table 3-1: Information Reviewed

Information	***Date***	***Content***	***Relevance***
City of Terrace – Floodplain Hazard Assessment	*May, 2001*	Findings and recommendations of a floodplain hazard assessment completed for the City of Terrace	Information was reviewed as part of overall Inundation and Flood Hazard Assessment
Channel Stability Assessment: Skeena and Kitsumkalum Rivers in the vicinity of Terrace	*July, 2009*	Findings and recommendations of channel stability and associated river hazards assessment conducted along the Skeena River	Reviewed for hydrology and channel behavior management information relating to the Skeena River
Channel Stability Assessment: Skeena and Kitsumkalum Rivers in the vicinity of Terrace	*March, 2018*	Compilation of Floodplain maps and historical air photos.	Provides information on historical channel conditions and flood levels that can be used for verifying the current model.
Skeena & Kitsumkalum Rivers Hydrotechnical Studies Data Report, Channel Stability, Floodplain Mapping, & Hydrology	*May, 2018*	Significant events and observations that have led to the present-day channel geomorphology and hydrology of the Skeena, Kitsumkalum, and Zymoetz Rivers	Report was reviewed to glean pertinent information about erosion rates, periods of significant flood events, and changes to channel characteristics resulting from sediment deposition and land use activities.
City of Terrace Infrastructure GIS Database	*Ongoing*	Wastewater treatment systems	Identify the location of wastewater treatment ponds at risk from flooding

3.2. HISTORICAL FLOODING

Prior to commencing flood modeling, numerous sites were identified as being at risk of known flooding. This data was obtained through local knowledge of the team, discussion with representatives from the KFN, as well as a review of the existing information.

The COT and surrounding First Nations communities (i.e., the Kitselas Indian Band and Kitsumkalum First Nation) may be at risk from flooding due to their location and proximity to the Kitsumkalum, Zymoetz, and Skeena Rivers. Recorded flood events in the Skeena River occurred in 1936, 1964, 1972, and 2007. The Kitsumkalum River had a recorded a significant flood event in 1936.

Figure 3-1 looks upstream of the Kalum River Bridge where erosion problems have been previously identified. *Figure 3-2* looks downstream from the CN Rail Bridge where an abutment has been identified as affecting the natural movement of water at the confluence of the Zymoetz and Sheena Rivers.

Figure 3-1: Lower Kitsumkalum River at upstream of the Kalum/Highway 16 Bridge.

Figure 3-2: Confluence of the Skeena and Kitsumkalum Rivers at downstream of the CNR Bridge.

Spring freshet caused the June 2007 flood event in the Skeena and Zymoetz Rivers (Miles and Associates, 2009). The WSC station on the Zymoetz River recorded a peak flow of 817 m^3/s on June 4th. The Skeena River (at Usk) peaked at 7,550 m^3/s on June 7th.

The June 1972 event was also the result of rapid snowmelt of a large snowpack. Melting of this snowpack caused the Skeen River to rise 60 cm in 24 hours. Rapid snowmelt caused by high temperatures followed by heavy rains in late May 1972 led to record water levels in many rivers within the B.C. Interior (Environment and Natural Resources Canada, 2010). On June 12, 1972, the *Skeena River (at Usk)* recorded a maximum instantaneous flow of 8,100 m^3/s ((McMullen et al., 1979).

A large snowpack in winter 1964 produced a spring runoff that caused extensive flooding in the Skeena Valley. Comparable to the June 2007 and June 1972 floods, the 1964 flood event was not preceded by a large rainstorm. However, a heavy rain occurred during the snowmelt from June 8-11 (Septer and Schwab,1995). Instead, the week leading up to the peak discharge was marked by high temperatures. Maximum temperatures for Terrace were 9.2°C above normal, with a daily maximum of 28.3°C recorded in June 1964 (Environment and Natural Resources Canada, 2019). Mean daily temperatures were 0.3° to 5.1°C above normal in May and July of the same year.

In all three events, high snowmelt rates caused extensive flooding in the latter part of May and early June. This suggests that most of the snow had not melted from the lower elevations and snow that likely persisted in the alpine played a contributing factor to all three flood events. The key difference between all three floods was the occurrence of a rainfall event in 2007. The 1964 and 1972 events are attributed to above average snowpack while an extreme daily rainfall rate of 115.0 mm in January 2007 contributed to the June flood of that year.

In addition to these three recorded major floods, anecdotal evidence was obtained that indicates there was a large flood that preceded consistent WSC hydrology measurements in the Skeena Valley (Miles et. al, 2009). The Great Flood of 1894 continued for 57 days and produced highwaters “the likes of which have never been recorded in history”.

The flood of record for the Skeena River was Spring 1948 (May 25-June 10). The WSC gauge at Usk recorded an average daily flow of 9340 m3/s, which is 20% larger than any other peak recorded over the 84 years of record. Floods were the result of rapid snowmelt from high temperatures. Numerous washouts of Highway 16 and the CN Railway occurred, and communities were isolated (*Septer and Schwab, 1995*).

On June 3, 1936, the Kitsumkalum River near Terrace had a maximum daily flow of 883 m^3/s to set a record while the flood water conditions in the Skeena River forced it to change course near Terrace ((Environment Canada, 1991) in Miles and Associates Ltd., 2009). The late spring timing of this flood suggests a similar flood pattern (i.e., snowmelt-elevated streamflow) as that observed in 1964, 1972, and 2007. Other significant flood events recorded in 1978 and 1991 are attributed to rain or rain-on-snow events instead of snowmelt. The October rainstorm events for both years caused significant infrastructure damage in the smaller communities near Terrace.

3.3. LIDAR AND BATHYMETRIC SURVEYS

Aerial *Light Detection and Ranging* (LiDAR) was acquired for the study area, through the Skeena Channel Management Program – Phase I in 2009. LiDAR was flown over the study area again in July 2018. This information was provided to the project team in September 2019. An orthophoto image (15 cm pixel resolution) acquired as part of the LiDAR flight was also included.

LiDAR does not provide channel bathymetry. A boat-based bathymetric survey of the Skeena River and the Kalum River was completed in December 2018. The survey included cross-sections and spot elevations. Land based spot elevations in the lower Kitsumkalum/Kalum and Skeena Rivers were also acquired, although dense vegetation hindered the completion of cross sections on certain locations within the study area. *Figure 3-3* shows the bathymetric survey points acquired within the study area.

To develop an accurate and reasonable representation of the channel bathymetry, we relied on cross-sectional information to develop representative channel geometries for numerous main and secondary channels in the study area. The representative channel geometries were translated upstream and downstream of the actual cross-sections using the bathymetric spot elevations in these sections as a guide to channel slope.

The LiDAR and channel bathymetry surfaces were combined into a comprehensive digital terrain model using Autodesk's Civil 3D 2018 software (Civil3D). The resulting surface was exported as a digital elevation model (DEM) at a 0.5 m x 0.5 m gridded resolution.

Additional LiDAR was acquired for the southwestern part of the study area (New Remo). This information was incorporated into the digital elevation model to expand the domain of the model to include these areas of interest in November 2019. Subsequently, the RDKS requested that the area around Copper Estates, near the confluence of the Skeena and Zymoetz Rivers be included. LiDAR acquired in 2008 was processed and incorporated into the composite surface in May 2021. We note that no additional bathymetry was acquired for the Skeena River adjacent to New Remo, and for the Zymagotitz River. The limits of the bathymetry are shown in *Figure 3-3*. Channel depths and shape were assumed based on channel slope, river character in other reaches, and professional judgement.

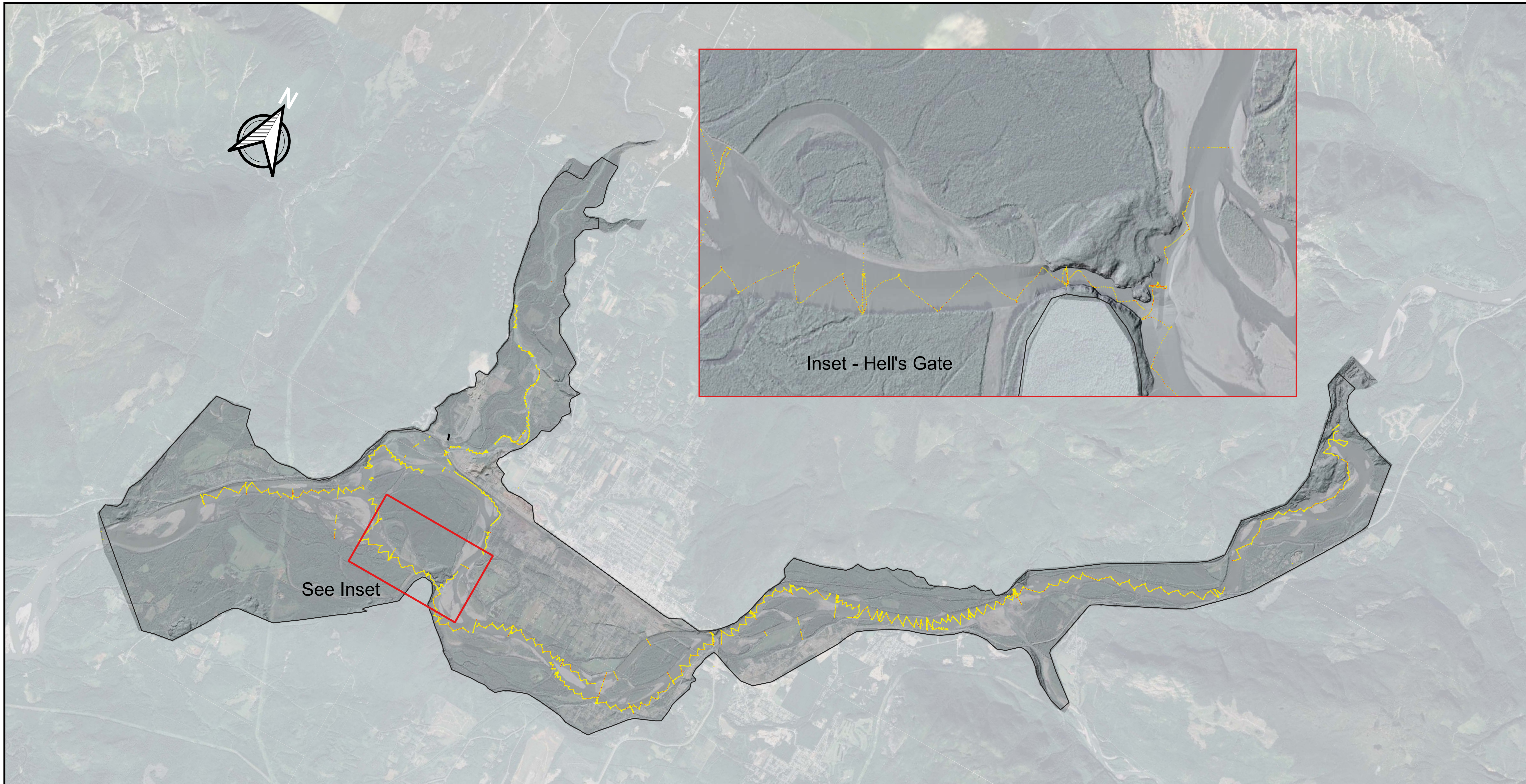
3.4. EXISTING FLOOD PROTECTION INFRASTUCTURE

Much of the rip rap riverbank protection existing in the COT was damaged during the 2007 flood. Sandbags were deployed during emergency works to minimize damage to facilities as the water levels increased (City of Terrace Annual Report, 2007). Since then, the COT's flood protection strategies have focused on the following:

- Riprap armoring along the Skeena River;
- Designating lands within floodplains as development permit areas with stringent guidelines; and
- The creation of a Master Drainage Plan (MDP) to guide structural upgrades and mitigate the effects of climate change.

In the Kitsumkalum community, flood protection infrastructure includes railbeds along the lower Kitsumkalum and Skeena Rivers that act as protection berms, and building covenants designed to uphold certain floodproofing standards.

The 2007 shoreline armoring work protecting properties along the Queen’s Way is an example of existing flood protection infrastructure in the Kitselas community.



Regional District of **Kitimat-Stikine**

McElhanney

0 1 2 3 4 5 km

Scale = 1:75,000

Imagery: September 2018
Source: Google Earth Satalite
Projection: BC Albers
Datum: NAD83

Project No. 2321-01515-01

Date: March 2020

LEGEND

Figure 3-3

Bathymetric Survey Points

Skeena-Kitsumkalum Flood Hazard Study

4. Hydrologic Analysis

The purpose of the hydrologic analysis is to estimate extreme flows, for various return periods, in the main watercourses in the study area: the Skeena River, the Zymoetz River, the Kitsumkalum River, and the Zymagotitz River. The Water Survey of Canada operates hydrometric stations across Canada. These stations record water elevation at a location. The elevation (stage) is translated to flow through rating curves which are developed by regularly measuring the water velocity and recording the river cross-section for at various stages. All four major rivers in the study area have, or have had, a WSC hydrometric station near the study area.

The Skeena River and the Zymoetz River have established WSC gauging stations located near the upstream limit of the study area (Station #08EF001 and #08EF005, respectively). To estimate flows in these watercourses, a statistical flood frequency analysis was performed on the annual peak instantaneous flow and annual peak average daily flow data from these stations.

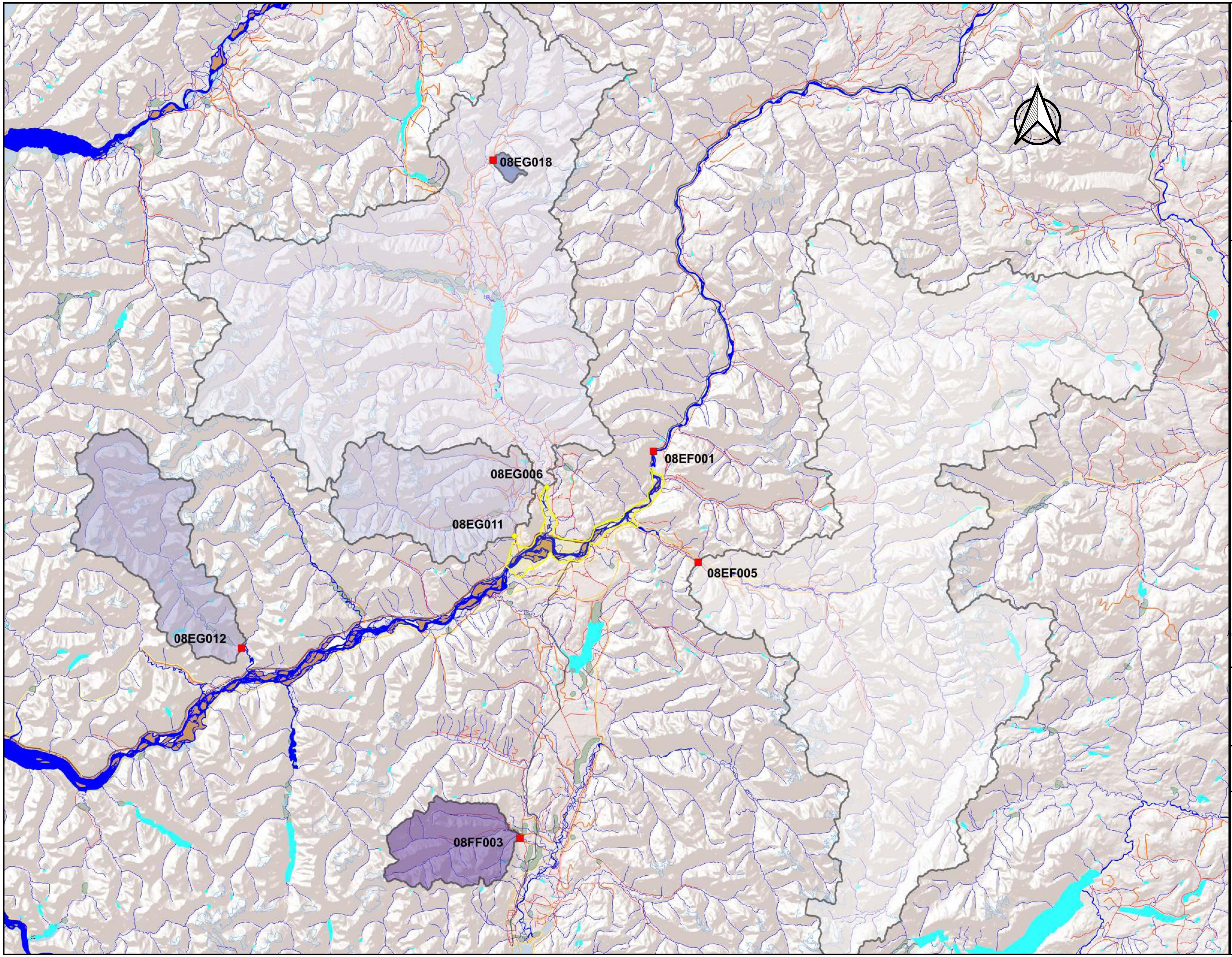
The Kitsumkalum River had a WSC hydrometric station (Station #08EG006) that operated from 1938 to 1952, at which time it was discontinued. This station provides 22 years of record for annual peak flows (1929 to 1950). The period of record is sufficient to perform a flood frequency analysis on the data set. WSC installed and new hydrometric station in 2018 (#08EG019). Preliminary flow data is available for the previous 18-month period the station, in near real-time, through the WSC website.

Similarly, WSC operated a hydrometric station on the Zymagotitz River from 1960 to 1994, at which time it was discontinued. The result was a 35-year period of record. Flood frequency analysis on the annual peak instantaneous and annual average daily peak flow data. *Table 4-1* summarizes the WSC stations used in this analysis.

Table 4-1: WSC Stations Located on Four Major Rivers in Study Area

WSC Station		**Area**	**Data Record**		**Station Status**
Number	*Name*	*(km²)*	*Period*	*# of Years*	
08EF001	Skeena River at Usk	42,300	*1928-2018*	85	Active
08EF005	Zymoetz River above O.K. Creek	2,850	*1963-2017*	55	Active
08EG006	Kitsumkalum River near Terrace	2,180	*1929-1952*	22	Discontinued
08EG011	Zymagotitz River near Terrace	376	*1960-1994*	35	Discontinued
08EG019	Kitsumkalum River below Alice Creek	2070	*2018-2021*	2	Active

A map showing the locations of the stations and their upstream watershed boundaries is presented in *Figure 4-1*. Additional stations in the area are also shown. Data from these additional stations were considered in our analysis for comparison, however they were not used directly.



Regional District of Kitimat-Stikine

Skeena-Kitsumkalum Flood Hazard Study

LEGEND

WSC Stations

- Active-Natural
- Discontinued-Natural

WSC Watersheds

- 08EG018
- 08EG006
- 08EF005
- 08EG011
- 08EG012
- 08FF005

McElhanney

100

Scale=1:500,000

Projection: BC Albers
Datum: NAD83

Project No.	Date
2321-01515-01	March 2020

Figure 4-1

WSC Stations near Study Area

4.1. FLOOD FREQUENCY ANALYSIS

Flood frequency analysis was performed on the annual peak instantaneous flow and annual peak average daily flow data for each WSC station. For years where only annual peak average daily flow (D) data was available, the corresponding annual peak instantaneous flow (I) was estimated by plotting the relationship between instantaneous and average daily for years where both were reported, then applying the regression equation of that relationship to the average daily peak flow. The statistical analysis which comprised the flood frequency analysis included the following steps:

- Determining the L-moments for each data set. L-moments are an ordered sequence of statistics used to summarize the parameters of a probability distribution (mean, variance, scale, skew, kurtosis, etc.);
- Fitting up to six statistical distributions to each data, including:
    - General Extreme Value (GEV)
    - Three Parameter Log-normal (3LN)
    - Log-Pearson Type III (LP3)
    - Wakeby (WAK)
    - Gumbell (EV1); and
    - Generalized Logistic (GLO)
- Visually assessing the goodness-of-fit for each distribution against the empirical probability distribution for the data.

The Generalized Extreme Value (GEV) distribution was selected as the best-fit distribution across all stations.

Since a seasonal (spring, fall) flood frequency analysis was also required, a process for deriving the season data sets was employed. For years where the seasonal peak was also the annual peak, then the annual values (Instantaneous and Ave Daily) were used. As with the annual data set, the instantaneous value, if missing, was populated using the I:D relationship. For years where the seasonal peak was not the annual peak, the seasonal peak average daily flow value was extracted from the daily flow data set. The corresponding seasonal instantaneous peak was estimated using the annual data set's I:D relationship.

Flood frequency analysis was then completed on the seasonal instantaneous and average daily peak data sets. Detailed flood frequency analysis for annual and seasonal data for each station is provided in *Appendix A*. A summary of the analysis is presented in Section 4.2.

4.2. TIMING OF EXTREME FLOWS

Rivers in the study area do not necessarily experience peak flows at the same time of year or experience the same magnitude of peak flow (return period) in a given same year. Predicting how the timing and magnitude of the flow in each watercourse occurs will have significant effect on flows throughout the study area. The flow between the Zymoetz River and the Kitsumkalum River/New Remo is the combination of the Skeena River (at Usk) and the Zymoetz River. Flow in the Skeena adjacent to New Remo and Old Remo includes flow the Skeena (at Usk), the Zymoetz, and the Kitsumkalum.

There are two flood "seasons" where annual peak flows have been recorded for the four rivers in the study area. The spring season extends from April 1st to July 31st, with annual peaks usually occurring mid-May to late-June. Spring peaks are the result of snowmelt, with extreme flows often the result of snowmelt combined with intense rainfall. The fall season coves the period from August 1st to March 31st, with annual peaks most prevalent in October and November. Fall peak flows are the result of intense rain and/or rain-on-snow events.

The timing of the extreme flows in each watershed is presented below. The relative timing of extreme flows will determine the "design" flows for the flood hazard mapping and flood mapping.

4.2.1. Skeena River (at Usk)

The Skeena River watershed comprises 42,300 km^2 upstream of the study area. Major tributaries include the Babine River and the Bulkley River. The Skeena River is a nival watershed with peak flows generally occurring in late May to late June as a result of snowmelt. An active WSC hydrometric station (#08EF001) is located immediately upstream of the study area at the community of Usk. The period of record for the station extends from 1928 to 2018 and includes 85 full years of data. In all but three years, the annual peak flow (both instantaneous and average daily) occurred during spring freshet, between May 5th and July 2nd. Three annual peaks occurred in October and November. Two of these peaks represented a 5-year return period events, with the thirds representing a 2-year flow. 48 of the largest 50 annual peak flows occurred in the spring freshet, including the 15 largest peak flows. The estimated flows for various return periods, both annual and seasonal, are presented in *Table 4-2* and *Table 4-3*. A 10% allowance for climate change is also presented.

Table 4-2: Peak Instantaneous Flows (m^3/s) for the Skeena River at Usk under Current and Future Climate Conditions.

Season	Return Period									
	200-yr		100-yr		20-yr		10-yr		2-yr	
	Current	with C.C.	Current	with C.C.	Current	with C.C.	Current	with C.C.	Current	with C.C.
Annual	8703	9573	8266	9093	7105	7816	6524	7177	4773	5250
Spring	8875	9763	8381	9219	7109	7820	6492	7141	4696	5166
Fall	5991	6590	5227	5750	3674	4041	3080	3388	1753	1928

Table 4-3: Peak Average Daily Flows (m^3/s) for the Skeena River at Usk under Current and Future Climate Conditions.

Season	Return Period									
	200-yr		100-yr		20-yr		10-yr		2-yr	
	Current	with C.C.	Current	with C.C.	Current	with C.C.	Current	with C.C.	Current	with C.C.
Annual	8586	9445	8136	8949	6957	7653	6375	7013	4650	5115
Spring	8747	9622	8244	9069	6963	7659	6348	6983	4582	5040
Fall	5854	6439	5105	5615	3581	3939	2998	3298	1696	1866

The Skeena River is a nival watershed and the seasonal flood frequency analysis demonstrate this fact. The spring flows are within 2% of the annual values, while the fall flows range between 68% for the larger flow, to 36% for the 2-year return period. The annual peak instantaneous flows, relative to the predicted return period, is shown in *Figure 4-2*.

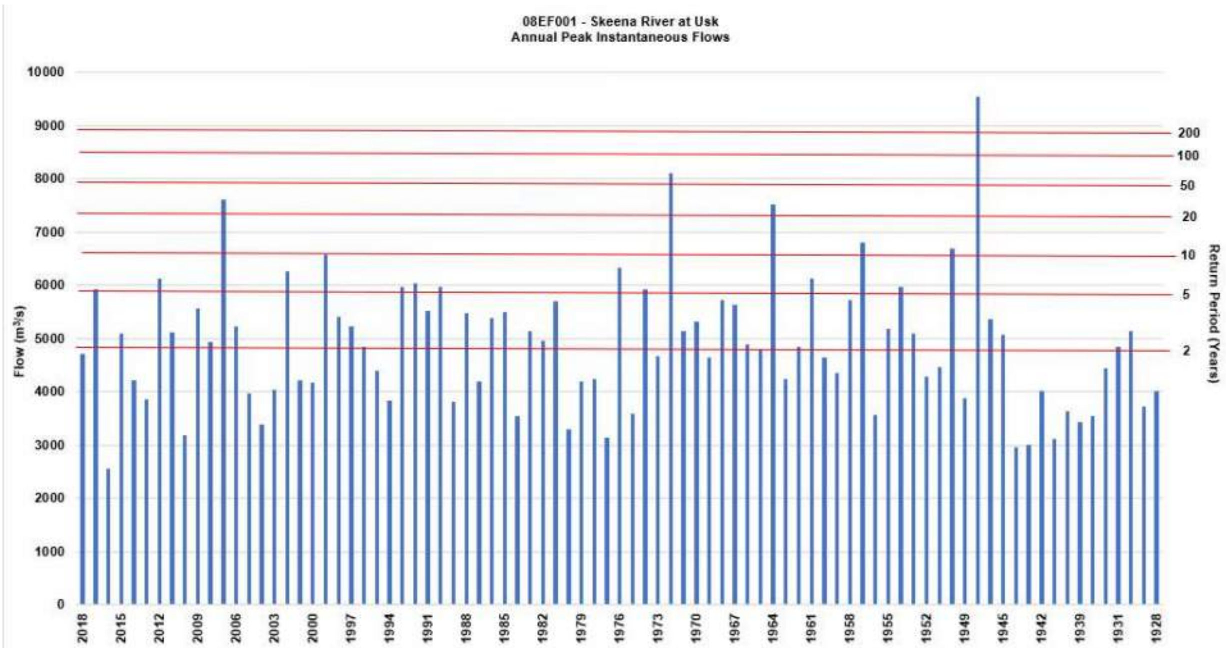


Figure 4-2: Skeena River at Usk - Annual Peak Instantaneous Flows

4.2.2. Zymoetz River (above OK Creek)

An active WSC hydrometric station (#08EF005) is located approximately 11.5 km upstream of the study area. The period of record for the station extends from 1964 to 2017 and includes 55 full years of data. The flow records indicate that the Zymoetz River experiences annual peak flows in both spring and fall, with 29 peaks occurring in the spring, and 26 in the fall. Further examination of the data, however, reveals that the 10 of the 11 highest flows on record occurred in the fall including the 6 largest flows. This suggests that extreme flow events occur in the fall. The season flood frequency analysis prove this point. *Table 4-4* and *Table 4-5* present the flood frequency analysis data for the Zymoetz River WSC station under current and future climate conditions, respectively.

Table 4-4: Peak Instantaneous Flows (m^3/s) for the Zymoetz River above OK Creek under Current and Future Climate Conditions.

Season	Return Period									
	200-yr		100-yr		20-yr		10-yr		2-yr	
	Current	with C.C.	Current	with C.C.	Current	with C.C.	Current	with C.C.	Current	with C.C.
Annual	5534	6087	4048	4453	1981	2179	1463	1609	702	773
Spring	1201	1321	1103	1213	891	980	805	885	599	659
Fall	5894	6484	4814	5295	2882	3170	2239	2463	995	1094

Table 4-5: Peak Average Daily Flows (m³/s) for the Zymoetz River above OK Creek under Current and Future Climate Conditions.

Season	Return Period									
	200-yr		100-yr		20-yr		10-yr		2-yr	
	Current	with C.C.	Current	with C.C.	Current	with C.C.	Current	with C.C.	Current	with C.C.
Annual	3166	3483	2434	2677	1342	1476	1046	1150	576	633
Spring	1037	1141	965	1062	801	881	731	804	553	608
Fall	3686	4054	3017	3318	1830	2013	1439	1582	688	756

Despite exhibiting a relatively even split between timing of annual peak flows, the fall peaks represent the extreme flows within the watershed. The Zymoetz River also exhibits very flashy behaviour during fall peak flows, with the instantaneous peak approximately twice that of the corresponding average daily peaks. This is most noticeable for the rarer, more extreme (i.e. larger return period) events. The large difference is typical of a coastal watershed responding to extreme rain, and particularly rain-on-snow storm events.

The annual peak instantaneous flows and the estimated return periods are shown in *Figure 4-3*.

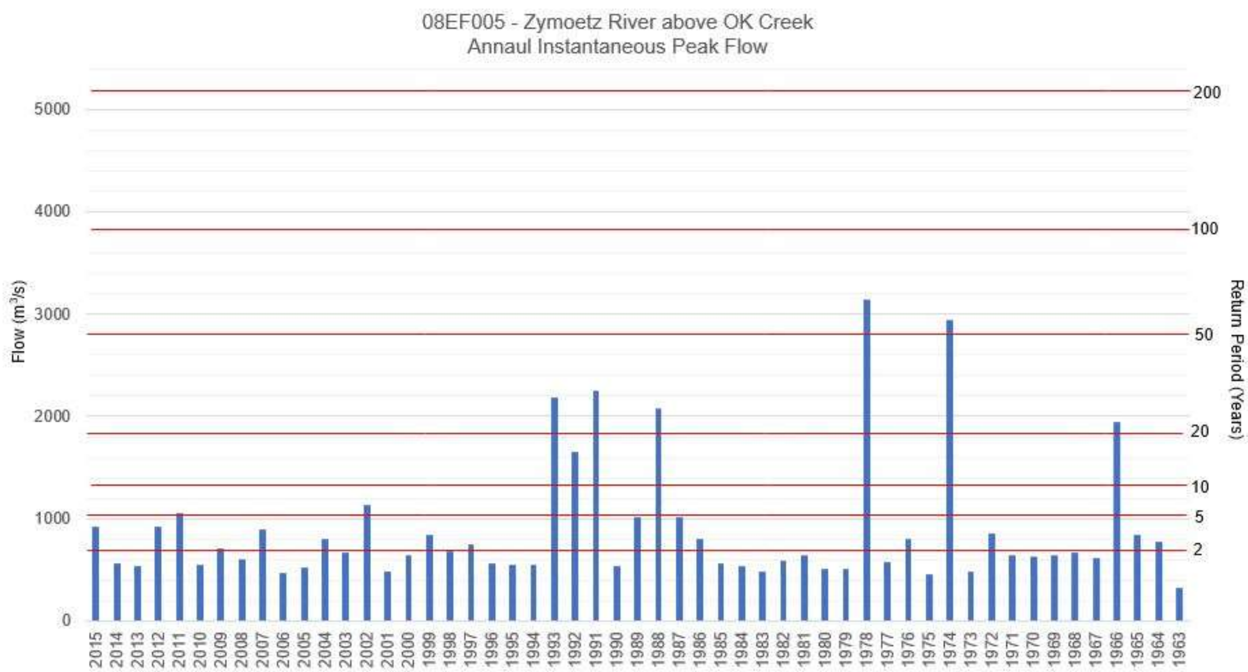


Figure 4-3: Zymoetz River above OK Creek - Annual Instantaneous Peak Flows

4.2.3. Kitsumkalum River (near Terrace)

WSC operated a hydrometric station hydrometric station (#08EG005) between 1929 and 1952. Located just upstream of Deep Creek, it provides 22 years of record. The flow records indicate that the Kitsumkalum River experiences annual peak flows in both spring and fall. Spring peak flows accounted for 16 of the 22 annual peaks record. Of the ten larger peak flows recorded, they were distributed evenly with 5 occurring in the spring and 5 in the fall, with the larger recorded flow occurring in the fall of 1936.

Table 4-6 and *Table 4-7* present the flood frequency analysis data for the Kitsumkalum River WSC station under current and future climate conditions, respectively.

We note that a new WSC station was installed on the Kitsumkalum River just below Alice Creek (#08EG019) in 2018. Results from the stations have yet be published, however near real-time flow and stage records from that station are available through WSC's website.

Table 4-6: Peak Instantaneous Flows (m^3/s) for the Kitsumkalum River near Terrace under Current and Future Climate Conditions.

Season	Return Period									
	200-yr		100-yr		20-yr		10-yr		2-yr	
	Current	with C.C.	Current	with C.C.	Current	with C.C.	Current	with C.C.	Current	with C.C.
Annual	1192	1311	1059	1165	788	867	684	753	449	494
Spring	1423	1565	1137	1250	700	770	578	636	380	418
Fall	1137	1251	977	1075	668	735	557	612	322	355

Table 4-7: Peak Average Daily Flows (m^3/s) for the Zymoetz River near Terrace under Current and Future Climate Conditions.

Season	Return Period									
	200-yr		100-yr		20-yr		10-yr		2-yr	
	Current	with C.C.	Current	with C.C.	Current	with C.C.	Current	with C.C.	Current	with C.C.
Annual	1160	1276	1033	1137	773	850	672	739	444	488
Spring	1420	1562	1133	1246	695	765	574	631	376	414
Fall	1074	1181	930	1023	648	712	543	598	319	351

The spring peak flows are predicted to be approximately 25% larger than the fall peak flows. The difference between the instantaneous and average daily peak flows are negligible. This is typical of a river downstream of a large lake which will attenuation the flow. Approximately 85% of the Kitsumkalum watershed flows into Kalum Lake.

The annual peak instantaneous flows and the estimated return periods are shown in *Figure 4-4*.

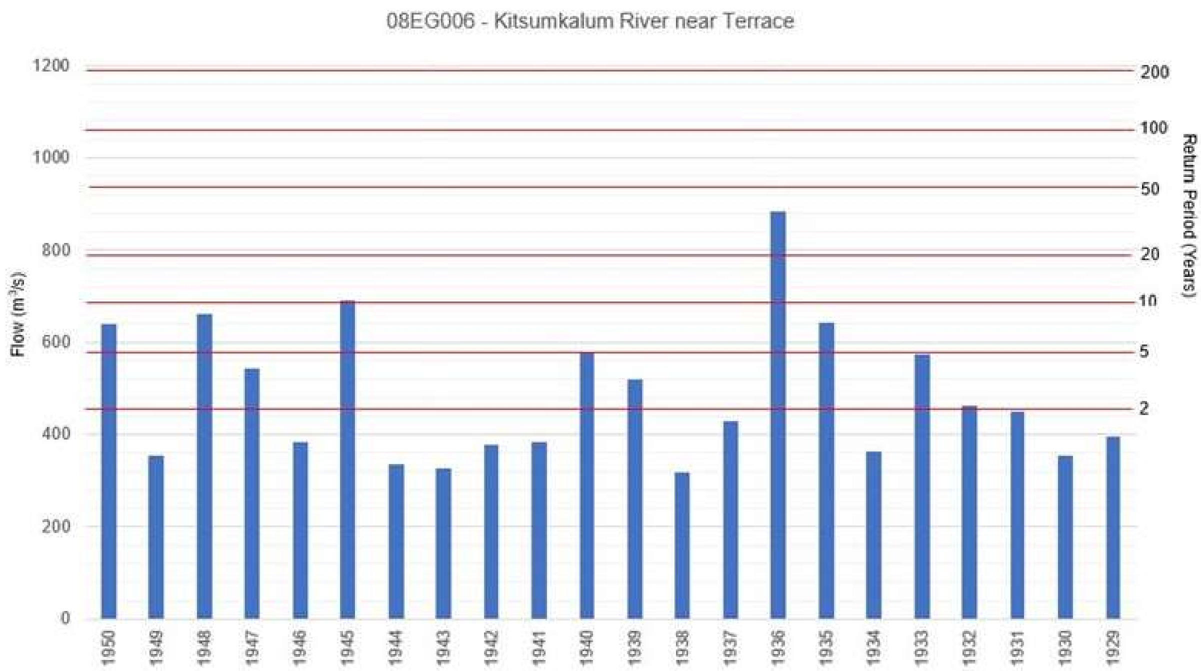


Figure 4-4: Kitsumkalum River near Terrace - Annual Instantaneous Peak Flows (1929-1950)

4.2.4. Zymagotitz River (near Terrace)

WSC operated a hydrometric station hydrometric station (#08EG011) on the Zymagotitz River from 1960 to 1994. Located approximately 4.5 km upstream of the Skeena River, the station provides 35 years of record. The flow records indicate that the Zymagotitz River experiences the majority of annual peak flows in the fall. Spring peak flows accounted for only 5 of the 35 annual peaks record. The 24 largest peak flows occurred in the fall. *Table 4-8* and *Table 4-9* present the flood frequency data for the Zymagotitz River WSC station under current and future climate conditions, respectively.

Table 4-8: Peak Instantaneous Flows (m^3/s) for the Zymagotitz River near Terrace under Current and Future Climate Conditions.

Season	**Return Period**									
	200-yr		*100-yr*		*20-yr*		*10-yr*		*2-yr*	
	Current	*with C.C.*	*Current*	*with C.C.*	*Current*	*with C.C.*	*Current*	*with C.C.*	*Current*	*with C.C.*
Annual	*783*	861	*709*	780	*535*	589	*457*	503	*250*	275
Spring	*250*	275	*234*	258	*198*	217	*181*	199	*137*	150
Fall	*731*	804	*677*	744	*534*	587	*463*	509	*249*	274

Table 4-9: Peak Average Daily Flows (m^3/s) for the Zymagotitz River near Terrace under Current and Future Climate Conditions.

Season	**Return Period**									
	200-yr		*100-yr*		*20-yr*		*10-yr*		*2-yr*	
	Current	*with C.C.*	*Current*	*with C.C.*	*Current*	*with C.C.*	*Current*	*with C.C.*	*Current*	*with C.C.*
Annual	*526*	578	*466*	513	*339*	373	*287*	316	*165*	182
Spring	*173*	191	*162*	178	*136*	150	*125*	137	*96*	106
Fall	*473*	520	*436*	479	*341*	375	*295*	324	*161*	177

The Zymagotitz River exhibits the characteristics of a steep coastal watershed. Peak flows are the result of rain and rain on snow events in the fall. The instantaneous to average daily peak ratio is close to two, suggest that peak flows are flashy, starting and ending quickly. *Figure 4-5* shows the annual peak instantaneous flows and the associated annual return periods.

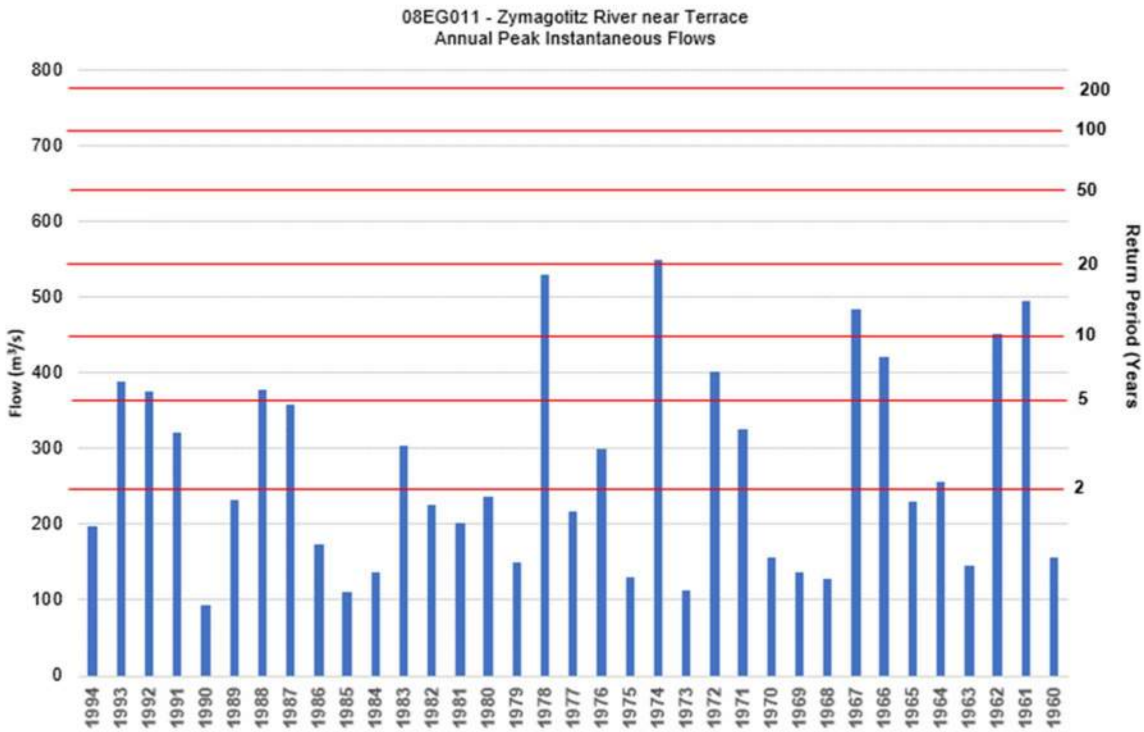


Figure 4-5: Zymagotitz River near Terrace - Annual Instantaneous Peak Flows (1960-1994)

4.3. CLIMATE CHANGE

Engineers and Geoscientists of British Columbia require that the potential effects of climate change be considered in any design. To understand the changes to climatic conditions anticipated by 2080, we employed the Plan2Adapt tool that was developed and is maintained by the Pacific Climate Impacts Consortium (PCIC). This tool generates maps, graphs, and data describing projected future climate conditions for various regions within British Columbia. These are drawn from a set of 30 Global Climate Model (GCM) projections based on 15 different GCMs, each driven by two different greenhouse gas emissions scenarios. These emissions scenarios are the A2 (high) and B1 (low), which predict atmospheric concentrations of greenhouse gases in the year 2100 at approximately 1250 ppm and 600 ppm, respectively. The Plan2Adapt tool presents the median changes predicted by this ensemble of model projections. The ensemble will predict a range of possible outcomes; the median is a robust estimate of the central tendency of the ensemble members.

The results of the scenarios were selected for the appropriate region, time period, and season via the interactive mapping tool. A summary of the average results is presented in *Table 4-10*.

Table 4-10: Predicted Average Changes in Precipitation and Temperature due to Climate Change - Year 2080 (from PCIC).

Category	Average Change (2080)
Annual Precipitation	***+9%***
Summer Precipitation	*+0%*
Winter Precipitation	*+13%*
Winter Snowfall	*-12%*
Spring Snowfall	*-70%*
Annual Temperature	***Inc. 2.7 °C***

The information presented in *Table 4-10* indicates that there will be a decrease in winter snowfall, and a dramatic decrease in spring snowfall. Precipitation, as rain, will increase in the spring, with an overall increase in total precipitation estimated to be 17% (Pacific Climate Impacts Consortium, 2012). Recent extreme events in the region (May 2007) were the result of a larger late spring snowmelt coupled with a rain event. The anticipated effects of climate change will begin to shift the character of the watersheds in the area from nival (snow) to pluvial-nival (rain-and-snow) dominated. The predicted changes will result in earlier spring freshet timing and larger fall flows.

It is challenging to predict the changes in extreme peak flows based on climatic information. We have adopted a **10%** increase to peak flow to account for potential climate change.

4.4. DESIGN FLOWS FOR FLOOD HAZARD AND FLOOD MAPPING

A single “design” flow for the entire study area is not appropriate, since certain areas will experience the largest flows during different seasons.

Two design flows have been identified. Most of the study area will consider the **Fall 200-year peak instantaneous flow with climate change.** The results of this scenario will be applied to the Skeena River downstream of the Zymoetz River to the downstream boundary of the study area.

The section from the upstream boundary (Kitselas Canyon) to the Zymoetz River will consider the **Spring 200-year peak instantaneous flow with climate change**. *Table 4-11* presents the spring (seasonal) design flows with considerations for climate change. The Kitsumkalum River will also consider this scenario, however the area surrounding the confluence of the Skeena River will be compared to the Fall scenario with the one producing the highest water elevation being adopted.

Table 4-11: Spring (Seasonal) instantaneous Peak Instantaneous Flows (m^3/s) with Future Climate Conditions.

	Watercourse (Upstream Boundary)			
	Skeena	***Zymoetz***	***Kitsumkalum***	***Zymagotitz.***
200-year	*9598*	*9116*	*7191*	*5253*
20-year	*5861*	*4263*	*1532*	*752*

Flood mapping also requires the extent and elevation of the 20-year peak instantaneous water level. The Spring 20-year peak instantaneous flow will be employed for the entire study area, with the exception of the Zymagotitz River, which will use the Fall 20-year scenario.

A summary of the two seasonal flows for the four rivers in the study area is presented in *Table 4-12* and *Table 4-13* for Fall and Spring, respectively.

Table 4-12: Fall (Seasonal) instantaneous Peak Instantaneous Flows (m^3/s) with Future Climate Conditions.

	Watercourse (Upstream Boundary)			
	Skeena	**Zymoetz**	**Kitsumkalum**	**Zymagotitz.**
200-year	*6590*	*6483*	*1251*	*804*
20-year	*3170*	*4041*	*735*	*591*

Table 4-13: Spring (Seasonal) instantaneous Peak Instantaneous Flows (m^3/s) with Future Climate Conditions.

	Watercourse (Upstream Boundary)			
	Skeena	**Zymoetz**	**Kitsumkalum**	**Zymagotitz.**
200-year	*9763*	*1321*	*1565*	*275*
20-year	*7820*	*980*	*770*	*218*

5. Hydraulic Modeling

A 2-D hydraulic analysis was built for the study area. We employed the Hydrologic Engineering Center - River Analysis System (HEC-RAS) v6.0 computational modeling software for this assignment. Developed and maintained by the US Army Corps of Engineers, the software is recognized as an industry standard and is freely available to the public.

Primary inputs for the 2-D hydraulic model included the DEM of the channel and surrounding ground, flow information, in the form of input hydrographs, for upstream extents of the model (upstream boundary conditions) for the scenarios examined, the downstream boundary condition, and hydraulic roughness (Manning's "n") for areas in the model domain.

Using the primary inputs, the model performs a series of calculations over the model domain in order to predict the water surface elevation (and water depth), water velocities, and direction of flow (current vector) for areas within the model domain.

Three upstream boundary conditions locations were identified in the model, including the Skeena River at Kitselas canyon; the Zymoetz/Copper River, and the Kitsumkalum/Kalum River downstream of the canyon (upstream of Deep Creek). The input hydrographs for the Skeena and Zymoetz/Copper Rivers were created based on flow data obtained from the WSC gauge stations on each watercourse. The Kitsumkalum/Kalum River input hydrograph relied on flows derived from the regional hydrologic analysis.

5.1. MODEL DOMAIN AND CALCULATION MESH

The model domain represents the area, including channels and flood plain, over which the model will perform the hydraulic calculations. The model domain is limited to areas where potential flooding can occur in order to reduce the computational intensity and time required to run the model. *Figure 5-1* shows the model domain and highlights the three upstream boundary locations: Skeena River at Kitselas Canyon, the Zymoetz River 1.3 km upstream of the Highway 16 bridge, and the Kitsumkalum River upstream of Deep Creek. The downstream boundary of the model is the Skeena River immediately downstream of the Zymagotitz River confluence. The modeled stream lengths are approximately 32.2 km, 8.1 km, 1.3 km, and 2.9 km for the Skeena, Kitsumkalum, and Zymoetz, and Zymagotitz Rivers, respectively. The total area captured in the model domain is 65.4 km^2.

5.1.1. Calculation Meshes and Regions

A 2-D hydraulic model uses a calculation mesh. The mesh, which is comprised of cells in a regular grid and irregular shaped cells, is used to calculate water surface elevation, water velocity, and flow direction within the model. Hydraulic calculations are completed for each cell. HEC-RAS allows further refinement of the calculation mesh by having different sized meshes within the model domain. These are referred to as *regions*. For the Skeena River model, we assigned an overall mesh size of 15 m x 15 m (the "domain mesh"). For the main channels (bank to bank) of the Skeena, Zymoetz and Kitsumkalum Rivers, the mesh size was increased to 20 m x 20 m. Break lines were added for features like riverbanks, roads, berms, and local heights of land to ensure a division of computational cells at that location. *Figure 5-2* shows an

Regional District of **Kitimat-Stikine**

McElhanney

0 1 2 3 4 5 km

Scale = 1:75,000

Imagery: September 2018
Source: Google Earth Satalite
Projection: BC Albers
Datum: NAD83

Project No. 2321-01515-01

Date: March 2020

LEGEND

Study Area/Model Domain

Figure 5-1

Study Area / Hydraulic Model Domain

Skeena-Kitsumkalum Flood Hazard Study

example of the calculation mesh, the channel refinement region, and enforced breaklines superimposed on the DEM and aerial imagery.

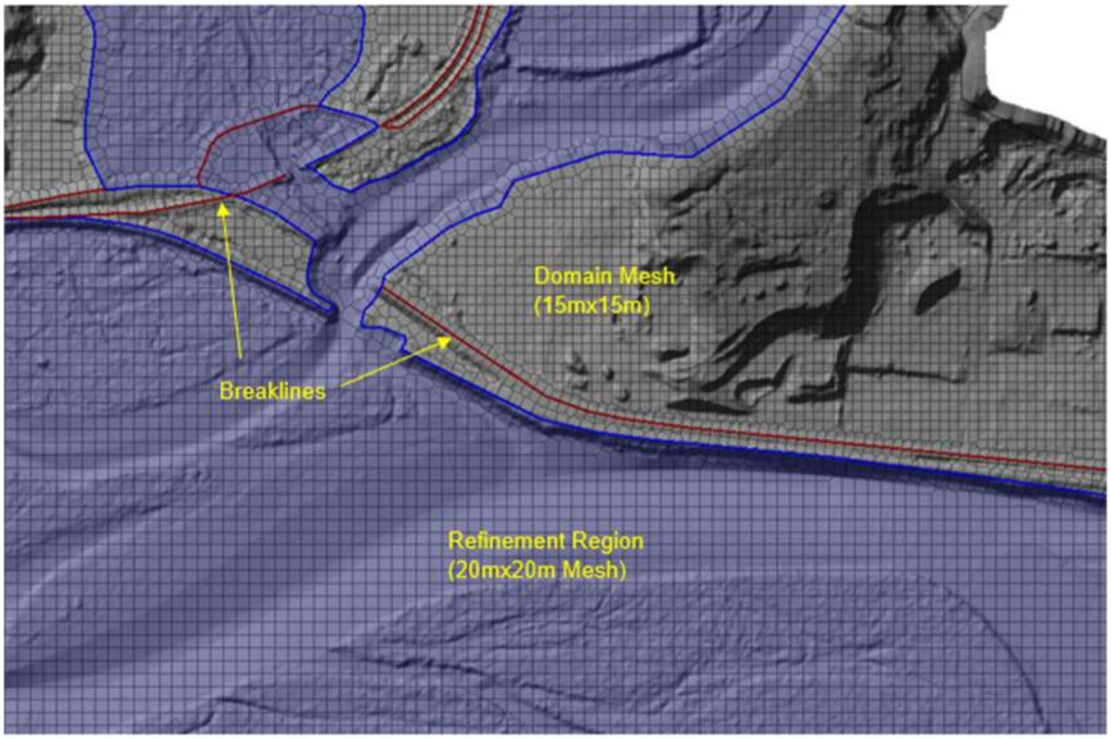


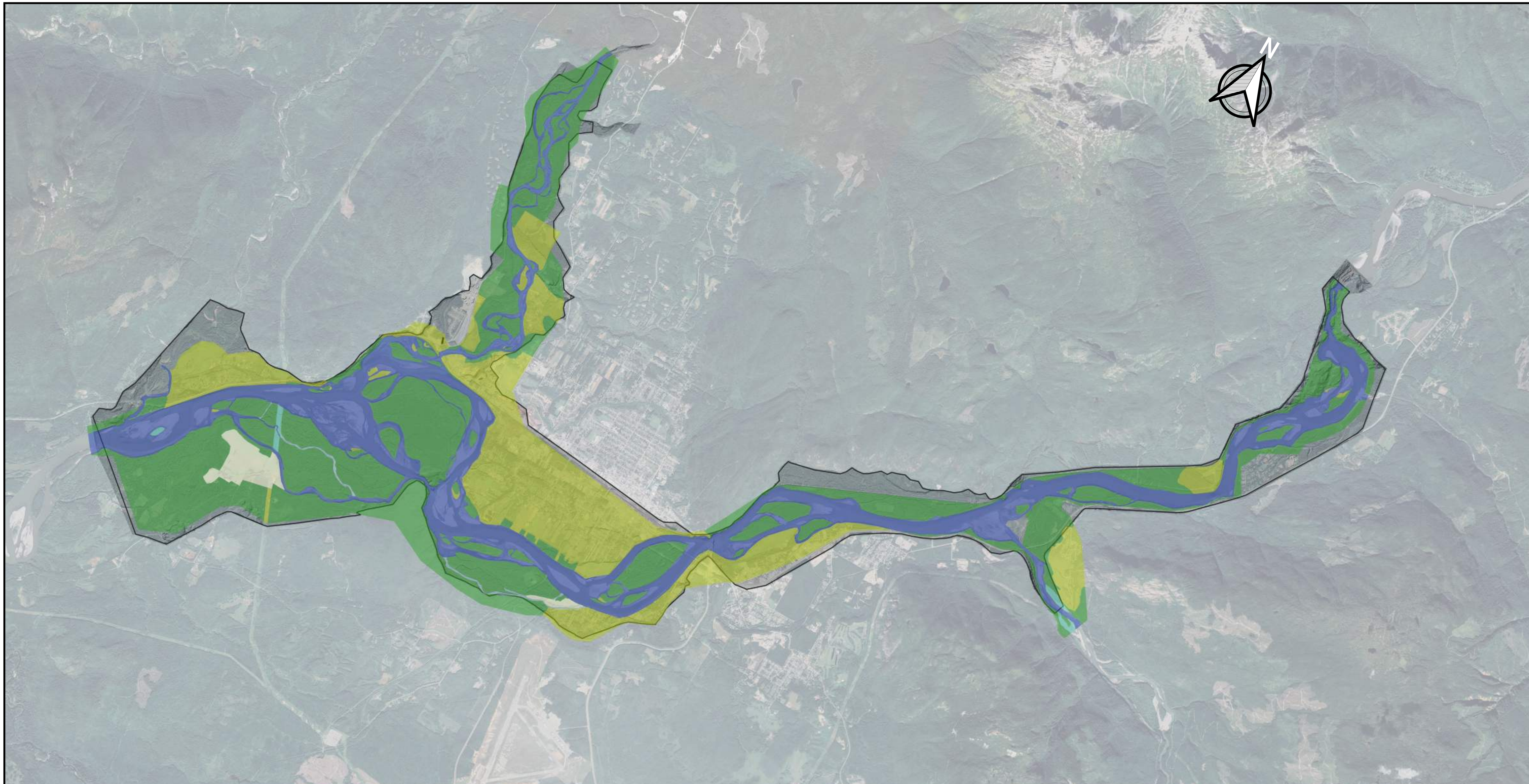
Figure 5-2: Calculation Mesh with Refinement Region (confluence of Skeena and Kitsumkalum Rivers shown).

5.1.2. Hydraulic Roughness

The hydraulic roughness, expressed as a Mannings "n" value, is used to characterize the physical resistance that a surface exerts on flowing water. The 2D model allows for multiple hydraulic roughness values to be assigned over the model domain. We delineated areas that exhibit difference hydraulic roughness based on land cover identified from aerial imagery. *Figure 5-3* highlights the land use areas identified for the study area. *Table 5-1* relates the land cover to a Mannings "n" value. The Mannings "n" value is based on published values for similar land cover. The Mannings "n" values were then adjusted during model calibration so results match closely with observed flows.

Table 5-1: Manning's "n" based on Land Cover used in the Hydraulic Model

Landcover	Manning's "n"
Channel (Skeena River, Zymoetz River)	0.0375
Channel (Kitsumkalum River)	0.040
Channel (Zymagotitz River)	0.0425
Dense Trees	0.10
Sparse Trees	0.08
Shrubs	0.075
Grasses	0.041
Secondary Channel	0.06
Side Channel	0.07
Marsh (Zymagotitz)	0.045
Undefined	0.08



Regional District of Kitimat-Stikine

McElhanney

0 1 2 3 4 5 km

Scale = 1:75,000

Imagery: September 2018
Source: Google Earth Satalite
Projection: BC Albers
Datum: NAD83

Project No. 2321-01515-01

Date: June 202

LEGEND

Landcover

- Channel
- Dense Trees
- Sparse Trees
- Grass
- Shrubs
- Side-channel

Figure 5-3

Landcover Used for Hydraulic Roughness

Skeena-Kitsumkalum Flood Hazard Study

5.2. FLOW SCENARIOS

Classic flood maps have examined the 200-year and 20-year flows. The EGBC guidelines do not state exact criteria for the design flood for flood mapping. They rely on the qualified professional to make recommendations for the flood event based on potential risk, type of flooding anticipated (freshet, ice jam, etc.), and professional judgement. As described in detail in Section 4.2 and 4.3, a single “design” flow for the entire study area is not appropriate, since certain areas will experience the largest flows during different seasons.

Two design flows have been identified. Most of the study area will consider the **Fall 200-year peak instantaneous flow with climate change.** The results of this scenario will be applied to the Skeena River downstream of the Zymoetz River to the downstream boundary of the study area.

The section from the upstream boundary (Kitselas Canyon) to the Zymoetz River will consider the **Spring 200-year peak instantaneous flow with climate change**. The Kitsumkalum River will also consider this scenario, however the area surrounding the confluence of the Skeena River will be compared to the Fall scenario with the one producing the highest water elevation being adopted.

Flood mapping also requires the extent and elevation of the 20-year peak instantaneous water level. The 20-year flow relates to the Public Health Act requirements for septic systems (EGBC, 2017). The Spring 20-year peak instantaneous flow will be employed for the entire study area, with the exception of the Zymagotitz River, which will use the Fall 20-year scenario.

5.2.1. Model Run Parameters

The 2-year annual peak instantaneous flow for the four rivers in the study area and representing the upstream boundary conditions for the model was run in a 24-hour model simulation. The results of the model were saved as a “re-start” file for all subsequent model runs. The restart file provides initial water surface elevations (based on the 2-year return period in this case) for subsequent model scenarios. This approach reduces the overall model run time and reduces the modeling instabilities associated with initial start-up of a “dry” model.

For all subsequent model scenarios, the model was runs were 18-hours in duration. Each upstream boundary condition started with their respective annual peak instantaneous 2-year flow (the restart file condition), and the flow was increased to the maximum flow for the scenario (Fall 200-year return period peak instantaneous flow, for example) over six hours of model time. The peak flow was then run for remaining 12 hours of simulation time and the results were reported at the end of the model run.

The downstream boundary condition (the Skeena River downstream of the Zymagotitz River) was set to *Normal Depth* with a channel slope of 0.1% for all scenarios.

The model timestep was permitted to vary based on the Courant number. The starting timestep was 12 seconds and the model was permitted to reduce to 0.375 seconds if required. Results of the model was reported ever 15 minutes (simulation time).

5.3. MODEL CALIBRATION

Calibration is the process of adjusting model parameters in order to match the model results with observed results within the study area. Often, calibration relies on water surface elevation measurements at (a) hydrometric station(s) within the study area. There are no hydrometric stations within our model domain. This approach is also of limited value for a model as large as one in this project, since examining a few isolated locations is not necessarily representative of the entire model domain. Furthermore, the gauges become less reliable on water overtops the channel banks near the station. This is why hydrometric stations tend to be located where the river channel is well defined and mostly confined.

A more common approach to flood model calibration is to rely on photographs/imagery taken during flood events. If flows are known, then those flows can be incorporated into the model, and water levels and extents of inundation can be assessed.

The June 2007 flood experienced in the Skeena valley around Terrace and the Kitsumkalum valley has a large photographic record. Peak instantaneous flows for the Skeena River at Usk and the Zymoetz River WSC gauges were recorded. The flood corresponded to an approximate 50-year return period spring flow under current climate conditions. No flow information was available for the Kitsumkalum or Zymagotitz Rivers (no hydrometric stations were in operation). The main parameter that can be adjusted in a 2D model is the hydraulic roughness for various land cover. The roughness value is a catch-all number for hydraulic energy losses, with includes turbulence.

Our model achieved acceptable results for the areas upstream Little Island/Ferry Island. Downstream of that point, the model could not replicate flooding that was witnessed, specifically along the reach of the Skeena between the entrance to Hell’s Gate and the Kitsumkalum River, and flood waters that traveled overland adjacent to the City of Terrace sewage lagoons. It was posited that the poor agreement at these locations may have been the result of significant channel changes upstream and downstream of Hell’s Gate. These changes that occurred during and after the June 2007 flood resulted in a significant larger portion of the flow in the Skeena going through Hell’s Gate as opposed to flowing in the northern channel towards the Kitsumkalum confluence. Since our model relied on LiDAR and bathymetry acquired in 2018, it represents current channel conditions. A more detailed description on changes at Hell’s Gate will follow.

The spring of 2021 provided an additional opportunity to calibrate the model. Between June 1st and June 5th, the Skeena and Kitsumkalum River rose dramatically, with the peak in Terrace occurring between 8am and 2pm on Friday June 4th. Realtime flow measurements were recorded on the Skeena, Zymoetz and Kitsumkalum Rivers every 5 minutes. Representatives of the RDKS, the City of Terrace and McElhanney took a helicopter flight over the entire project area. It resulted in over 1000 photographs and videos of the project area and provides and excellent record of the flood near its peak. The real-time hydrometric data indicated that that Skeena River achieved a 20-year return period flow and the Kitsumkalum River experienced between a 25-year and 50-year return period event. The Zymoetz River experienced between a 25 year and 50-year *Spring* seasonal event. This corresponds to a 5-year annual event, or a 2-year fall seasonal event.

To calibrate the model, the 5-minute data from the three hydrometric stations from June 3rd at 6:00am to June 5th at 6am was used as the inflow hydrographs at the upstream boundary conditions. The annual 2-year peak instantaneous flow was assumed for the Zymagotitz River since it is not gauged. Model results were compared the photographs and videos, aligning the model time with the time the images were taken. The parameters of the model were adjusted, and reasonable agreement was achieved in all parts of model. This included the Kitsumkalum River which could not be calibrated using the 2007 event due to no flow information and significant channel changes during and after the 2007 event, and the Skeena River adjacent to New Remo and Old Remo.

5.3.1. Hell's Gate

Hell's Gate is a 70 m wide, 380 m long bedrock canyon located on the left bank of the Skeena River opposite Braun's Island southwest of the City of Terrace. Bathymetry show that the channel bottom drops off over 10 m near the entrance to the canyon. The approximate water depth thru near the canyon entrance is approximately 20 m during average summer low flow conditions. The 2018 LiDAR imagery of Hell's Gate is shown in *Figure 5-4*.

Figure 5-4: Hell's Gate - July 2018 (LiDAR Imagery)

Progressive channel changes immediately upstream (east) and downstream (west) of Hell's Gate are documented in the Miles and Associates report (2018) (Figures A3-7A and A3-7B, A3-9A and A3-9B). *Figure 5-5* and *Figure 5-6* are presented for context and show Hell's Gate in 1937 and Hell's Gate in 1977.

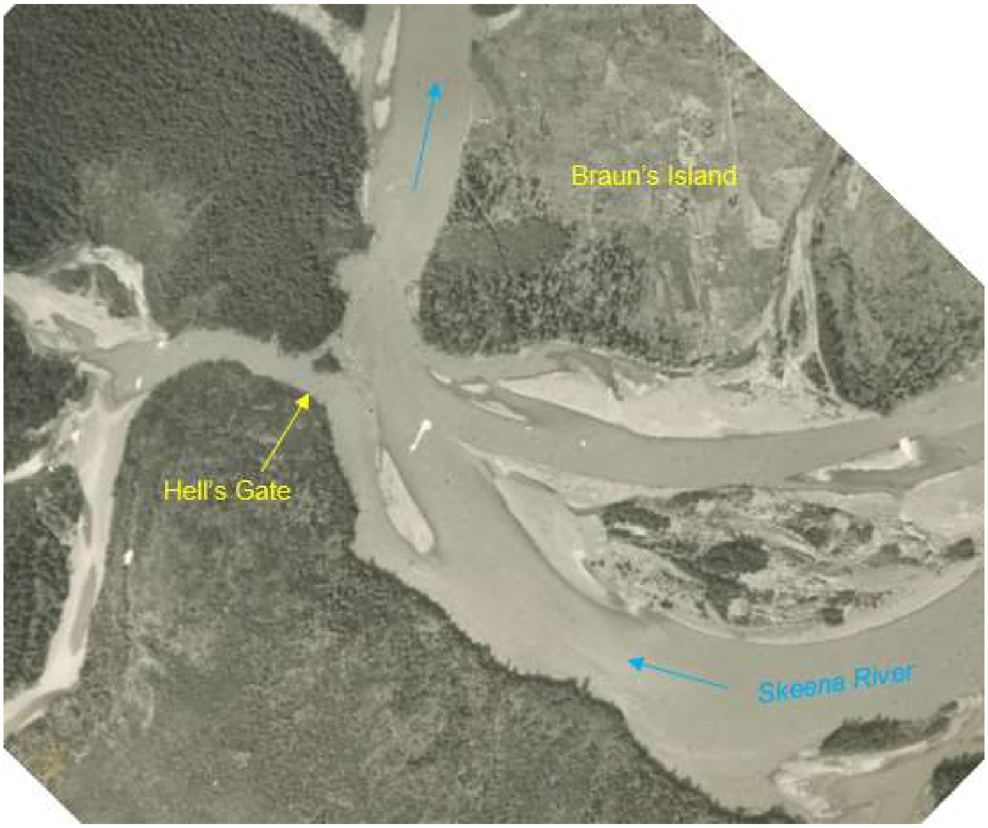


Figure 5-5: Hell's Gate -1937 Air Photos (provided by RDKS).

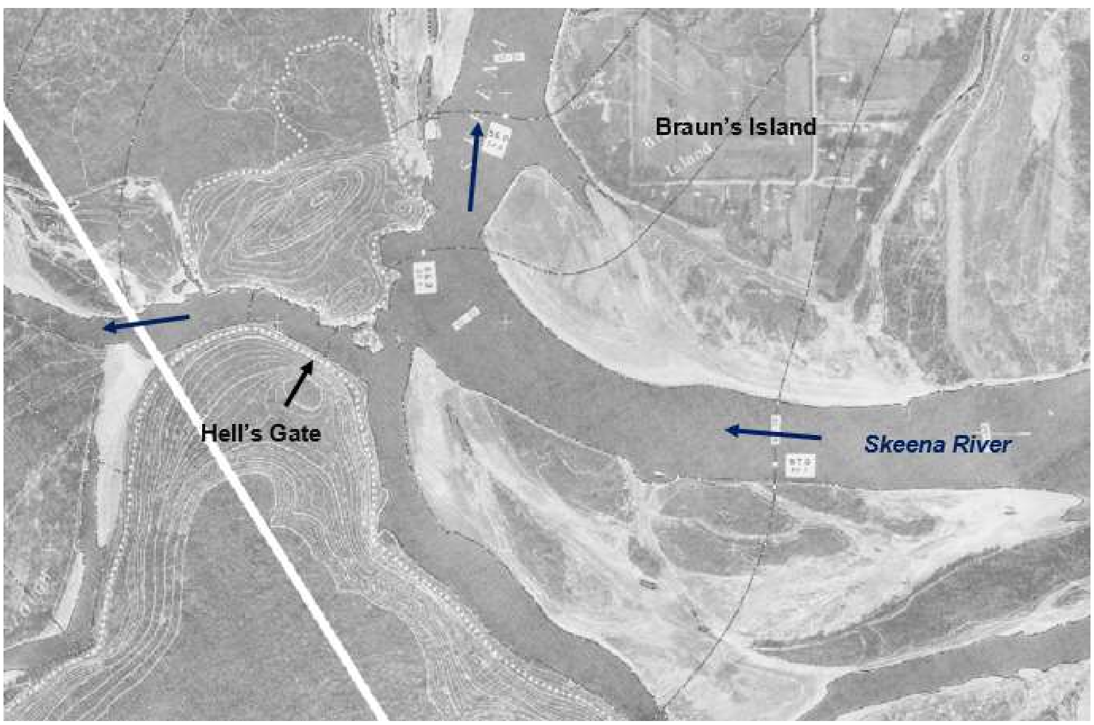


Figure 5-6: Hell's Gate - 1977 Imagery (from 1982 BC Floodplain Maps).

Two processes have occurred that have altered the flow path at Hell's Gate. Upstream the thalweg of the Skeena River has shifted left, so it is now located adjacent to the left, outer bank of the river as the flow approaches Hell's Gate. This represents a lateral shift of approximately 400 m. The result is that most of the flow is directed into Hell's Gate. Substantial deposition on the center and right side of the river channel has resulted in larger bar formation extending out from Braun's Island. Comparing the 2018 and the 1977 images, the thalweg was more centered in the channel, with channel bar present near the Hell's Gate entrance.

Downstream of Hell's Gate, the channels are significantly widening and deepening, which indicates that more flow is being conveyed through Hell's Gate. This was documented in the 2018 report (Miles and Associates, 2018).

The change in flow patterns at Hell's Gate will influence water surface elevations between Hell's Gate and the Kitsumkalum River during extreme events. Given the changes that have occurred in this section of the Skeena River, and the changes are occurring and will continue to occur, we recommend monitoring of this area to note significant changes in flow paths.

5.4. SITE SPECIFIC CONCERNS AND SCENARIOS

During the meeting with representatives from the RDKS and local stakeholders that occurred on July 3rd, 2019, specific areas of concern were identified by officials from the City of Terrace (COT) and the Kitsumkalum First Nations (KFN). Some of the concerns are addressed by the modeling work completing, including predicted hydraulic conditions at the Dutch Valley slope failure, hydraulics near the sewage outfall for the City of Terrace, and the elevation of the RDKS sewage lagoons located on the south side of the Skeena River.

Debris accumulation, specifically at the Highway 16 bridge over the Kitsumkalum River was noted as a potential problem. The left (east) channel at the bridge shows significant aggradation. There is a potential for a partial debris blockage at the bridge. This area should be monitored.

6. Flood Mapping and Model Results

The Engineers and Geoscientists (EGBC) guidelines for Flood Mapping in BC established the following definitions for flood mapping:

- ***Inundation Maps***: Topographic maps showing the extent of floodwater in plan, under defined flood events; and
- ***Flood Hazard Maps***: Maps that provide information on the flood hazard rating associated with defined flood events. The rating is based on the water depth, water velocity, debris hazard and the velocity / duration of flooding.

Classic provincial floodplain mapping is a type of inundation mapping, however it references the Flood Construction Level (FCL), which is the predicted water surface elevation for the 200-year flow, plus and allowance (increase in elevation) for freeboard. The freeboard is either 0.3 m above the peak instantaneous flow, or 0.6 above the peak average daily flow. The combination that produces the highest FCL is used.

6.1. FLOOD MAPPING

The hydraulic model predicted the extent of inundation, water depth, and water velocities for the seasonal 200-year peak instantaneous flow. The flood (inundation) maps maps were produced based on these flows, plus an allowance for the potential effects of climate change to the year 2100. The FCL presented on the flood maps included a 0.3 allowance for freeboard. The water surface elevations for the seasonal 20-year peak instantaneous flow are also depicted on the maps.

6.2. FLOOD HAZARD MAPPING

The flood hazard maps build on the inundation mapping and present the flood intensity characteristics. The EGBC Professional Practice Guidelines on flood mapping in BC suggests that there are several ways to characterise flood hazards. Maps can be prepared to show variations in water depths and water velocities for a given event. Although there are no specific hazard classifications for flood hazard ratings specific to Canada at this time, the EGBC guidelines provide the ratings combining both water depth and water velocity developed in the UK (Surendran et al., 2008). This rating system characterizes hazard as a function of water depth, water velocity, and the potential for floating debris, primarily based on the consideration of the direct risks to people exposed to floodwaters. The premise for flood hazard is simple: the deeper the water, the faster moving the water, the greater the hazard to life and property.

For the purpose of this study, we have used this UK classification, as provided by EGBC. The formula is:

$$HR = d \, x \, (v + 0.5) + DF$$

where, HR = (flood) hazard rating;

d = depth of flooding (m);

v = velocity of flood water (m/s); and

DF = debris factor

(DF = 0, 0.5, or 1 depending on probability that debris will lead to a significantly greater hazard).

We have assessed the potential for mobile debris in the river as high, however, the potential for this debris to be mobilized from the river to the populated areas is slightly lower. Accordingly, the debris factor has been set to 0.5.

This hazard rating classification framework provides a proxy for physical hazard to persons directly exposed to inundation, with the classification as set out in *Table 6-1*.

Table 6-1: Hazard-to-People Classification (from Defra/Environment Agency, 2006)

HAZARD RATING (HR)	HAZARD TO PEOPLE CLASSIFICATION
< 0.75	**Low** - *Low Hazard (Caution)*
0.75 – 1.25	**Moderate** - *Danger for Some (includes children, elderly, and the infirm)*
1.25 – 2.0	**High** - *Danger for Most (includes the General Public)*
> 2.0	**Extreme** - *Danger for all (includes Emergency Services)*

Figure 6-1 presents the concept in a similar way, using the water velocity and water depth variables instead of the derived hazard rating.

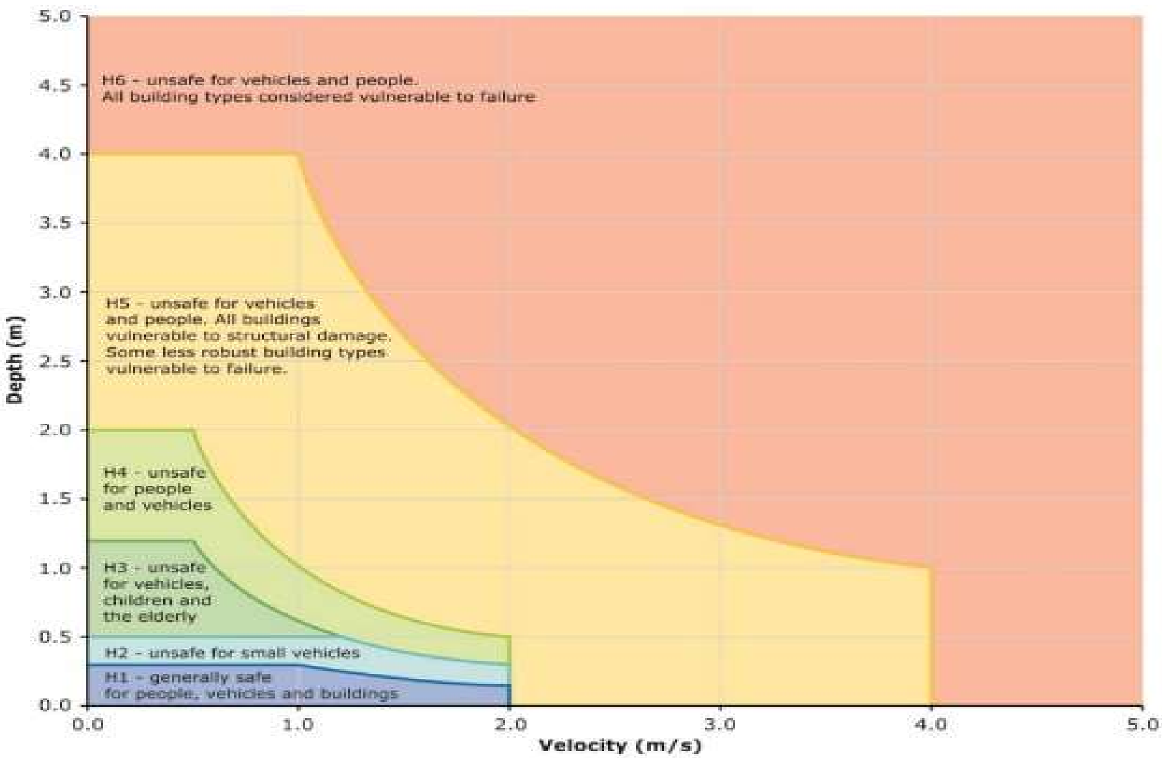


Figure 6-1: Flood Hazard presented as a function of water depth and velocity (from Smith et al., 2014).

This hazard classification has been applied to the flooding predicted in the study area. This classification can be used by the RDKS to inform emergency planning procedures and identify areas where resources may be needed in the event of a flooding situation.

A set of flood hazard maps accompanied the report.

6.3. DISCUSSION OF HAZARD MAPPING AND MODELLING RESULTS

The flood hazard maps show the hazard rating at a particular location. Main channels and secondary channels will usually display an extreme hazard rating since this is where water flows the fastest and deepest. The design flood in the comments that follows refers to the appropriate season 200-year peak instantaneous flood with consideration for climate change. The following is a summary of the flood hazard mapping:

Skeena River upstream of the Zymoetz River

- Properties immediately adjacent to the right (north) bank of the Skeena River on Kshish 4 I.R. the are at High to Extreme hazard for the design flood.
- Properties on the south bank have flood hazards of Low to Extreme, however the buildings appear to be either out of the hazard area, or in Low to Moderate hazard areas.
- Most of the Copper River Estates subdivision is in Low to Moderate flood hazard. There are paths of High to Extreme hazard areas, that appear to follow natural depressions in terrain, in ditches. Flood in this area is the result of the extreme flows in the Zymoetz (fall event). Under the spring design flood, no flooding occurs in Copper Estates. When looking at the 200-year fall event under current climate condition (no allowance for climate change), the portions of the subdivision are under Low, Moderate and High hazard with Extreme hazard limited to ditches.

Skeena River - Zymoetz River to the Old Bridge

- Properties on Schremp Island are under Extreme flood hazard during the design flood. This is true for current climate scenarios as well.
- Properties on the south bank have flood hazards of Low to Extreme, however the buildings appear to be either out of the hazard area, or in Low to Moderate hazard areas.
- Most of the Copper River Estates subdivision is in Low to Moderate flood hazard. There are paths of High to Extreme hazard areas, that appear to follow natural depressions in terrain, in ditches. Flood in this area is the result of the extreme flows in the Zymoetz (fall event). Under the spring design flood, no flooding occurs in Copper Estates. When looking at the 200-year fall event under current climate condition (no allowance for climate change), the portions of the subdivision are under Low, Moderate and High hazard with Extreme hazard limited to ditches.
- Thornhill Hill residents are outside of the flood hazard area under the design flood scenario with two exceptions: the farm on the lower bench is under Extreme hazard and a single industrial building at the end of Dejardines Avenue. Minor, if any, reduction in hazard to these properties is evident under current climate scenarios.

Skeena River - Old Bridge to Braun's Island

- Properties located between Queensway Avenue and the Skeena downstream to the trailer park are in Extreme hazard for the design scenario. A closer examination of how the area floods (is the dike too low, or is water going around the dike in the Bobsein Slough/ Thornhill Creek) should be conducted to inform potential mitigation options.
- The RDKS sewage lagoons berms located downstream of the Queensway subdivision are 300 mm below the 200 year with current climate conditions. This deficit increases to 750 mm under the design scenario.
- The flood plain south of Graham Avenue up to Medeek in the City of Terrace is subject to some flooding under the design scenarios, with Extreme hazard concentrated in the lower elevation terrain and flow paths, similar to those active in the 2007 flood event. Some residents are on higher ground and are out of the hazard, however some are not, and are in Low, Moderate, and High hazard areas.
- Little Island is under Extreme flood hazard during the design flood.
- There are also flow paths that converge towards Graham Avenue that are active and predict Low, Moderate and High hazard conditions. Residents are within these flow paths.
- City of Terrace sewage lagoons are not overtopped under current or future climate scenarios.
- Properties on Braun's Island are under Moderate to Extreme hazard. Some buildings are above the hazard, many are not.

Braun's Island to Kitsumkalum

- Riverfront properties south of Haugland Avenue are in Extreme hazard areas under design conditions. Under current conditions, hazard decrease to High for most area, with some properties remaining under Extreme hazard.
- Overbank flooding is not predicted along Skeena Avenue properties, or north of Haugland Avenue under current climate conditions. We suspect this is due to the increase in flow through Hell's Gate. Minor flooding with Low and Moderate hazard is predicted under future climate conditions, however the flow path for this water originated in from the Braun's Island slough.
- Building structures in the Kitsumkalum community are not subject to inundation from the Skeena River under current or future climate scenarios.

New Remo and Old Remo

- Under design scenario flows, New Remo is under Extreme hazard with a few isolated residents under Low hazard. Under the current climate scenario, hazard in some areas decrease. This is most notable in the northern end of the community. Some high, isolated residents are above the hazard area. Flooding in New Remo, under the current climate scenario, originated from the Zymagotitz River, backwatered by the Skeena. The highway is overtopped the Zymacord Bridge by the downstream slough. Under design scenarios, the highway is overtopped along most of its length.
- Old Remo, east of the Lakelse River Rd/Old Remo Rd junction, is under High to extreme hazard in both the design scenario flood, and current climate conditions. The extents of flood do not change significant between the two scenarios. Flood, for the most part, occurs via overbank flooding from the Skeena, with minor flooding occurring from Hell's Gate Slough to the north.

Kitsumkalum/Kalum River

- Properties in Dutch Valley along Bohler Road are subject to inundation and Low to High hazard under the current climate scenario. Under the design scenario, hazard increases and most of the area is inundated. Flooding is the result of both overland land flooding directly from the river and increasing water levels eventually overtopping the banks of the slough/back-channels at the end of Bohler Road.
- In Kitsumkalum, most residents are outside of the flood hazard, or on the edge and in Low hazard areas. Residential and commercial properties that front Highway 16 and properties at the south end of Spokeshute Road are in Moderate to Extreme hazard areas.
- Under current climate scenarios, the extent of inundation, and associated hazard is not as severe, with residences opposite the main Council offices subject to Moderate or High hazard.
- Flooding occurs via back-watering of the slough due to extreme water levels in the Kitsumkalum and Skeena Rivers.

We note that in all areas, the flood hazard maps reflect surface water flooding from major watercourses. Inundation due to groundwater seepage, minor tributaries, or ditch lines with small culverts were not considered in this scope of work and may contributing factor to flooding and inundation during extreme flows.

7. Recommendations

The flood hazard assessment has provided a basis for continuing with flood mitigation planning. Our recommendations follow this theme, and include areas were refinement of the assumptions made in the study would be beneficial, and for some areas where flood mitigation planning and options analysis is required. The recommendations are as follows:

1. The downstream reach of the Skeena immediately upstream and downstream of the Zymagotitz River was not covered by bathymetric survey. We recommend a survey of the Skeena be completed down to the Lakelse River, and the study be expanded in Old Remo. Similarly, The Zymagotitz was not surveyed, but should be to properly understand the flood mechanisms for New Remo. Incorporating the new bathymetry and additional LiDAR into the model requires only modest effort, with the most effort expended to acquire the survey and LiDAR. This will provide greater confidence in the prediction.

2. The importance of Hell's Gate cannot be understated with respect to flood hazard from Braun's Island to Kitsumkalum. We recommend that channel conditions be monitored upstream of Hell's Gate. If the thalweg begins to shift right, towards Braun's Island and way from the left bank, this could signal increased flows and associated flood hazard for the area.

3. The berms containing the RDKS sewage lagoons along Queensway Ave need to be raised to avoid overtopping in the design flood, and also under current climate conditions. With freeboard, we estimate a raise of approximately 1.0 m is required.

4. Properties immediately adjacent to the Skeena River in the Queensway subdivision between Thornhill Creek and Bobsein Slough are in a high hazard area. Flood mitigation options should be investigated for this area.

5. Flood mitigation planning is required for areas within the City of Terrace and mitigation options developed. Both structure and non-structural options should be assessed. Engineered solutions, either permanent or temporary, constructed at strategic locations, may provide a substantial reduction in flood hazard for certain areas.

6. Flood mitigation planning for Copper Estates may also be useful. Due to the nature of flooding, temporary mitigation options may be beneficial at this location.

7. Inundation and flood hazard are predicted to increase in the Dutch Valley adjacent to the Kitsumkalum/Kalum River under future climate scenarios. The most effective approach to reduce flood hazard in this location is to work with individual properties owns to reduce flood hazard on a very localized level. Many residences are higher than predicted flood levels under current climate conditions, information to residences would allow additional measures to be assessed and undertaken.

8. Flood mitigation planning for Kitsumkalum village, and specifically the commercial and residential properties near Highway 16 should occur as significant inundation is predicted under the design scenario.

In addition to flood mitigation and management planning, the result of the study, and specifically the hydraulic model, will continue to provide the RDKS and stakeholders with information and design parameters to various works within the study area, including erosion and scour protection, civil engineering design and transportation planning and design.

8. Closure

The assessment, report and mapping have been prepared by McElhanney for the benefit of the Regional District of Kitimat-Stikine. The information and data contained herein represent McElhanney's best professional judgement in light of the knowledge and information available to McElhanney at the time of preparation.

McElhanney denies any liability whatsoever to other parties who may obtain access to this report for any injury, loss or damage suffered by such parties arising from their use of, or reliance upon, this document or any of its contents without the express written consent of McElhanney and the Regional District of Kitimat-Stikine.

We thank you for the opportunity to work on this project. Please do not hesitate to contact us if you have any questions.

Yours truly,

McElhanney Ltd.

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APPENDIX A – STATEMENT OF LIMITATIONS

Statement of Limitations

Use of this Report. This report was prepared by McElhanney Ltd. ("**McElhanney**") for the particular site, design objective, development and purpose (the "**Project**") described in this report and for the exclusive use of the client identified in this report (the "**Client**"). The data, interpretations and recommendations pertain to the Project and are not applicable to any other project or site location and this report may not be reproduced, used or relied upon, in whole or in part, by a party other than the Client, without the prior written consent of McElhanney. The Client may provide copies of this report to its affiliates, contractors, subcontractors and regulatory authorities for use in relation to and in connection with the Project provided that any reliance, unauthorized use, and/or decisions made based on the information contained within this report are at the sole risk of such parties. McElhanney will not be responsible for the use of this report on projects other than the Project, where this report or the contents hereof have been modified without McElhanney's consent, to the extent that the content is in the nature of an opinion, and if the report is preliminary or draft. This is a technical report and is not a legal representation or interpretation of laws, rules, regulations, or policies of governmental agencies.

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Information from Client and Third Parties. McElhanney has relied in good faith on information provided by the Client and third parties noted in this report and has assumed such information to be accurate, complete, reliable, non-fringing, and fit for the intended purpose without independent verification. McElhanney accepts no responsibility for any deficiency, misstatements or inaccuracy contained in this report as a result of omissions or errors in information provided by third parties or for omissions, misstatements or fraudulent acts of persons interviewed.

Effect of Changes. All evaluations and conclusions stated in this report are based on facts, observations, site-specific details, legislation and regulations as they existed at the time of the report preparation. Some conditions are subject to change over time and the Client recognizes that the passage of time, natural occurrences, and direct or indirect human intervention in the study area may substantially alter such evaluations and conclusions. Construction activities can significantly alter flooding conditions in the area. McElhanney should be requested to re-evaluate the conclusions of this report and to provide amendments as required prior to any reliance upon the information presented herein upon any of the following events: a) any changes (or possible changes) to the study area upon which this report was based, b) any changes to applicable laws subsequent to the issuance of the report, or c) new information is discovered in the future.

Independent Judgments. McElhanney will not be responsible for the independent conclusions, interpretations, interpolations and/or decisions of the Client, or others, who may come into possession of this report, or any part thereof. This restriction of liability includes decisions made to purchase, finance or sell land or with respect to public offerings for the sale of securities.

APPENDIX B – FLOOD FREQUENCY ANALYSIS

08EF001 - Annual	Skeena at Usk				Watershed Area:	Published:	42300	
						Measured:	42300	
INSTANTANEOUS					Flow (m^3/s)			
Prob of Non-exceedance	Return Period	GEV	3-Parm Log-Normal	Log Pearson III	Wakeby	Generalized Logistic	Weibull	Gumbel
0.5	2	4773	4777	4783	4845	4788	4777	4696
0.8	5	5869	5861	5863	5768	5779	5904	5803
0.9	10	6524	6509	6502	6375	6428	6539	6536
0.95	20	7105	7091	7071	7020	7075	7079	7238
0.96	25	7280	7270	7244	7239	7288	7239	7461
0.98	50	7794	7802	7759	7955	7970	7701	8148
0.99	100	8266	8312	8246	8730	8693	8123	8830
0.995	200	8703	8804	8714	9570	9465	8512	9509
0.998	500	9231	9436	9307	10788	10569	8988	10405
0.999	1000	9597	9905	9742	11798	11475	9324	11083

AVERAGE DAILY					Flow (m^3/s)			
Prob of Non-exceedance	Return Period	GEV	3-Parm Log-Normal	Log Pearson III	Wakeby	Generalized Logistic	Weibull	Gumbel
0.5	2	4650	4654	4660	4720	4666	4653	4584
0.8	5	5725	5719	5720	5626	5638	5762	5667
0.9	10	6375	6362	6355	6227	6280	6393	6384
0.95	20	6957	6943	6925	6870	6924	6932	7072
0.96	25	7133	7122	7099	7089	7136	7092	7290
0.98	50	7653	7658	7620	7807	7821	7555	7962
0.99	100	8136	8172	8117	8589	8550	7979	8629
0.995	200	8586	8671	8597	9442	9331	8371	9293
0.998	500	9136	9315	9211	10687	10457	8851	10170
0.999	1000	9521	9794	9664	11727	11386	9191	10833

ANNUAL RECORDS								
Station Number	Year	Annual Ave Daily	Instantaneous	Inst. Used	Emp Prob	Rank	Count	I/D ratio
08EF001	2018	4640	4710	4710.0	0.5469	47	85	1.02
08EF001	2017	5730	5920	5920.0	0.1831	16		1.03
08EF001	2016	2530	2560	2560.0	0.9930	85		1.01
08EF001	2015	5030	5090	5090.0	0.4413	38		1.01
08EF001	2014	4040	4210	4210.0	0.6878	59		1.04
08EF001	2013	3780	3860	3860.0	0.7934	68		1.02
08EF001	2012	6060	6130	6130.0	0.1244	11		1.01
08EF001	2011	5070	5120	5120.0	0.4178	36		1.01
08EF001	2010	3150	3180	3180.0	0.9343	80		1.01
08EF001	2009	5470	5560	5560.0	0.2535	22		1.02
08EF001	2008	4860	4930	4930.0	0.4765	41		1.01
08EF001	2007	7550	7620	7620.0	0.0305	3		1.01
08EF001	2006	4860	5240	5240.0	0.3474	30		1.08
08EF001	2005	3920	3980	3980.0	0.7700	66		1.02
08EF001	2004	3350	3390	3390.0	0.9108	78		1.01
08EF001	2003	3970	4040	4040.0	0.7347	63		1.02
08EF001	2002	6190	6270	6270.0	0.1009	9		1.01
08EF001	2001	4180	4230	4230.0	0.6761	58		1.01
08EF001	2000	4090	4180	4180.0	0.7230	62		1.02
08EF001	1999	6440	6580	6580.0	0.0775	7		1.02
08EF001	1998	5300	5400	5400	0.3005	26		1.02
08EF001	1997	5060	5220	5220	0.3592	31		1.03
08EF001	1996	4790	4840	4840	0.5117	44		1.01
08EF001	1995	4370	4410	4410.0	0.6174	53		1.01
08EF001	1994	3730	3830	3830	0.8052	69		1.03
08EF001	1993	5770	5980	5980	0.1479	13		1.04
08EF001	1992	5960	6030	6030	0.1362	12		1.01
08EF001	1991	5310	5530	5530	0.2653	23		1.04
08EF001	1990	5840	5980	5980	0.1479	13		1.02
08EF001	1989	3640	3820	3820	0.8169	70		1.05
08EF001	1988	5230	5480	5480	0.2887	25		1.05
08EF001	1987	4090	4200	4200	0.6995	60		1.03
08EF001	1986	5190	5380	5380	0.3122	27		1.04
08EF001	1985	5310	5490	5490	0.2770	24		1.03
08EF001	1984	3510	3550	3550	0.8756	75		1.01
08EF001	1983	4930	5140	5140	0.3826	33		1.04
08EF001	1982	4880	4950	4950	0.4648	40		1.01
08EF001	1981	5600	5710	5710	0.2300	20		1.02
08EF001	1980	3260	3290	3290	0.9225	79		1.01
08EF001	1979	3980	4190	4190	0.7113	61		1.05
08EF001	1978	3940	4250	4250	0.6526	56		1.08
08EF001	1977	3090	3140	3140	0.9460	81		1.02
08EF001	1976	6230	6340	6340	0.0892	8		1.02
08EF001	1975	3540	3600	3600	0.8521	73		1.02
08EF001	1974	5640	5920	5920	0.1831	16		1.05
08EF001	1973	4640	4670	4670	0.5587	48		1.01
08EF001	1972	7790	8100	8100	0.0188	2		1.04
08EF001	1971	4900	5130	5130	0.4061	35		1.05
08EF001	1970	5130	5320	5320	0.3357	29		1.04
08EF001	1969	4500	4640	4640	0.5704	49		1.03
08EF001	1968	5520	5720	5720	0.2066	18		1.04
08EF001	1967	5580	5640	5640	0.2418	21		1.01
08EF001	1966	4760	4900	4900	0.4883	42		1.03
08EF001	1965	4760	4810	4810	0.5352	46		1.01
08EF001	1964	7480	7530	7530	0.0423	4		1.01
08EF001	1963	4190	4250	4250	0.6526	56		1.01
08EF001	1962	4670	4840	4840	0.5117	44		1.04
08EF001	1961	5970	6140	6140	0.1127	10		1.03
08EF001	1960	4560	4640	4640	0.5704	49		1.02
08EF001	1959	4280	4360	4360	0.6291	54		1.02
08EF001	1958	5660	5720	5720	0.2066	18		1.01
08EF001	1957	6650	6800	6800	0.0540	5		1.02
08EF001	1956	3480		3571.47	0.8638	74		
08EF001	1955	5100	5180	5180	0.3709	32		1.02
08EF001	1954	5920	5970	5970	0.1714	15		1.01
08EF001	1953	5010	5100	5100	0.4296	37		
08EF001	1952	4190		4295.18	0.6408	55		
08EF001	1951	4360		4468.46	0.5939	51		
08EF001	1950	6540		6690.55	0.0657	6		
08EF001	1949	3790		3887.46	0.7817	67		
☺	1948	9340		9544.62	0.0070	1		
08EF001	1946	5240		5365.45	0.3239	28		
08EF001	1945	4960		5080.05	0.4531	39		
08EF001	1944	2890		2970.08	0.9812	84		
08EF001	1943	2920		3000.66	0.9695	83		
08EF001	1942	3910		4009.77	0.7465	64		
08EF001	1941	3030		3112.78	0.9577	82		
08EF001	1940	3540		3632.63				
08EF001	1939	3340		3428.77	0.8991	77		
08EF001	1938	3450		3540.89	0.8873	76		
08EF001	1937	4330		4437.88	0.6056	52		
08EF001	1931	4730		4845.61	0.5000	43		
08EF001	1930	5010		5131.01	0.3944	34		
08EF001	1929	3620		3714.17	0.8286	71		
08EF001	1928	3910		4009.77	0.7465	64		

08EF001 - Spring	Skeena at Usk				Watershed Area:	Published:	42300	
						Measured:	42300	

INSTANTANEOUS				Flow (m³/s)				
Prob of Non-exceedance	Return Period	GEV	3-Parm Log-Normal	Log Pearson III	Wakeby	Generalized Logistic	Weibull	Gumbel
0.5	2	4696	4699	4703	4762	4713	4698	
0.8	5	5809	5805	5805	5730	5721	5852	
0.9	10	6492	6480	6475	6360	6392	6514	
0.95	20	7109	7095	7085	7023	7071	7084	
0.96	25	7297	7285	7273	7246	7296	7254	
0.98	50	7856	7856	7837	7974	8023	7746	
0.99	100	8381	8407	8381	8756	8803	8198	
0.995	200	8875	8945	8910	9596	9644	8617	
0.998	500	9486	9642	9594	10805	10865	9131	
0.999	1000	9918	10163	10104	11799	11879	9496	

AVERAGE DAILY				Flow (m³/s)				
Prob of Non-exceedance	Return Period	GEV	3-Parm Log-Normal	Log Pearson III	Wakeby	Generalized Logistic	Weibull	Gumbel
0.5	2	4582	4585	5012	4644	4599	4583	
0.8	5	5673	5671	6310	5596	5588	5718	
0.9	10	6348	6339	6310	6225	6250	6374	
0.95	20	6963	6950	6310	6887	6924	6941	
0.96	25	7152	7139	7943	7109	7147	7109	
0.98	50	7714	7710	7943	7830	7873	7600	
0.99	100	8244	8263	7943	8603	8654	8051	
0.995	200	8747	8804	7943	9429	9500	8471	
0.998	500	9374	9508	10000	10611	10733	8987	
0.999	1000	9822	10036	10000	11578	11763	9354	

ANNUAL RECORDS

Station Number	Year	Annual Ave Daily	Instantaneous	Inst. Used	Emp Prob	Rank	Count	I/D ratio
08EF001	2018	4640	4710	4710	0.5235	45	85	1.02
08EF001	2017	5730	5920	5920	0.1831	16		1.03
08EF001	2016	2530	2560	2560	0.9930	85		1.01
08EF001	2015	5030	5090	5090	0.4178	36		1.01
08EF001	2014	4040	4210	4210	0.6526	56		1.04
08EF001	2013	3780	3860	3860	0.7700	66		1.02
08EF001	2012	6060	6130	6130	0.1244	11		1.01
08EF001	2011	5070	5120	5120	0.3944	34		1.01
08EF001	2010	3150	3180	3180	0.9225	79		1.01
08EF001	2009	5470	5560	5560	0.2418	21		1.02
08EF001	2008	4860	4930	4930	0.4531	39		1.01
08EF001	2007	7550	7620	7620	0.0305	3		1.01
08EF001	2006	4860	5240	5240	0.3239	28		1.08
08EF001	2005	3920	3980	3980	0.7465	64		1.02
08EF001	2004	3350	3390	3390	0.8991	77		1.01
08EF001	2003	3970	4040	4040	0.6995	60		1.02
08EF001	2002	6190	6270	6270	0.1009	9		1.01
08EF001	2001	4180	4230	4230	0.6408	55		1.01
08EF001	2000	4090	4180	4180	0.6878	59		1.02
08EF001	1999	6440	6580	6580	0.0775	7		1.02
08EF001	1998	5300	5400	5400	0.2770	24		1.02
08EF001	1997	5060	5220	5220	0.3357	29		1.03
08EF001	1996	4790	4840	4840	0.4883	42		1.01
08EF001	1995	4370	4410	4410	0.5939	51		1.01
08EF001	1994	3730	3830	3830	0.7934	68		1.03
08EF001	1993	5770	5980	5980	0.1479	13		1.04
08EF001	1992	5960	6030	6030	0.1362	12		1.01
08EF001	1991	3030		3113	0.9460	81		0.00
08EF001	1990	5840	5980	5980	0.1479	13		1.02
08EF001	1989	3640	3820	3820	0.8052	69		1.05
08EF001	1988	5230	5480	5480	0.2653	23		1.05
08EF001	1987	4090	4200	4200	0.6643	57		1.03
08EF001	1986	5190	5380	5380	0.2887	25		1.04
08EF001	1985	5310	5490	5490	0.2535	22		1.03
08EF001	1984	3510	3550	3550	0.8638	74		1.01
08EF001	1983	4930	5140	5140	0.3592	31		1.04
08EF001	1982	4880	4950	4950	0.4413	38		1.01
08EF001	1981	5600	5710	5710	0.2183	19		1.02
08EF001	1980	3260	3290	3290	0.9108	78		1.01
08EF001	1979	3980	4190	4190	0.6761	58		1.05
08EF001	1978	3740		3836	0.7817	67		0.00
08EF001	1977	3090	3140	3140	0.9343	80		1.02
08EF001	1976	6230	6340	6340	0.0892	8		1.02
08EF001	1975	3540	3600	3600	0.8404	72		1.02
08EF001	1974	3910		4010	0.7113	61		0.00
08EF001	1973	4640	4670	4670	0.5352	46		1.01
08EF001	1972	7790	8100	8100	0.0188	2		1.04
08EF001	1971	4900	5130	5130	0.3826	33		1.05
08EF001	1970	5130	5320	5320	0.3122	27		1.04
08EF001	1969	4500	4640	4640	0.5469	47		1.03
08EF001	1968	5520	5720	5720	0.1948	17		1.04
08EF001	1967	5580	5640	5640	0.2300	20		1.01
08EF001	1966	4760	4900	4900	0.4648	40		1.03
08EF001	1965	4760	4810	4810	0.5117	44		1.01
08EF001	1964	7480	7530	7530	0.0423	4		1.01
08EF001	1963	4190	4250	4250	0.6291	54		1.01
08EF001	1962	4670	4840	4840	0.4883	42		1.04
08EF001	1961	5970	6140	6140	0.1127	10		1.03
08EF001	1960	4560	4640	4640	0.5469	47		1.02
08EF001	1959	4280	4360	4360	0.6056	52		1.02
08EF001	1958	5660	5720	5720	0.1948	17		1.01
08EF001	1957	6650	6800	6800	0.0540	5		1.02
08EF001	1956	3480		3571	0.8521	73		
08EF001	1955	5100	5180	5180	0.3474	30		1.02
08EF001	1954	5920	5970	5970	0.1714	15		1.01
08EF001	1953	5010	5100	5100	0.4061	35		
08EF001	1952	4190		4295	0.6174	53		
08EF001	1951	4360		4468	0.5704	49		
08EF001	1950	6540		6691	0.0657	6		
08EF001	1949	3790		3887	0.7582	65		
☺	1948	9340		9545	0.0070	1		
08EF001	1946	5240		5365	0.3005	26		
08EF001	1945	4960		5080	0.4296	37		
08EF001	1944	2890		2970	0.9812	84		
08EF001	1943	2920		3001	0.9695	83		
08EF001	1942	3910		4010	0.7113	61		
08EF001	1941	3030		3113	0.9460	81		
08EF001	1940	3540		3633				
08EF001	1939	3340		3429	0.8873	76		
08EF001	1938	3450		3541	0.8756	75		
08EF001	1937	4330		4438	0.5822	50		
08EF001	1931	4730		4846	0.4765	41		
08EF001	1930	5010		5131	0.3709	32		
08EF001	1929	3620		3714	0.8169	70		
08EF001	1928	3910		4010	0.7113	61		

08EF001 - Fall	Skeena at Usk				Watershed Area:	Published:	42300	
						Measured:	42300	

INSTANTANEOUS				Flow (m³/s)				
Prob of Non-exceedance	Return Period	GEV	3-Parm Log-Normal	Log Pearson III	Wakeby	Generalized Logistic	Weibull	Gumbel
0.5	2	1753	1748	1769	1762	1768	1737	
0.8	5	2515	2536	2543	2459	2470	2589	
0.9	10	3080	3107	3087	3044	3010	3165	
0.95	20	3674	3689	3631	3689	3615	3706	
0.96	25	3873	3880	3809	3910	3828	3874	
0.98	50	4524	4490	4370	4642	4564	4383	
0.99	100	5227	5127	4951	5448	5429	4874	
0.995	200	5991	5795	5555	6336	6454	5350	
0.998	500	7102	6730	6396	7650	8108	5960	
0.999	1000	8029	7480	7066	8762	9636	6409	

AVERAGE DAILY				Flow (m³/s)				
Prob of Non-exceedance	Return Period	GEV	3-Parm Log-Normal	Log Pearson III	Wakeby	Generalized Logistic	Weibull	Gumbel
0.5	2	1696	1691	1585	1705	1711	1680	
0.8	5	2443	2464	2512	2389	2400	2517	
0.9	10	2998	3025	3162	2963	2929	3081	
0.95	20	3581	3595	3162	3595	3523	3612	
0.96	25	3776	3783	3981	3812	3732	3777	
0.98	50	4415	4381	3981	4530	4454	4276	
0.99	100	5105	5006	5012	5321	5303	4758	
0.995	200	5854	5662	5012	6193	6308	5225	
0.998	500	6945	6579	6310	7482	7931	5824	
0.999	1000	7854	7315	6310	8573	9431	6265	

ANNUAL RECORDS								
Station Number	Year	Annual Ave Daily	Instantaneous	Inst. Used	Emp Prob	Rank	Count	I/D ratio
08EF001	2018	524		558	0.9931	87	87	0.00
08EF001	2017	2490		2562	0.1904	17		0.00
08EF001	2016	2000		2063	0.3165	28		0.00
08EF001	2015	2770		2848	0.1216	11		0.00
08EF001	2014	2330		2399	0.2362	21		0.00
08EF001	2013	1160		1207	0.8326	73		0.00
08EF001	2012	1360		1411	0.7179	63		0.00
08EF001	2011	2510		2583	0.1674	15		0.00
08EF001	2010	1720		1777	0.5229	46		0.00
08EF001	2009	1400		1451	0.6835	60		0.00
08EF001	2008	1040		1084	0.8784	77		0.00
08EF001	2007	1890		1951	0.3853	34		0.00
08EF001	2006	999		1043	0.8899	78		0.00
08EF001	2005	1230		1278	0.7982	70		0.00
08EF001	2004	2100		2165	0.2936	26		0.00
08EF001	2003	3380		3470	0.0642	6		0.00
08EF001	2002	2140		2206	0.2821	25		0.00
08EF001	2001	1870		1930	0.4197	37		0.00
08EF001	2000	2360		2430	0.2248	20		0.00
08EF001	1999	2170		2236	0.2706	24		0.00
08EF001	1998	1300		1349	0.7638	67		0.00
08EF001	1997	1620		1676	0.6032	53		0.00
08EF001	1996	1960		2022	0.3280	29		0.00
08EF001	1995	676		713	0.9817	86		0.00
08EF001	1994	1880		1941	0.3968	35		0.00
08EF001	1993	1410		1461	0.6720	59		0.00
08EF001	1992	3190		3276	0.0872	8		0.00
08EF001	1991	5310	5530	5530	0.0183	2		1.04
08EF001	1990	727		765	0.9702	85		0.00
08EF001	1989	1180		1227	0.8211	72		0.00
08EF001	1988	2890		2970	0.1101	10		0.00
08EF001	1987	3010		3092	0.0986	9		0.00
08EF001	1986	2700		2776	0.1330	12		0.00
08EF001	1985	1100		1146	0.8555	75		0.00
08EF001	1984	1830		1890	0.4541	40		0.00
08EF001	1983	1550		1604	0.6147	54		0.00
08EF001	1982	1450		1502	0.6606	58		0.00
08EF001	1981	1340		1390	0.7408	65		0.00
08EF001	1980	2620		2695	0.1560	14		0.00
08EF001	1979	1660		1716	0.5573	49		0.00
08EF001	1978	3940	4250	4250	0.0298	3		1.08
08EF001	1977	1330		1380	0.7523	66		0.00
08EF001	1976	1710		1767	0.5344	47		0.00
08EF001	1975	946		989	0.9358	82		0.00
08EF001	1974	5640	5920	5920	0.0069	1		1.05
08EF001	1973	1750		1808	0.5000	44		0.00
08EF001	1972	1680		1737	0.5459	48		0.00
08EF001	1971	2040		2104	0.3050	27		0.00
08EF001	1970	1240		1288	0.7867	69		0.00
08EF001	1969	1480		1533	0.6261	55		0.00
08EF001	1968	1480		1533	0.6261	55		0.00
08EF001	1967	2380		2450	0.2133	19		0.00
08EF001	1966	1920		1981	0.3509	31		0.00
08EF001	1965	1780		1839	0.4885	43		0.00
08EF001	1964	3790		3887	0.0528	5		0.00
08EF001	1963	1480		1533	0.6261	55		0.00
08EF001	1962	2510		2583	0.1674	15		0.00
08EF001	1961	3880		3979	0.0413	4		0.00
08EF001	1960	1930		1992	0.3394	30		0.00
08EF001	1959	1840		1900	0.4427	39		0.00
08EF001	1958	2410		2481	0.2018	18		0.00
08EF001	1957	1800		1859	0.4771	42		
08EF001	1956	1400		1451	0.6835	60		0.00
08EF001	1955	1140		1186	0.8440	74		0.00
08EF001	1954	1850		1910	0.4312	38		
08EF001	1953	1640		1696	0.5803	51		
08EF001	1952	1730		1788	0.5115	45		
08EF001	1951	1830		1890	0.4541	40		
08EF001	1950	2280		2348	0.2592	23		
08EF001	1949	1910		1971	0.3739	33		
08EF001	1948	1880		1941	0.3968	35		
08EF001	1947	1640		1696	0.5803	51		
08EF001	1946	736		774	0.9587	84		
08EF001	1945	2690		2766	0.1445	13		
08EF001	1944	1390		1441	0.7064	62		
08EF001	1943	997		1041	0.9014	79		
08EF001	1942	1230		1278				
08EF001	1941	1360		1411	0.7179	63		
08EF001	1940	1920		1981	0.3509	31		
08EF001	1939	2290		2358	0.2477	22		
08EF001	1938	974		1017	0.9128	80		
08EF001	1937	949		992	0.9243	81		
08EF001	1936	3260		3347	0.0757	7		
08EF001	1931	1090		1135	0.8670	76		
08EF001	1930	1260		1309	0.7752	68		
08EF001	1929	1660		1716	0.5573	49		
08EF001	1928	796		836	0.9472	83		

08EF005 - Annual	Zymoetz (Copper) River above OK Creek			Watershed Area:		Published:	2850	
						Measured:	2918	

INSTANTANEOUS				Flow (m^3/s)				
Prob of Non-exceedance	Return Period	GEV	3-Parm Log-Normal	Log Pearson III	Wakeby	Generalized Logistic	Weibull	Gumbel
0.5	2	702	685	680	686	707	665	831
0.8	5	1079	1110	1106	1115	1072	1155	1304
0.9	10	1463	1551	1574	1543	1440	1645	1617
0.95	20	1981	2117	2225	2085	1941	2219	1917
0.96	25	2185	2330	2485	2289	2141	2419	2012
0.98	50	2969	3096	3496	3034	2922	3089	2305
0.99	100	4048	4044	4904	3979	4023	3822	2596
0.995	200	5534	5203	6867	5179	5581	4615	2886
0.998	500	8398	7111	10692	7276	8683	5749	3269
0.999	1000	11536	8888	14925	9367	12194	6666	3558

AVERAGE DAILY				Flow (m^3/s)				
Prob of Non-exceedance	Return Period	GEV	3-Parm Log-Normal	Log Pearson III	Wakeby	Generalized Logistic	Weibull	Gumbel
0.5	2	576	567	568	566	580	556	643
0.8	5	815	833	837	830	809	860	924
0.9	10	1046	1089	1099	1082	1029	1137	1110
0.95	20	1342	1401	1430	1390	1316	1446	1289
0.96	25	1456	1515	1554	1503	1428	1551	1345
0.98	50	1878	1916	2008	1904	1855	1894	1520
0.99	100	2434	2394	2585	2395	2435	2258	1693
0.995	200	3166	2959	3319	2995	3227	2642	1865
0.998	500	4505	3858	4603	3998	4739	3178	2092
0.999	1000	5899	4668	5884	4955	6382	3602	2264

ANNUAL RECORDS								
Station Number	Year	Annual Ave Daily	Instantaneous	Inst. Used	Emp Prob	Rank	Count	I/D ratio
08EF005	2017	1670	2450	2450	0.0471	3	55	1.47
08EF005	2016	583	893	893	0.2826	16		1.53
08EF005	2015	700		926.41	0.2283	13		0.00
08EF005	2014	530	561	561	0.7174	40		1.06
08EF005	2013	478	535	535	0.8261	46		1.12
08EF005	2012	810	920	920	0.2464	14		1.14
08EF005	2011	628	1050	1050	0.1739	10		1.67
08EF005	2010	412	551	551	0.7536	42		1.34
08EF005	2009	630	711	711	0.4457	25		1.13
08EF005	2008	555	611	611	0.6268	35		1.10
08EF005	2007	817	901	901	0.2645	15		1.10
08EF005	2006	417	470	470	0.9529	53		1.13
08EF005	2005	449	519	519	0.8442	47		1.16
08EF005	2004	606	807	807	0.3551	20		1.33
08EF005	2003	472	666	666	0.5000	28		1.41
08EF005	2002	795	1130	1130	0.1558	9		1.42
08EF005	2001	427	491	491	0.8986	50		1.15
08EF005	2000	539	646	646	0.5543	31		1.20
08EF005	1999	802	849	849	0.3370	19		1.06
08EF005	1998	611	683	683	0.4638	26		1.12
08EF005	1997	581	755	755	0.4275	24		1.30
08EF005	1996	537	562	562	0.6812	38		1.05
08EF005	1995	510	552	552	0.7355	41		1.08
08EF005	1994	449	545	545	0.7717	43		1.21
08EF005	1993	1090	2180	2180	0.0833	5		2.00
08EF005	1992	1380	1650	1650	0.1377	8		1.20
08EF005	1991	1810	2250	2250	0.0652	4		1.24
08EF005	1990	521	543	543	0.7899	44		1.04
08EF005	1989	544	1020	1020	0.1920	11		1.88
08EF005	1988	1280	2080	2080	0.1014	6		1.63
08EF005	1987	819	1020	1020	0.1920	11		1.25
08EF005	1986	690	804	804	0.3732	21		1.17
08EF005	1985	539	562	562	0.6812	38		1.04
08EF005	1984	444	541	541	0.8080	45		1.22
08EF005	1983	425	483	483	0.9348	52		1.14
08EF005	1982	538	593	593	0.6449	36		1.10
08EF005	1981	538	638	638	0.5725	32		1.19
08EF005	1980	453	513	513	0.8623	48		1.13
08EF005	1979	465	513	513	0.8623	48		1.10
08EF005	1978	1980	3140	3140	0.0109	1		1.59
08EF005	1977	385	578	578	0.6630	37		1.50
08EF005	1976	572	799	799	0.3913	22		1.40
08EF005	1975	439	464	464	0.9710	54		1.06
08EF005	1974	1470	2940	2940	0.0290	2		2.00
08EF005	1973	453	490	490	0.9167	51		1.08
08EF005	1972	694	855	855	0.3007	17		1.23
08EF005	1971	566	651	651	0.5181	29		1.15
08EF005	1970	552	629	629	0.5906	33		1.14
08EF005	1969	566	651	651	0.5181	29		1.15
08EF005	1968	631	677	677	0.4819	27		1.07
08EF005	1967	538	620	620	0.6087	34		1.15
08EF005	1966	1250	1940	1940	0.1196	7		1.55
08EF005	1965	646	850	850	0.3188	18		1.32
08EF005	1964	694	776	776	0.4094	23		1.12
08EF005	1963	283	326	326	0.9891	55		1.15

08EF005-Spring	Zymoetz (Copper) River above OK Creek				Watershed Area:	Published:	2850	
						Measured:	2918	

INSTANTANEOUS				Flow (m^3/s)				
Prob of Non-exceedance	Return Period	GEV	3-Parm Log-Normal	Log Pearson III	Wakeby	Generalized Logistic	Weibull	Gumbel
0.5	2	599	599	598	595	602	598	
0.8	5	720	722	723	739	712	730	
0.9	10	805	807	813	825	794	815	
0.95	20	891	892	903	895	883	893	
0.96	25	919	919	933	915	914	917	
0.98	50	1009	1004	1028	969	1019	989	
0.99	100	1103	1092	1128	1014	1139	1057	
0.995	200	1201	1182	1233	1050	1278	1122	
0.998	500	1337	1305	1381	1089	1496	1205	
0.999	1000	1447	1402	1502	1112	1691	1265	

AVERAGE DAILY				Flow (m^3/s)				
Prob of Non-exceedance	Return Period	GEV	3-Parm Log-Normal	Log Pearson III	Wakeby	Generalized Logistic	Weibull	Gumbel
0.5	2	553	553	501	548	555	552	
0.8	5	659	660	631	668	651	666	
0.9	10	731	732	794	743	721	737	
0.95	20	801	801	794	807	795	801	
0.96	25	824	823	794	826	820	820	
0.98	50	894	891	1000	877	905	878	
0.99	100	965	960	1000	921	1000	932	
0.995	200	1037	1029	1000	958	1108	983	
0.998	500	1135	1122	1259	999	1272	1048	
0.999	1000	1210	1195	1259	1024	1417	1094	

ANNUAL RECORDS								
Station Number	Year	Annual Ave Daily	Instantaneous	Inst. Used	Emp Prob	Rank	Count	I/D ratio
08EF005	2017	593		661	0.2325	13	54	0.00
08EF005	2016	299		334	0.9889	54		0.00
08EF005	2015	581		648	0.2694	15		0.00
08EF005	2014	530	561	561	0.4908	27		1.06
08EF005	2013	478	535	535	0.5646	31		1.12
08EF005	2012	810	920	920	0.0111	1		1.14
08EF005	2011	543		606	0.4170	23		0.00
08EF005	2010	358		400	0.9520	52		0.00
08EF005	2009	630	711	711	0.1587	9		1.13
08EF005	2008	555	611	611	0.3985	22		1.10
08EF005	2007	817	901	901	0.0295	2		1.10
08EF005	2006	417	470	470	0.8413	46		1.13
08EF005	2005	449	519	519	0.5830	32		1.16
08EF005	2004	353		394	0.9705	53		0.00
08EF005	2003	458		511	0.6384	35		0.00
08EF005	2002	795		886	0.0480	3		0.00
08EF005	2001	427	491	491	0.7122	39		1.15
08EF005	2000	412		460	0.8967	49		0.00
08EF005	1999	802	849	849	0.0664	4		1.06
08EF005	1998	611	683	683	0.1956	11		1.12
08EF005	1997	581	755	755	0.1402	8		1.30
08EF005	1996	537	562	562	0.4539	25		1.05
08EF005	1995	510	552	552	0.5092	28		1.08
08EF005	1994	425		474	0.8229	45		0.00
08EF005	1993	637		710	0.1771	10		0.00
08EF005	1992	564		629	0.3432	19		0.00
08EF005	1991	442		493	0.6937	38		0.00
08EF005	1990	521	543	543	0.5461	30		1.04
08EF005	1989	459		512	0.6199	34		0.00
08EF005	1988	492		549	0.5277	29		0.00
08EF005	1987	457		510	0.6568	36		0.00
08EF005	1986	690	804	804	0.0849	5		1.17
08EF005	1985	539	562	562	0.4539	25		1.04
08EF005	1984	363		405	0.9336	51		0.00
08EF005	1983	425	483	483	0.7491	41		1.14
08EF005	1982	538	593	593	0.4354	24		1.10
08EF005	1981	538	638	638	0.3063	17		1.19
08EF005	1980	413		461	0.8782	48		0.00
08EF005	1979	465	513	513	0.6015	33		1.10
08EF005	1978	430		480	0.7675	42		0.00
08EF005	1977	453		506	0.6753	37		0.00
08EF005	1976	572		638	0.2878	16		0.00
08EF005	1975	439	464	464	0.8598	47		1.06
08EF005	1974	411		459	0.9151	50		0.00
08EF005	1973	453	490	490	0.7306	40		1.08
08EF005	1972	694		774	0.1218	7		0.00
08EF005	1971	566		631	0.3247	18		0.00
08EF005	1970	552	629	629	0.3616	20		1.14
08EF005	1969	566	651	651	0.2509	14		1.15
08EF005	1968	631	677	677	0.2140	12		1.07
08EF005	1967	538	620	620	0.3801	21		1.15
08EF005	1966	430		480	0.7675	42		0.00
08EF005	1965	428		478	0.8044	44		0.00
08EF005	1964	694	776	776	0.1033	6		1.12

08EF005 - Fall	Zymoetz (Copper) River above OK Creek				Watershed Area:	Published:	2850	
						Measured:	2918	

INSTANTANEOUS — Flow (m^3/s)

Prob of Non-exceedance	Return Period	GEV	3-Parm Log-Normal	Log Pearson III	Wakeby	Generalized Logistic	Weibull	Gumbel
0.5	2	995	984	949	966	1008	966	
0.8	5	1676	1708	1692	1769	1645	1768	
0.9	10	2239	2294	2391	2374	2179	2373	
0.95	20	2882	2933	3257	2977	2816	2976	
0.96	25	3109	3151	3579	3171	3050	3171	
0.98	50	3894	3875	4734	3772	3887	3774	
0.99	100	4814	4670	6170	4372	4930	4376	
0.995	200	5894	5542	7951	4970	6237	4978	
0.998	500	7622	6825	10967	5758	8490	5774	
0.999	1000	9201	7900	13874	6353	10709	6375	

AVERAGE DAILY — Flow (m^3/s)

Prob of Non-exceedance	Return Period	GEV	3-Parm Log-Normal	Log Pearson III	Wakeby	Generalized Logistic	Weibull	Gumbel
0.5	2	688	681	631	670	695	670	
0.8	5	1098	1117	1000	1153	1079	1154	
0.9	10	1439	1473	1585	1520	1403	1522	
0.95	20	1830	1863	1995	1889	1790	1890	
0.96	25	1969	1996	2512	2009	1933	2009	
0.98	50	2450	2440	3162	2381	2444	2379	
0.99	100	3017	2929	3981	2754	3084	2749	
0.995	200	3686	3467	5012	3130	3888	3120	
0.998	500	4762	4261	6310	3630	5281	3611	
0.999	1000	5751	4928	7943	4011	6659	3983	

ANNUAL RECORDS

Station Number	Year	Annual Ave Daily	Instantaneous	Inst. Used	Emp Prob	Rank	Count	I/D ratio
08EF005	2017	1670	2450	2450	0.0471	3	55	1.47
08EF005	2016	583	893	893	0.2464	14		1.53
08EF005	2015	700		1053	0.1739	10		0.00
08EF005	2014	437		649	0.4275	24		0.00
08EF005	2013	234		337	0.8261	46		0.00
08EF005	2012	446		663	0.3913	22		0.00
08EF005	2011	628	1050	1050	0.1920	11		1.67
08EF005	2010	412	551	551	0.5725	32		1.34
08EF005	2009	426		632	0.4819	27		0.00
08EF005	2008	209		299	0.8986	50		0.00
08EF005	2007	348		512	0.6630	37		0.00
08EF005	2006	124		168	0.9710	54		0.00
08EF005	2005	253		366	0.8080	45		0.00
08EF005	2004	606	807	807	0.3188	18		1.33
08EF005	2003	472	666	666	0.3732	21		1.41
08EF005	2002	786	1130	1130	0.1558	9		1.44
08EF005	2001	279		406	0.7536	42		0.00
08EF005	2000	539	646	646	0.4457	25		1.20
08EF005	1999	272		396	0.7899	44		0.00
08EF005	1998	553		827	0.3007	17		0.00
08EF005	1997	343		505	0.6812	38		0.00
08EF005	1996	388		574	0.5362	30		0.00
08EF005	1995	167		234	0.9348	52		0.00
08EF005	1994	183	545	545	0.6087	34		2.98
08EF005	1993	1090	2180	2180	0.0833	5		2.00
08EF005	1992	1380	1650	1650	0.1377	8		1.20
08EF005	1991	1810	2250	2250	0.0652	4		1.24
08EF005	1990	178		251	0.9167	51		0.00
08EF005	1989	544	1020	1020	0.2101	12		1.88
08EF005	1988	1280	2080	2080	0.1014	6		1.63
08EF005	1987	819	1020	1020	0.2101	12		1.25
08EF005	1986	370		546	0.5906	33		0.00
08EF005	1985	155		216	0.9529	53		0.00
08EF005	1984	444	541	541	0.6268	35		1.22
08EF005	1983	309		452	0.7174	40		0.00
08EF005	1982	318		466	0.6993	39		0.00
08EF005	1981	278		405	0.7717	43		0.00
08EF005	1980	453	513	513	0.6449	36		1.13
08EF005	1979	423		627	0.5000	28		0.00
08EF005	1978	1980	3140	3140	0.0109	1		1.59
08EF005	1977	385	578	578	0.5181	29		1.50
08EF005	1976	552	799	799	0.3370	19		1.45
08EF005	1975	107		142	0.9891	55		0.00
08EF005	1974	1470	2940	2940	0.0290	2		2.00
08EF005	1973	309		452	0.7174	40		0.00
08EF005	1972	498	855	855	0.2645	15		1.72
08EF005	1971	496	651	651	0.4094	23		1.31
08EF005	1970	230		331	0.8442	47		0.00
08EF005	1969	459		683	0.3551	20		0.00
08EF005	1968	224		322	0.8804	49		0.00
08EF005	1967	428		635	0.4638	26		0.00
08EF005	1966	1250	1940	1940	0.1196	7		1.55
08EF005	1965	646	850	850	0.2826	16		1.32
08EF005	1964	374		552	0.5543	31		0.00
08EF005	1963	283	326	326	0.8623	48		1.15

Flood Frequency Analysis

08EG006 - Annual	Kitsumkalum River near Terrace				Watershed Area:	Published:	2180	
						Measured:	2190	

INSTANTANEOUS				Flow (m^3/s)				
Prob of Non-exceedance	Return Period	GEV	3-Parm Log-Normal	Log Pearson III	Wakeby	Generalized Logistic	Weibull	Gumbel
0.5	2	449	449	445	444	452	447	459
0.8	5	584	588	588	605	576	597	596
0.9	10	684	689	698	708	672	699	686
0.95	20	788	791	816	797	778	794	773
0.96	25	823	824	856	823	816	823	800
0.98	50	937	931	988	896	944	912	885
0.99	100	1059	1042	1134	960	1096	998	969
0.995	200	1192	1158	1294	1015	1274	1081	1053
0.998	500	1383	1321	1533	1077	1562	1187	1163
0.999	1000	1542	1451	1736	1117	1826	1265	1247

AVERAGE DAILY				Flow (m^3/s)				
Prob of Non-exceedance	Return Period	GEV	3-Parm Log-Normal	Log Pearson III	Wakeby	Generalized Logistic	Weibull	Gumbel
0.5	2	444	443	398	439	446	441	453
0.8	5	575	579	631	596	568	588	586
0.9	10	672	676	631	695	660	686	674
0.95	20	773	775	794	781	763	778	759
0.96	25	807	808	794	806	799	806	785
0.98	50	916	910	1000	876	924	892	868
0.99	100	1033	1017	1000	937	1069	975	950
0.995	200	1160	1129	1259	989	1241	1054	1031
0.998	500	1342	1284	1585	1046	1516	1157	1139
0.999	1000	1493	1409	1585	1083	1769	1232	1220

ANNUAL RECORDS								
Station Number	Year	Annual Ave Daily	Instantaneous	Inst. Used	Emp Prob	Rank	Count	I/D ratio
08EG006	1950	631	640	640	0.2072	5	22	1.01
08EG006	1949	351	354	354	0.7928	18		1.01
08EG006	1948	657	660	660	0.1171	3		1.00
08EG006	1947	535	544	544	0.3423	8		1.02
08EG006	1946	379	385	385	0.6126	14		1.02
08EG006	1945	646	691	691	0.0721	2		1.07
08EG006	1944	331	334	334	0.8829	20		1.01
08EG006	1943	323	326	326	0.9279	21		1.01
08EG006	1942	374	377	377	0.7027	16		1.01
08EG006	1941	385	385	385	0.6126	14		1.00
08EG006	1940	566	580	580	0.2523	6		1.02
08EG006	1939	510	518	518	0.3874	9		1.02
08EG006	1938	314		318.4	0.9730	22		
08EG006	1937	428	430	430	0.5225	12		1.00
08EG006	1936	883	883	883	0.0270	1		1.00
08EG006	1935	634		642.89	0.1622	4		
08EG006	1934	357		362	0.7477	17		
08EG006	1933	566		573.93	0.2973	7		
08EG006	1932	459	462	462	0.4324	10		1.01
08EG006	1931	447	450	450	0.4775	11		1.01
08EG006	1930	348	354	354	0.7928	18		1.02
08EG006	1929	388	396	396	0.5676	13		1.02

08EG006 - Spring	Kitsumkalum River near Terrace				Watershed Area:	Published:	2180	
						Measured:	2190	
INSTANTANEOUS				**Flow (m^3/s)**				
Prob of Non-exceedance	**Return Period**	**GEV**	**3-Parm Log-Normal**	**Log Pearson III**	**Wakeby**	**Generalized Logistic**	**Weibull**	**Gumbel**
0.5	2	380	377	376	376	382	373	
0.8	5	482	490	496	494	479	501	
0.9	10	578	595	610	600	571	614	
0.95	20	700	722	750	724	689	739	
0.96	25	746	768	802	768	735	781	
0.98	50	916	928	985	919	907	917	
0.99	100	1137	1117	1209	1095	1139	1061	
0.995	200	1423	1338	1484	1300	1452	1211	
0.998	500	1936	1685	1944	1623	2042	1418	
0.999	1000	2462	1995	2385	1915	2674	1581	

AVERAGE DAILY				Flow (m^3/s)				
Prob of Non-exceedance	**Return Period**	**GEV**	**3-Parm Log-Normal**	**Log Pearson III**	**Wakeby**	**Generalized Logistic**	**Weibull**	**Gumbel**
0.5	2	376	373	398	372	378	368	
0.8	5	478	485	501	489	475	496	
0.9	10	574	590	631	595	566	610	
0.95	20	695	717	794	719	684	734	
0.96	25	741	764	794	763	730	777	
0.98	50	912	924	1000	915	903	913	
0.99	100	1133	1113	1259	1092	1135	1057	
0.995	200	1420	1335	1585	1299	1450	1208	
0.998	500	1938	1685	1995	1626	2042	1417	
0.999	1000	2469	1997	2512	1922	2679	1581	

ANNUAL RECORDS

Station Number	Year	Annual Ave Daily	Instantaneous	Inst. Used	Emp Prob	Rank	Count	I/D ratio
08EG006	1951	328		332	0.7928	18	22	
08EG006	1950	631	640	640	0.1171	3		1.01
08EG006	1949	351	354	354	0.5676	13		1.01
08EG006	1948	657	660	660	0.0721	2		1.00
08EG006	1947	535	544	544	0.1622	4		1.02
08EG006	1946	379	385	385	0.3874	9		1.02
08EG006	1945	345		350	0.7027	16		
08EG006	1944	331	334	334	0.7477	17		1.01
08EG006	1943	323	326	326	0.8378	19		1.01
08EG006	1942	374	377	377	0.4775	11		1.01
08EG006	1941	385	385	385	0.3874	9		1.00
08EG006	1940	320		324	0.8829	20		
08EG006	1939	510	518	518	0.2072	5		
08EG006	1938	314		318	0.9279	21		
08EG006	1937	428	430	430	0.3423	8		1.00
08EG006	1936	883	883	883	0.0270	1		
08EG006	1935	286		289	0.9730	22		
08EG006	1934	348		353	0.6577	15		
08EG006	1933	365		370	0.5225	12		
08EG006	1932	459	462	462	0.2523	6		1.01
08EG006	1931	447	450	450	0.2973	7		1.01
08EG006	1930	348	354	354	0.5676	13		1.02

Flood Frequency Analysis

08EG006 - Fall	Kitsumkalum River near Terrace				Watershed Area:	Published:	2180	
						Measured:	2190	

INSTANTANEOUS				Flow (m^3/s)				
Prob of Non-exceedance	Return Period	GEV	3-Parm Log-Normal	Log Pearson III	Wakeby	Generalized Logistic	Weibull	Gumbel
0.5	2	322	321	317	317	325	319	
0.8	5	454	459	459	473	447	469	
0.9	10	557	563	576	581	545	575	
0.95	20	668	673	709	681	657	678	
0.96	25	706	710	755	711	697	710	
0.98	50	834	828	914	801	837	809	
0.99	100	977	955	1098	884	1007	906	
0.995	200	1137	1090	1309	961	1213	1000	
0.998	500	1381	1283	1641	1053	1554	1123	
0.999	1000	1591	1441	1937	1117	1877	1215	

AVERAGE DAILY				Flow (m^3/s)				
Prob of Non-exceedance	Return Period	GEV	3-Parm Log-Normal	Log Pearson III	Wakeby	Generalized Logistic	Weibull	Gumbel
0.5	2	319	318	316	314	321	316	
0.8	5	446	450	501	465	439	460	
0.9	10	543	549	501	567	532	560	
0.95	20	648	651	631	658	637	655	
0.96	25	683	685	794	686	674	685	
0.98	50	800	795	794	766	805	776	
0.99	100	930	910	1000	839	961	865	
0.995	200	1074	1033	1259	904	1148	952	
0.998	500	1288	1207	1585	982	1456	1063	
0.999	1000	1471	1348	1995	1033	1745	1146	

ANNUAL RECORDS								
Station Number	Year	Annual Ave Daily	Instantaneous	Inst. Used	Emp Prob	Rank	Count	I/D ratio
08EG006	1951	280		283	0.5862	14	23	
08EG006	1950	182		183	0.9741	23		
08EG006	1949	328		332	0.4138	10		
08EG006	1948	286		289	0.5431	13		
08EG006	1947	292		296	0.5000	12		
08EG006	1946	267		270	0.6724	16		
08EG006	1945	646	691	691	0.0259	1		
08EG006	1944	248		251	0.7586	18		
08EG006	1943	204		206	0.9310	22		
08EG006	1942	223		225	0.8879	21		
08EG006	1941	272		275	0.6293	15		
08EG006	1940	566	580	580	0.1121	3		1.02
08EG006	1939	442		448	0.2845	7		
08EG006	1938	231		233	0.8448	20		
08EG006	1937	294		298	0.4569	11		0.00
08EG006	1936	530		538	0.1983	5		
08EG006	1935	634		644	0.0690	2		
08EG006	1934	357		362	0.3707	9		
08EG006	1933	556		565	0.1552	4		
08EG006	1932	447		453	0.2414	6		
08EG006	1931	261		264	0.7155	17		
08EG006	1930	242		245	0.8017	19		
	1929	388	396	396	0.32758621	8		1.02

08EG011- Annual	Zymagotitz River near Terrace				Watershed Area:	Published:	376	
						Measured:	372	

INSTANTANEOUS				Flow (m^3/s)				
Prob of Non-exceedance	Return Period	GEV	3-Parm Log-Normal	Log Pearson III	Wakeby	Generalized Logistic	Weibull	Gumbel
0.5	2	249.6	249.7	242.5	241.5	251.7	249.0	248.7
0.8	5	374.9	375.7	376.3	409.2	365.8	382.1	374.0
0.9	10	457.0	457.1	471.3	484.2	445.5	462.5	457.0
0.95	20	535.0	534.1	566.3	526.8	528.8	533.7	536.6
0.96	25	559.7	558.3	597.2	535.8	557.0	555.1	561.9
0.98	50	635.1	632.6	694.6	554.6	650.0	618.2	639.6
0.99	100	709.4	706.1	794.7	564.3	752.9	677.0	716.9
0.995	200	782.8	779.6	898.0	569.4	867.3	732.3	793.8
0.998	500	878.7	877.3	1040.0	572.4	1039.2	801.1	895.3
0.999	1000	950.5	951.9	1151.9	573.5	1187.1	850.5	972.0

AVERAGE DAILY				Flow (m^3/s)				
Prob of Non-exceedance	Return Period	GEV	3-Parm Log-Normal	Log Pearson III	Wakeby	Generalized Logistic	Weibull	Gumbel
0.5	2	165.1	164.8	158.5	162.6	166.4	164.0	168.5
0.8	5	236.5	237.9	251.2	248.5	232.0	242.5	240.3
0.9	10	287.3	288.9	316.2	299.5	280.7	293.3	287.8
0.95	20	338.8	339.3	316.2	341.0	333.9	340.0	333.3
0.96	25	355.7	355.6	398.1	352.6	352.4	354.4	347.8
0.98	50	409.7	406.9	398.1	384.1	415.2	397.5	392.3
0.99	100	466.2	459.5	501.2	409.7	487.5	438.4	436.5
0.995	200	525.6	513.7	631.0	430.5	571.1	477.7	480.5
0.998	500	608.8	588.2	631.0	452.2	702.8	527.5	538.6
0.999	1000	675.6	646.8	794.3	465.0	821.3	563.8	582.5

ANNUAL RECORDS								
Station Number	Year	Annual Ave Daily	Instantaneous	Inst. Used	Emp Prob	Rank	Count	I/D ratio
08EG011	1994	135	197	197	0.3580	23	35	1.46
08EG011	1993	213	388	388	0.7841	8		1.82
08EG011	1992	316	376	376	0.7273	10		1.19
08EG011	1991	290	321	321	0.6420	13		1.11
08EG011	1990	88.2	93.5	93.5	0.0170	35		1.06
08EG011	1989	155	233	233	0.5000	18		1.50
08EG011	1988	184	377	377	0.7557	9		2.05
08EG011	1987	226	358	358	0.6989	11		1.58
08EG011	1986	125	173	173	0.3295	24		1.38
08EG011	1985	98.7	110	110	0.0455	34		1.11
08EG011	1984	108	136	136	0.1875	29		1.26
08EG011	1983	243	305	305	0.6136	14		1.26
08EG011	1982	177	227	227	0.4432	20		1.28
08EG011	1981	156	202	202	0.3864	22		1.29
08EG011	1980	168	237	237	0.5284	17		1.41
08EG011	1979	107	151	151	0.2443	27		1.41
08EG011	1978	334	530	530	0.9545	2		1.59
08EG011	1977	132	217	217	0.4148	21		1.64
08EG011	1976	181	300	300	0.5852	15		1.66
08EG011	1975	94	130	130	0.1307	31		1.38
08EG011	1974	382	549	549	0.9830	1		1.44
08EG011	1973	89.5	114	114	0.0739	33		1.27
08EG011	1972	208	402	402	0.8125	7		1.93
08EG011	1971	216	326	326	0.6705	12		1.51
08EG011	1970	127	157	157	0.3011	25		1.24
08EG011	1969	106	136	136	0.1875	29		1.28
08EG011	1968	123	129	129	0.1023	32		1.05
08EG011	1967	309	484	484	0.8977	4		1.57
08EG011	1966	211	422	422	0.8409	6		2.00
08EG011	1965	169	230	230	0.4716	19		1.36
08EG011	1964	164	257	257	0.5568	16		1.57
08EG011	1963	98.8	145	145	0.2159	28		1.47
08EG011	1962	213	453	453	0.8693	5		2.13
08EG011	1961	300	496	496	0.9261	3		1.65
08EG011	1960	118	157	157	0.3011	25		1.33

08EG011-Spring	Zymagotitz River near Terrace				Watershed Area:	Published:	376	
						Measured:	372	

INSTANTANEOUS				Flow (m^3/s)				
Prob of Non-exceedance	Return Period	GEV	3-Parm Log-Normal	Log Pearson III	Wakeby	Generalized Logistic	Weibull	Gumbel
0.5	2	136.5	136.5	137.1	138.8	137.0	136.4	
0.8	5	163.5	163.6	163.7	158.8	161.5	165.0	
0.9	10	181.0	181.0	180.5	174.8	178.6	182.1	
0.95	20	197.6	197.4	196.2	193.9	196.3	197.3	
0.96	25	202.8	202.5	201.1	200.8	202.3	201.8	
0.98	50	218.8	218.3	216.1	225.2	222.1	215.2	
0.99	100	234.4	233.8	230.8	254.6	243.8	227.7	
0.995	200	249.7	249.3	245.6	290.0	268.0	239.4	
0.998	500	269.7	269.9	265.0	348.1	304.1	253.9	
0.999	1000	284.6	285.5	279.9	402.6	335.1	264.4	

AVERAGE DAILY				Flow (m^3/s)				
Prob of Non-exceedance	Return Period	GEV	3-Parm Log-Normal	Log Pearson III	Wakeby	Generalized Logistic	Weibull	Gumbel
0.5	2	96.3	96.3	100.0	97.4	96.6	96.2	
0.8	5	113.4	113.6	125.9	111.4	112.2	114.5	
0.9	10	124.9	125.1	125.9	122.1	123.3	125.9	
0.95	20	136.1	136.1	125.9	134.3	135.2	136.1	
0.96	25	139.7	139.6	125.9	138.7	139.2	139.2	
0.98	50	150.8	150.4	158.5	153.6	152.6	148.3	
0.99	100	162.0	161.2	158.5	170.9	167.7	156.9	
0.995	200	173.3	172.1	158.5	191.0	184.7	165.0	
0.998	500	188.4	186.8	199.5	222.6	210.5	175.1	
0.999	1000	199.9	198.1	199.5	251.0	233.2	182.5	

ANNUAL RECORDS								
Station Number	Year	Annual Ave Daily	Instantaneous	Inst. Used	Emp Prob	Rank	Count	I/D ratio
08EG011	1994	81.4		115	0.1637	29	34	0.00
08EG011	1993	116		169	0.8655	5		0.00
08EG011	1992	95.5		137	0.4854	18		0.00
08EG011	1991	106		153	0.7193	10		0.00
08EG011	1990	88.2	93.5	94	0.0175	34		1.06
08EG011	1989	83.5		118	0.2222	27		0.00
08EG011	1988	101		145	0.6023	14		0.00
08EG011	1987	118		172	0.8947	4		0.00
08EG011	1986	108		156	0.7778	8		0.00
08EG011	1985	98.7		142	0.5146	17		0.00
08EG011	1984	68.8		95	0.0468	33		0.00
08EG011	1983	107		155	0.7485	9		0.00
08EG011	1982	104		150	0.6608	12		0.00
08EG011	1981	113		164	0.8363	6		0.00
08EG011	1980	79		111	0.1053	31		0.00
08EG011	1979	89.6		128	0.3684	22		0.00
08EG011	1978	79.3		112	0.1345	30		0.00
08EG011	1977	72.5		101	0.0760	32		0.00
08EG011	1976	106		153	0.7193	10		0.00
08EG011	1975	94	130	130	0.4269	20		1.38
08EG011	1974	85.2		121	0.2515	26		0.00
08EG011	1973	89.5		127	0.3392	23		0.00
08EG011	1972	120		175	0.9240	3		0.00
08EG011	1971	101		145	0.6023	14		0.00
08EG011	1970	87.5	157	157	0.8070	7		1.79
08EG011	1969	106	136	136	0.4561	19		1.28
08EG011	1968	123	129	129	0.3977	21		1.05
08EG011	1967	143		211	0.9532	2		0.00
08EG011	1966	86.7		123	0.2807	25		0.00
08EG011	1965	88.1		125	0.3099	24		0.00
08EG011	1964	164		244	0.9825	1		0.00
08EG011	1963	98.8		142	0.5439	16		0.00
08EG011	1962	83.5		118	0.2222	27		0.00
08EG011	1961	103		149	0.6316	13		0.00

Flood Frequency Analysis

08EG011-Fall	Zymagotitz River near Terrace				Watershed Area:	Published:	376	
						Measured:	372	

INSTANTANEOUS				Flow (m^3/s)				
Prob of Non-exceedance	Return Period	GEV	3-Parm Log-Normal	Log Pearson III	Wakeby	Generalized Logistic	Weibull	Gumbel
0.5	2	248.8	249.3	245.1	246.0	250.7	249.3	
0.8	5	382.6	381.7	391.7	405.2	371.7	386.9	
0.9	10	462.8	460.9	477.0	478.0	450.9	464.6	
0.95	20	534.0	532.3	548.6	525.4	530.2	530.8	
0.96	25	555.5	554.1	569.3	536.8	556.2	550.4	
0.98	50	618.5	619.5	627.6	563.8	639.9	607.1	
0.99	100	676.7	682.0	677.9	581.3	728.7	658.8	
0.995	200	730.6	742.6	721.6	592.7	823.6	706.5	
0.998	500	795.9	820.4	770.9	601.9	959.4	765.0	
0.999	1000	841.3	878.0	802.7	606.1	1071.0	806.2	

AVERAGE DAILY				Flow (m^3/s)				
Prob of Non-exceedance	Return Period	GEV	3-Parm Log-Normal	Log Pearson III	Wakeby	Generalized Logistic	Weibull	Gumbel
0.5	2	161.1	161.3	158.5	161.8	162.3	161.2	
0.8	5	243.7	243.4	251.2	248.3	237.2	247.0	
0.9	10	294.5	293.7	316.2	298.2	287.1	296.3	
0.95	20	340.5	339.5	316.2	339.9	337.7	338.8	
0.96	25	354.6	353.7	398.1	351.8	354.4	351.4	
0.98	50	396.4	396.3	398.1	384.9	408.7	388.1	
0.99	100	435.7	437.6	398.1	412.7	467.0	421.8	
0.995	200	472.8	477.8	501.2	436.0	529.9	453.1	
0.998	500	518.8	530.0	501.2	461.2	621.3	491.6	
0.999	1000	551.4	569.0	501.2	476.8	697.4	518.9	

ANNUAL RECORDS								
Station Number	Year	Annual Ave Daily	Instantaneous	Inst. Used	Emp Prob	Rank	Count	I/D ratio
08EG011	1994	135	197	197	0.3580	23	35	1.46
08EG011	1993	213	388	388	0.7841	8		1.82
08EG011	1992	316	376	376	0.7273	10		1.19
08EG011	1991	290	321	321	0.6420	13		1.11
08EG011	1990	61		83	0.0739	33		0.00
08EG011	1989	155	233	233	0.5000	18		1.50
08EG011	1988	184	377	377	0.7557	9		2.05
08EG011	1987	226	358	358	0.6989	11		1.58
08EG011	1986	125	173	173	0.3295	24		1.38
08EG011	1985	58.9	110	110	0.1591	30		1.87
08EG011	1984	108	136	136	0.2159	28		1.26
08EG011	1983	243	305	305	0.6136	14		1.26
08EG011	1982	177	227	227	0.4432	20		1.28
08EG011	1981	156	202	202	0.3864	22		1.29
08EG011	1980	168	237	237	0.5284	17		1.41
08EG011	1979	107	151	151	0.2727	26		1.41
08EG011	1978	334	530	530	0.9545	2		1.59
08EG011	1977	132	217	217	0.4148	21		1.64
08EG011	1976	181	300	300	0.5852	15		1.66
08EG011	1975	34.3		41	0.0170	35		0.00
08EG011	1974	382	549	549	0.9830	1		1.44
08EG011	1973	86.9	114	114	0.1875	29		1.31
08EG011	1972	208	402	402	0.8125	7		1.93
08EG011	1971	216	326	326	0.6705	12		1.51
08EG011	1970	68.5		95	0.1023	32		0.00
08EG011	1969	72.8		101	0.1307	31		0.00
08EG011	1968	56.6		76	0.0455	34		0.00
08EG011	1967	309	484	484	0.8977	4		1.57
08EG011	1966	211	422	422	0.8409	6		2.00
08EG011	1965	169	230	230	0.4716	19		1.36
08EG011	1964	135	257	257	0.5568	16		1.90
08EG011	1963	83	145	145	0.2443	27		1.75
08EG011	1962	213	453	453	0.8693	5		2.13
08EG011	1961	300	496	496	0.9261	3		1.65
	1960	118	157	157	0.3011	25		1.33

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CANADA BEST MANAGED COMPANIES