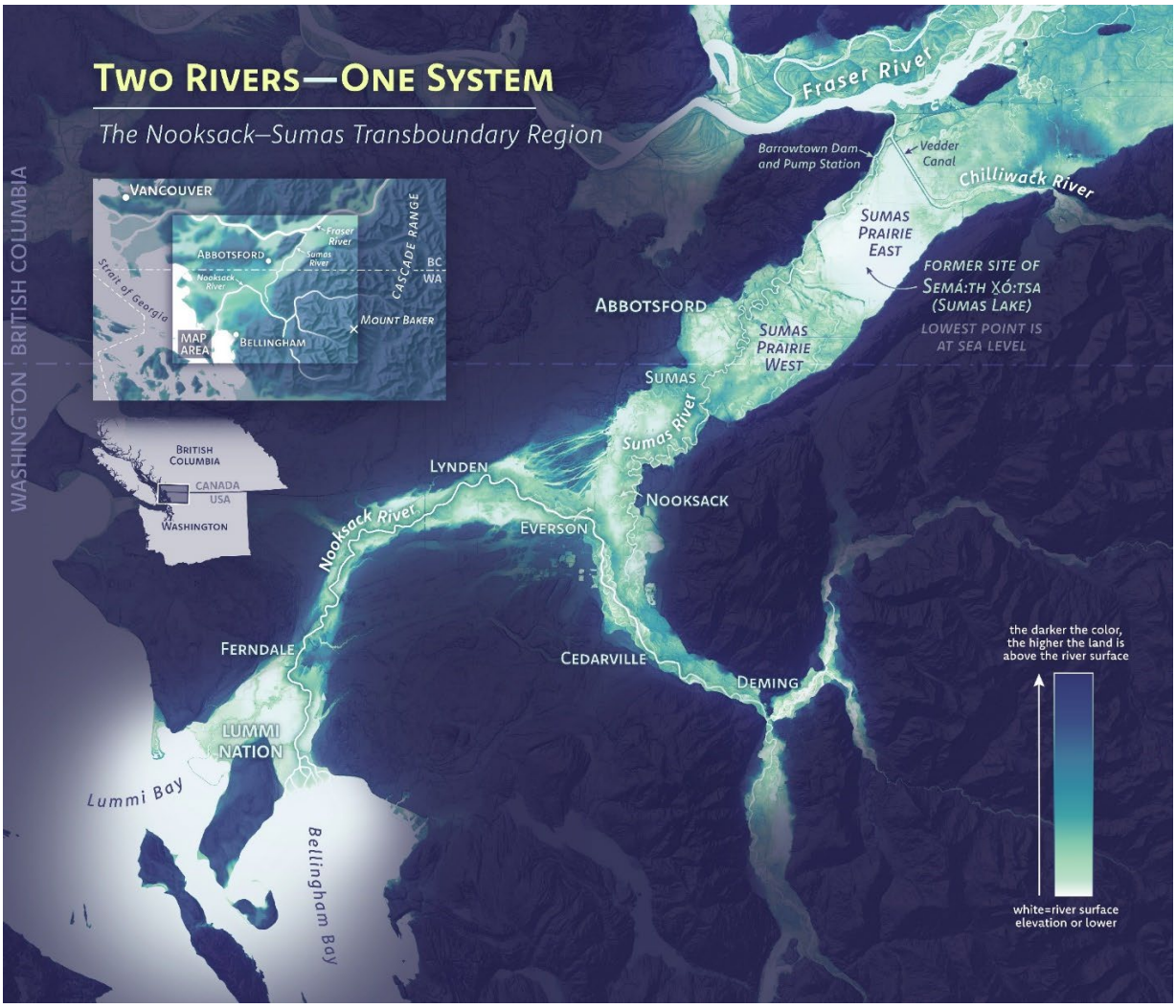
Transboundary Flood Initiative

Technical Table Status Report

September 2024



Disclaimer: This status report does not reflect the views or opinions of any individual government within the Transboundary Flood Initiative (TFI); rather it strives to reflect a shared understanding of the problem and current state of planning on both sides of the border. It is intended to serve as a living document that will be updated as new analyses are completed and as transboundary projects are developed.

I. Introduction

Transboundary Flood Initiative (TFI)

At high flows, the Nooksack River in northwestern Washington State, U.S. overflows its banks near the town of Everson and floodwaters enter the adjacent Sumas River watershed, which drains north into the Sumas Prairie near Abbotsford, British Columbia. The severe flooding in the Fraser, Nooksack, and Sumas River watersheds in November 2021 renewed interest in and reinforced the need for large-scale and coordinated transboundary flood management actions. The November 2021 flood caused extensive social, ecological and economic impacts including thousands of evacuations, hundreds of thousands of livestock deaths, further impact to salmon populations, significant pollution discharge into surface waters, and billions of dollars in damages to homes, businesses and infrastructure. The catastrophic damages on both sides of the border prompted a sense of urgency and call to action, leading to a collaborative agreement signed in 2023 by representatives of nine governments – including The Province of B.C. and Washington State, Semá:th, Máthxwi, and Leq'á:mel First Nations, The Nooksack Indian Tribe, Lummi Nation, the City of Abbotsford and Whatcom County. The Transboundary Flood Initiative (TFI) was thus established with the directive to collaboratively align planning and implementation of near-term and long-term solutions for flood risk reduction for collective benefit, in a manner consistent with ecosystem restoration.

The TFI builds upon previous work conducted by the Nooksack River International Task Force (NRITF) that was established in 1990 after a significant flooding event. However, the previous Task Force had limited participants, sporadic meetings with limited staff capacity, and did not include First Nations or Tribes in the process. This fundamental shift in participation is in recognition of treaty rights and jurisdiction under UNDRIP. The TFI recognizes that salmon decline, ecosystem degradation and increasing flood hazard are not independent issues and need to be addressed in a holistic manner. First Nations and Tribes involvement will be essential in ensuring a holistic watershed based approach to flood mitigation and ecosystem restoration. Flood control efforts to date have had immeasurable impacts on ecosystem services, treaty rights, and the inherent rights and title of Indigenous peoples within the transboundary area.

This status report was prepared by the TFI Technical Table to share the current state of knowledge, to facilitate and inform discussions at Policy and Leadership tables, and to provide a technical basis for decision-makers. The Technical Table is tasked with advancing research to better understand river flow changes and climate change impacts in the Transboundary Area, exchanging information among parties, and ultimately working together to explore integrated ecosystem restoration and flood mitigation strategies on both sides of the border. The group is the primary forum for collaboration between Whatcom County's Floodplain Integrated Planning (FLIP) and the B.C.-based Sumas River Watershed Flood Mitigation Plan (SRWFMP) workgroups. It supports the Policy and Leadership tables in their efforts to align and coordinate flood reduction and ecosystem restoration strategies within the transboundary area.

Geographic Setting

The Nooksack River is a complex and dynamic river system — with its headwaters originating in a high elevation sediment-rich volcanic basin, with rapidly receding glaciers, its current course flowing west to Bellingham Bay, and a historic flow path north to the Fraser River in Canada (Boyd et al. 2019). Indigenous knowledge, and geologic and archaeological evidence indicate that the mainstem Nooksack River flowed through what is now the Sumas Prairie and into the Fraser River as recently as several hundred years ago (Pittman 2009; Hutchings, 2004). The timing and occurrence of past avulsions of the Nooksack flowing north into the Fraser River, versus west to Bellingham and Lummi Bays, is not well understood. However, near Everson, Washington the historic flow path to the Sumas River watershed is still active during large floods. At peak flood flows, a portion of the Nooksack River overflows to the north, and is conveyed along the Johnson Creek corridor to the Sumas River, which crosses the international border, and discharges to the Fraser River in Canada. The transboundary flood area covers the Nooksack River, the overflow path along the Sumas River, the confluence with the Vedder River, and out to the Fraser River (report cover illustration). Much of the lower Nooksack – from Everson downstream to Ferndale, has agricultural levees on both sides of the river. These levees are designed to contain moderate floods and overtop to reconnect floodplain during large floods.

Relative to the Nooksack River, the Sumas River is a comparatively small system with lower elevation profile. Approximately 90 percent of Sumas River's length is diked along one or both banks between the Canada/US border and the Barrowtown Dam. Flows in the Sumas River are controlled at the Barrowtown Dam by gravity-draining floodgates which are typically closed May through July/August to prevent back-flooding during the Fraser River freshet, and May through September to store water for irrigation. Water levels downstream of Barrowtown Dam are influenced by both the Fraser River and tidal effects at lower flows. At higher Sumas flows (including winter floods), downstream water levels may be controlled by Fraser River and

Chilliwack River streamflow. When a fall or winter flood causes downstream water levels to rise, the floodgates can be closed for the duration of the event.

The Sumas Prairie includes a former lake bed that was drained through a major diking and drainage project in the early 1920's. The draining of Semá:th X̲ó:tsa (Sumas Lake) is a decision which has created lasting water management challenges, as the former lake bottom is at mean sea level and vulnerable to flooding. Runoff entering the former lake bottom area is collected by a series of irrigation ditches and canals and is pumped out by Barrowtown Pump Station with an existing design capacity of about 1,130 cfs (approximately 32 m^3/s).

II. Problem Overview

Flooding

Significant flooding on the lower mainstem Nooksack River floodplain in the U.S is common, and the Lummi Nation in particular is frequently impacted and was completely isolated in the 2021 flood event. However, the Nooksack River only enters Canada and the Sumas River as overflow during large flood events; this occurs infrequently but has had catastrophic impacts. This contributes to the condition of a changing population living at risk in the overflow corridor, often with little awareness of the flood hazard. In the U.S., the City of Sumas is located over 8 miles (13 km) from the point of overflow at Everson, the Sumas Prairie portion of Abbotsford is even further downstream.

Flood management of the Nooksack River and Everson overflow area is incredibly complex — with an international border bisecting its overflow path, Federal, Provincial, State, three Canadian First Nations, two U.S. Tribal Nations, multiple municipal governments, numerous industrial and utility operators, and thousands of farmers and floodplain residents, all who are all impacted by flood management decisions. Any flood management actions taken within the US to protect the Sumas River watershed must fully consider and account for impacts to Nooksack River communities downstream of Everson, particularly the Lummi Nation. Flood management in the Nooksack River must also recognize Treaty rights of the Nooksack Tribe and Lummi Nation, which in Washington State protects not only fisheries, but also their habitat. Any floodplain management actions which further degrade Nooksack River habitat may be considered a violation of treaty rights. Further, floodplain management planning in Washington must integrate salmon recovery needs, a commitment in the local Salmon Recovery Plan.

With climate change, the frequency and magnitude of Nooksack floods and overflow events down the Sumas River are predicted to increase (Paul, 2023). Regional atmospheric river events, like the one that produced the November 2021 flood, are likely to become more common with climate change (Gillett et al. 2022). The Nooksack River is expected to continue to

see increased winter flooding due to a combination of more intense rain events and a higher snowline. With a higher snowline, more precipitation falls as rain and there is less snow and snowpack to store the rainfall, resulting in more fall/winter runoff and higher flows during flood events, and lower summer low flows. Similar changes are projected for the Fraser River, with less snow and more rain – moderate floods due to regional storms are expected to become larger and more frequent in the fall/winter (Curry et al. 2019) with a potential to coincide with Nooksack winter overflow events.

Though floodplain management is complex, timely actions will need to be taken, as unmitigated flood risk has been recognized as having significant consequences for communities, impacting human health and safety, trade, transportation, agriculture, food security, cultural and natural resources, Indigenous and tribal treaty rights, business, and personal property.

Floodplain Development

Although floodplains are expected to periodically be flooded by rivers, both the Nooksack and Sumas floodplains have been subject to over a century of settler development within the floodplain. What is now the Sumas Prairie – the land surrounding the former Semá:th X̲ó:tsa below 46' (14m) elevation – is now designated as Agricultural Land Reserve and is one of the most intensively and diversely farmed areas of Canada. The prairie supports a wide range of crop and livestock enterprises, and agriculture is the economic backbone of the area with an estimated $3.8 billion annual income and 25% of the area's employment (Chamber of Commerce Abbotsford, 2022). Sumas Prairie is also a critical infrastructure corridor of national importance, including the TransCanada Highway 1, railways, regional electrical transmission lines, fibre optic communications, and oil and gas pipelines connecting Canadian and US cities and also overseas trading partners. The connectivity through the floodplain is vital to supply chain resiliency, energy security and economic well-being for all Canadians.

In Washington, the Nooksack River floodplain has also been largely converted to agricultural production and today supports the valley's residents and workers. The area is known for its berry fields, dairies and grains and hay fields. More than half the red raspberries produced in the US come from Whatcom County. The small cities of Nooksack, Everson, Lynden and Ferndale all have residential structures and critical infrastructure – including wastewater treatment plants in the floodplain, and several pipelines cross under the Nooksack River.

There is a long history of adverse impacts of floodplain development and associated flood control actions on salmon populations in the Transboundary area. Notably the Sumas Prairie portion of Abbotsford B.C. includes a former highly productive lake of critical importance to Indigenous communities that was drained and appropriated through a major diking and drainage project in the early 1920's. The draining of Semá:th X̲ó:tsa (Sumas Lake) is a decision

which significantly impacted First Nations and the Nooksack Tribe; usurping the traditional foods and habitats that were once provided by the Lake. Today, it is important to recognize the ongoing influence of the Barrowtown facilities on fish, fish habitat, and water quality within the Sumas River system through water management impacts on biotic and abiotic processes such as heat exchange, gas exchange, nutrient cycling, transport of sediment and dissolved substances, and rates of sediment deposition (Shead, 2004).

The multitude of human impacts over the last century has resulted in the Nooksack river system being dynamic, difficult to predict, and performing below optimal geomorphic function for supporting habitat. With the floodplains on both sides of the border largely privately owned and utilized as high value agricultural lands, developing holistic flood solutions will require coordination with local landowners and may take time.

Habitat Status

While the Nooksack River is degraded, it continues to support Treaty anadromous species of importance to the Nooksack Tribe and Lummi Nation including chinook, coho, chum, pink, riverine sockeye, steelhead, cutthroat and bull trout. Runs of all these species have suffered major declines from historic levels. Chinook, steelhead and bull trout are listed as Threatened species and protected under the U.S. Endangered Species Act (ESA). The quantity, quality, and connectivity of habitats within the Lower Mainstem Nooksack have been degraded due to a legacy of historic practices – namely due to channelization of the river, levees and extensive bank armor, and clearing of riparian forests. There has also been a history of logjam removals, channel straightening and loss of side channels. The resulting lack of shade, lack of wood recruitment, loss of wetlands, loss of channel complexity and lack of access to off-channel habitats still limit salmon recovery today. While the timing, duration and uses vary among species, the Lower Mainstem Nooksack River provides important spawning, rearing, migration, holding and refuge habitat for this diverse assemblage of salmonids.

On the Canadian side, the loss of the Semá:th X̲ó:tsa (Sumas Lake) —which supported tremendous diversity and abundance of fish and bird populations, has decimated populations of white sturgeon, Semá:th sockeye, chinook, steelhead, trout, chum and other important fish species (Reimer, 2018). Fish access in and out of the Sumas River is now restricted when the Barrowtown Dam floodgates are closed (during times of high Fraser River level, and during the irrigation season). There is also minimal fish passage between the Sumas River and the Sumas Drainage Canal. While the four centrifugal pumps installed in 1984 are more fish-friendly than the previous vertical pumps, there are still significant pressure differentials that may cause fish mortality. Despite this, several fish species are still present in low abundances in the watershed, and the ditches, creeks and rivers of the Sumas Prairie are still used by two of Canada's Species at Risk – chinook salmon and white sturgeon. The Sumas River in the U.S. continues to have

consistent coho use and has documented presence of chum, pink, sockeye, cutthroat, steelhead and rainbow trout, and several other native fish species.

The quality and productivity of aquatic habitat within the Sumas River watershed is also degraded due to historic and current anthropogenic impacts such as diking, dredging, impoundment, drainage, sediment traps, water withdrawals and development. In the mainstem of the Sumas River, suitable spawning habitat is limited by naturally low velocities and channel gradients exacerbated by irrigation system operations, as well as lack of suitable gravel substrate. However, salmon rear and migrate through this area to higher quality spawning and rearing habitats further upstream in the tributaries, including along the base of Vedder Mountain and other locations like Johnson Creek (WDFW SGS database, 2024).

Flooding like the 2021 event has detrimental effects on fisheries resources in both the Nooksack and Sumas watersheds. A primary concern with flooding is water quality; one recent study demonstrated the fish habitat in the Sumas Prairie region was heavily degraded with excessive nutrients, metals, hydrocarbons and pesticides following the 2021 flood (Ross et al, 2022). Naturally occurring asbestos coming from the Swift Creek tributary in Washington during high flow events is a human health hazard and may be a hazard to aquatic species. Flooding has also caused fish stranding, redd loss, reduced smolt outmigrations and reduced adult salmon returns. When the Everson overflow initiates, Nooksack juvenile fish are lost to the Sumas, and will most likely home back to the Fraser instead of the Nooksack.

Climate change, and its anticipated changes in hydrology, turbidity, and water temperatures are also critical drivers impacting salmon productivity in both the Nooksack River and Sumas River systems. In addition to the anthropogenic stressors described above, the additional stress of climate change has the potential to have a severe impact on the survival of salmon. An example of such a situation was experienced in the South Fork Nooksack River in the summer of 2021 when over 2400 chinook salmon died before they were able to spawn, due to pathogens that thrive in high water temperatures.

In Washington State, there is a commitment to integrate salmon recovery with flood risk reduction through the Water Resources Inventory Area (WRIA) 1 Salmon Recovery Plan (https://salmonwria1.org/). Restoration actions identified during planning for the Mainstem Nooksack focus on restoring habitat diversity and key habitats, such as floodplain rearing. Some of the priority actions for the Mainstem near the flow split include levee setbacks, installing instream habitat structures that will restore channel functions, and reconnecting and restoring floodplain rearing habitats (Appendix 1, WRIA 1 Priority recovery actions). For the Sumas River and former Sumas Lake, there has been less synthesis of existing problems and habitat conditions, and identification of critical recovery actions. Barrowtown Dam is a significant fish passage barrier and only a sub-set of former fish species continue to exist in the Sumas system.

There is a need to determine existing conditions and opportunities comprehensively in the transboundary Sumas area, evaluate feasibility, and develop and implement a restoration plan. Today it is critical to fully integrate salmon recovery and Indigenous rights into flood risk reduction planning.

III. Key Technical Issues

Everson Overflow: Understanding the “flow split”

Figure 1. Relative digital elevation map of the flow split area near Everson, WA. Lighter colors show lower elevations, darker colors show higher elevation areas relative to the nearest river.

In November 2021, the Nooksack River overflowed its banks causing flood damage along nearly the entire 37 miles (60 km) river reach from Deming to Bellingham Bay, severely impacting the Lummi Nation, City of Ferndale and upriver cities and County residents. Near Everson, the Nooksack River overflowed into the Sumas River causing major flooding to the Cities of Everson, Nooksack and Sumas in Washington State, unincorporated areas of Whatcom County and north

into Canada. North of the border, the Fraser River was also high from the same storms that impacted Washington. When the Fraser River is higher than the Sumas River, floodwaters cannot flow out from the Sumas River through the floodgates at Barrowtown dam. Without anywhere to go, the Sumas River continued to rise as floodwaters came in from the south. Two breaches occurred on the Sumas Dike, resulting in Sumas Prairie East – the former lake bed, flooding to a depth of approximately 10 feet (3 metres). Flood inundation closed the Trans-Canada Highway, part of a broader set of disruptions that isolated Metro Vancouver from the rest of Canada.

This was not the first time. The overflow near Everson is a historic Nooksack River flow path and marks a very subtle divide between the Nooksack and Sumas watersheds. Emerson Road is the final hydraulic control before the water leaves the Nooksack River watershed and enters the Sumas River watershed. This bifurcation of high flows at Everson is now commonly referred to as the "flow split". The overflow has occurred intermittently at least since the early 1900's, but major overflows tend to be infrequent (Figure 2). The 2021 overflow is estimated to be the largest such overflow since record keeping began in 1945, as shown in Figure 2 below.

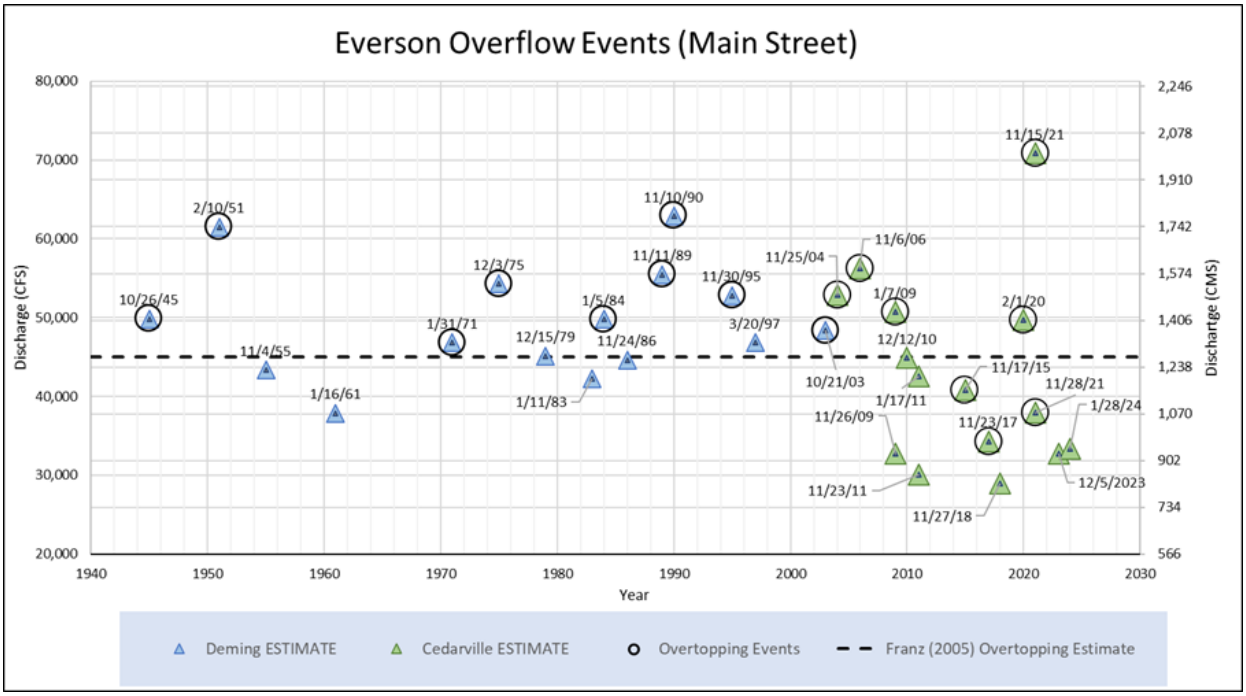


Figure 2. Nooksack high flow events as measured by Deming and Cedarville gages, 1945 – 2024. Major flood damages have occurred in the Sumas Prairie, B.C. in 1935, 1951, 1990, and 2021.

The magnitude and frequency of Nooksack River overflows at Everson vary significantly over time due to geomorphic and hydrologic changes, and are affected by changes in the floodplain such as man-made constrictions that impact river dynamics near Everson. The duration and

depth of overtopping at the watershed divide near Emerson Road largely determines the amount of flooding along the river corridor on both sides of the border. In Canada, modest Nooksack River overflows can be kept out of Sumas Prairie East/former Lake Bottom by the Sumas Dike and discharged to the Fraser River via the Barrowtown Dam floodgates with minimal damages, *if* the Fraser River level remains within historical winter low-flow conditions. In such cases flood damages still occur in the unprotected floodplain of Sumas Prairie West and there may be some infrastructure closures. However, during large Nooksack River overflows, the existing flood protection system can be overwhelmed, particularly if the Barrowtown Dam floodgates need to be closed due to high Fraser River level. The Sumas Dike has breached three times in its 100 year existence: 1935, 1951, and 2021 (Table 1). Uncertainties in streamflow estimates at the upstream gaging sites (Deming until 2005, and Cedarville after 2005) complicates the understanding of what conditions result in damaging events in Canada and the Everson overflow corridor.

Table 1. Summary of overflow events reaching Sumas Prairie, B.C. from 1935-2021 compiled by KWL, 2024. See Figure 3 below for map of Sumas Prairie East and West.

Year	Description
1935	major overflow event flooded Sumas Prairie West and contributed to breach of Sumas Dike
1951	major overflow event flooded Sumas Prairie West and contributed to breach of Sumas Dike
1909-1986	total of ten additional overflow events between 1909 and 1986 (variable in magnitude)
1989	relatively large overflow event resulting in flooding in Sumas Prairie West
1990	major overflow event resulting in widespread flooding and damage in Sumas Prairie West
1990-2021	total of ten additional overflow events between 1990 and 2021 (variable in magnitude, with 2009 described as significant)
2020	overflow event that resulted in closure of the Sumas border crossing
2021	major overflow event caused extensive damage throughout Sumas Prairie West, breach of Sumas Dike, and extensive flooding in Sumas Prairie East

Changes to sediment levels on riverbeds and gravel bars can affect the capacity of the river to convey water within the channel during flood events. A recent USGS study identified Nooksack River bed aggradation/degradation patterns based on a comparison of LiDAR surfaces and cross-sections and suggests an increase in overflow activity has occurred in recent years (Anderson et al. 2019). The USGS results show that between Deming and Bellingham Bay, the greatest increase in mean bed elevation has occurred at the point of overflow at Everson where, from 2006 to 2015, over a mile of channel showed an average bed elevation increase of one to three feet (0.3 to 0.9 m). This essentially reduced the threshold for the flow that initiates overflow at Everson. Estimates from the USGS and hydraulic modeling performed in the FLIP process suggest that the Cedarville gage threshold used to be in the mid 40,000s cfs

(approximately 1,300 m^3/s) in the early 1990's but is likely in the mid 30,000s cfs (approximately 900 m^3/s) in 2022. The USGS has also evaluated specific gage trends at several locations throughout the watershed, and hypothesized that the temporal trends at the gages collectively depict changes that propagate downstream, and that a long wave length pulse of sediment, which is related to long-term climatic trends, could be affecting the stage and relative discharge at which overflow occurs (Anderson et al. 2019). In addition, direct measurements before, during, and after the 2021 flooding showed substantial within-storm riverbed elevation changes at the Cedarville gage.

Commercial sand and gravel mining (as occurred during the 1990's) is frequently perceived as a viable sediment management strategy. However, an assessment in 1995 showed that gravel removal would have to be on the order of ten times greater than historic levels to reduce the level of a 100-year flood event in the Nooksack River (KCM, 1995). The 1990 flood occurred during the peak of the gravel mining period, yet it still caused devastating impacts in both the U.S. and Canada. Today, large scale dredging and gravel mining is no longer allowable in the Nooksack River due to the listing of three Nooksack River salmonid species as protected under the U.S. Endangered Species Act. Sediment inputs are predicted to further increase due to climate-associated changes to hydrology, snow cover, and mass wasting. When considered in context with changes in sediment transport capacity of the river due to levees and other human modifications to the river system, a new sediment management paradigm is needed.

The Everson overflow reach is probably the most complex section of the Lower Nooksack River with respect to the intersecting influences of hydrology, hydraulics, geomorphology, and existing development and infrastructure. A key future issue is to understand the potential for increased frequencies, volumes, and/or durations of Nooksack River overflows and sediment transport due to changing conditions. While a full avulsion of the Nooksack River into the Sumas River is theoretically possible, ongoing management efforts and existing channel conditions render this extreme scenario unlikely. An avulsion event would result in catastrophic impacts to both communities along the lower Nooksack River and along the Sumas River, ensuring that management activities to prevent this will remain a high priority.

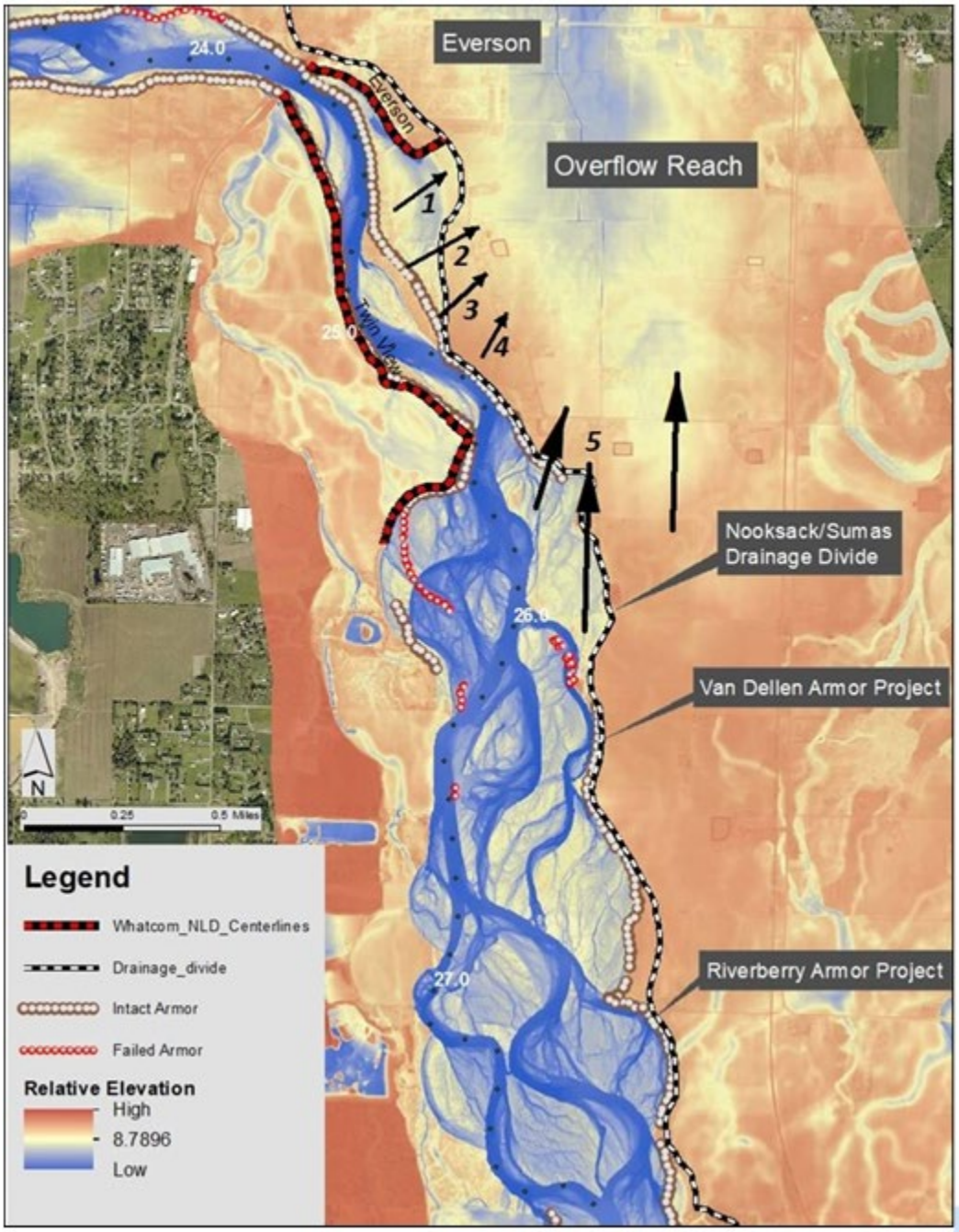


Figure 3. Relative elevation map of the Everson overflow reach showing armor, levees, and primary overflow paths in order of activation. Overflow paths (black arrows) are from the Nooksack River International Task Force mapped locations/magnitudes of overflows (NRITF, 2003).

Sumas Prairie Flood Protection

Sumas Prairie has a flood protection system designed for Sumas River floods but becomes overwhelmed when large Nooksack River overflows coincide with high flows on the Fraser River. Under "normal" Sumas flood conditions, the Sumas Dike directs flows toward Barrowtown Dam. While informally called a "dam", Barrowtown Dam is not a conventional dam

but is essentially an extension of the dike system. Barrowtown Dam includes four manual floodgates that function to keep the Fraser River from backwatering when it is at a high level (spring freshet and extreme wet weather periods in winter).

If the Sumas Dike is overtopped or breached, uncontrolled flood flows enter Sumas Prairie East – the former lake bottom, where it slowly exits via the Sumas Drainage Canal and the Barrowtown Pump Station (adjacent to Barrowtown Dam). Barrowtown Pump Station includes four drainage pumps that continuously pump flow from Sumas Drainage Canal to maintain the water level in the prairie. Two of the pumps can be diverted to pump flow from the Sumas River during the Fraser River freshets when the floodgates at Barrowtown Dam are closed. Importantly, the Barrowtown Pump Station was not designed to accommodate Nooksack River overflows; under winter conditions the Pump Station is typically dedicated to dewatering Sumas Prairie East, and the capacity of these pumps is much less than typical flood flows due to Nooksack River overflow.

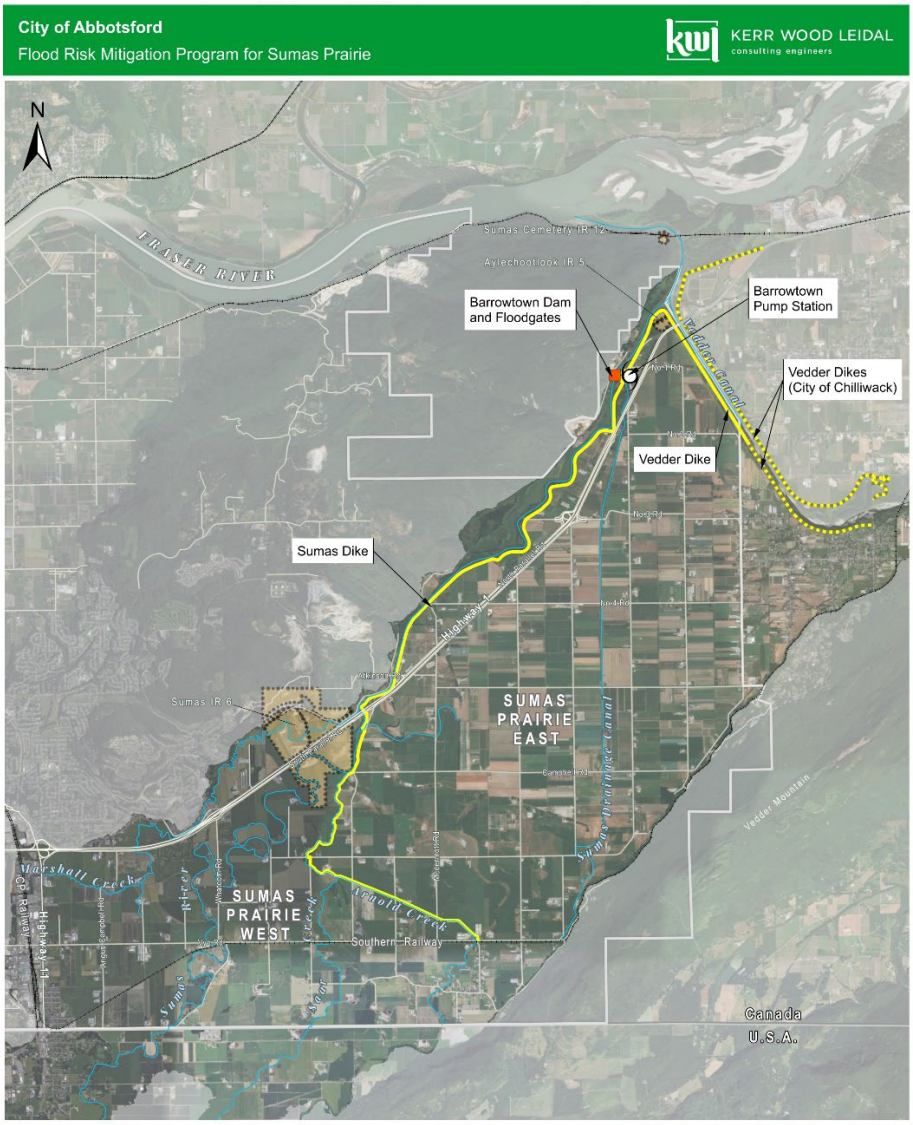


Figure 4. Map of the Sumas Prairie near Abbotsford, B.C. and flood protection works. Lands east of Sumas Dike are referred to as the former Lake Bottom by the Semá:th people.

IV. Flood Risk Reduction Strategies

U.S. Resiliency Planning

With the high level of uncertainty inherent in predicting future Nooksack River floods and overflows due to difficulty gaging flood flows, the large sediment transport supply/capacity and climate change projections, one core strategy for reducing risk is retreat from flood prone areas. Whatcom County's levee system is largely designed to withstand moderate flood events, and to overtop during large flood events. With more frequent large flood events, it has become critical to prioritize removal of residential structures from the floodway. Since the 2021 flood, Whatcom County has applied for nearly $50M in federal and state grant funding to support

property acquisitions and elevating homes in flood prone areas. The Everson overflow corridor and the community of Sumas, WA are priority areas for acquisitions. Since the 2021 flood, ten properties in the overflow corridor have been acquired, and five are currently in negotiation (as of February 2024).

Everson "Widen the Funnel" Concept

One key flood risk reduction strategy for the Everson overflow corridor is currently focused on assessing how to restore process-based functionality at the flow split, so that the river will be better able to accommodate sediment and water flow, within natural variability, and into the future with climate change. Whatcom County's FLIP process evaluated the capital project options shown in Table 2 for reducing flood risk in the Everson overflow corridor. Many of these options would divert flow from one flow path to another, potentially transferring flood risk from one area to another. "Widen the funnel" is a concept that refers to expanding the Everson "erodible corridor" by setting back levees and riprap within an approximate one-mile (1.6 km) river section upstream of the Everson Bridge on the left bank (non-overflow side). This would allow the river to move laterally and mobilize sediment stored in the floodplain, creating more local conveyance within the river channel, and restoring some of the river's capacity that was lost due to floodplain management practices and recent sediment aggradation. However, additional sediment transport modeling is needed to better understand how this could impact the flow of sediment and floodwater to downstream reaches of the river, including if sediment mobilization would impact fish habitat and treaty reserved fishing rights for tribal fishers downstream. Habitat elements will need to be included for this to move beyond concept phase to an alternative design. Preliminary hydraulic modeling has been completed to understand the expected magnitude of impact on the flood levels in the Everson overflow corridor and the floodplain downstream of Everson. Further work is needed to determine if the Everson bridge is creating backwater during floods and contributing to aggradation, that may also need to be addressed. Evaluation criteria are being developed and are yet to be applied to these projects to evaluate multiple-objective benefits based on the shared values developed by the FLIP stakeholders.

Table 2. Project concepts in the Everson overflow area (Figure 2) currently being evaluated with the calibrated 2D Nooksack River Hydraulic Model. ***These concepts have not yet been evaluated for habitat and other shared values.*** *(June 2023 Technical Memorandum, Herrera).*

Whatcom County Flow Split Early Project Concepts		
Option	**Option Name**	**Option Description**
A1	**Twin View Levee Setback/ Openings/Removal**	1,000 foot setback, for 2,000 feet length with roughly same top elevation profile as existing levee, at pinch point.
A2		Levee lowered to ground height (i.e., removed).
A3		Opening on Nooksack River left bank, just upstream of Everson Bridge for various widths.
A4		Various combinations of setback distances from river, lengths along river, levee elevations and locations (e.g., at pinch point and near Scott Ditch Overflow).
B1	**Berms**	Berms containing a flood flow corridor between developed land in the cities of Everson and Nooksack.
B2		Varying height and/or combinations of berms to route flood flow around developed areas on the eastern side of Sumas.
C1	**Side channels**	Left bank upstream of Everson bridge (much wider than existing side channel).
C2		Connect existing right bank channel, upstream of Everson Bridge near Lagerway Dike.
D1	**Scott Ditch Overflow**	~500 foot-wide opening centered on existing low ground at Everson Road in the left-bank (west) floodplain to route more flood flow into upstream end of Scott Ditch.
D2		Various opening widths centered on existing low ground at Everson Road in the left-bank (west) floodplain.
E1	**Everson-Sumas Overflow Corridor Projects**	SR 9/Easterbrook Road/RR upstream of Sumas conveyance opening.
E2		Regrade floodplain south of Sumas for high flow channel.
E3		Raising various roads in the overflow corridor (for storage).
F1	**Widen the Funnel**	1,500 foot-wide unrestrained channel migration corridor near upstream end of Twin View Levee tapering to existing Everson Bridge crossing width.
F2		2,000 foot-wide unrestrained channel migration corridor near upstream end of Twin View Levee tapering to existing Everson Bridge crossing width.
G1	**Everson Bridge Widening**	Widen bridge span to south where existing high-flow culvert is located.
G2		Replace existing high-flow culvert with a short bridge, with an "island" between that new bridge and the existing southern bridge abutment.
H-1	**Emerson Road Raising**	No overtopping flow (i.e., road raised high enough to prevent any overtopping flow to north) for Emerson Road, Massey Road, and Lagerway Dike.
H-2		Partial overtopping/raised to various elevations. One configuration to be analyzed to show proof of flood control concept.

Sumas River Watershed Flood Mitigation Planning (SRWFMP)

The primary challenge north of the border is that the volume of water from the Nooksack overflow overwhelms current diking infrastructure that is designed to funnel Sumas River water along the western edge of the floodplain out to the Fraser River. When the Fraser River is high, and the Barrowtown Dam floodgates close (as occurred in both 1990 and 2021), all the inflow from the Nooksack and Sumas River is trapped in Sumas Prairie. In 2021, water overtopped and breached the Sumas Dike (levee) that separates Sumas Prairie West (the unprotected portion of Sumas Prairie that includes the Sumas River channel) from Sumas Prairie East (the portion of Sumas Prairie which is protected by the Sumas Dike and is drained by the Barrowtown Pump Station, including the former lake area). Flood levels in Sumas Prairie East rose enough to threaten Barrowtown Pump Station, the only means to evacuate water from the former lake bottom.

In the future, the possibility of increased Nooksack River overflow (increasing inflow volume to Sumas Prairie) compounds with the potential for higher Fraser River levels (resulting in more frequent and longer floodgate closures) to create an extensive flood hazard area that could be inundated to depths of well over 10' (3 m). Developing a plan to identify and pursue actions for flood risk reduction and ecosystem restoration for collective benefit is the focus of the Sumas River Watershed Flood Mitigation Planning process.

The SRWFMP process is currently in the phase of refining objectives and developing tools to support an assessment of a preferred pathway to reduce flood risk in the region. In moving forward, it will be necessary for the SRWFMP to consider the Nooksack River flow split at Everson. Key factors for consideration are the extent that Nooksack River overflows could be retained with restoration of the floodplain corridor immediately upstream of Everson, feasibility of an overflow control structure that could manage the balance of flow to the Everson overflow and downstream mainstem Nooksack, anticipated changes in overflow due to climate change, and the potential for a worst-case catastrophic event. The timing of potential projects on the Nooksack River are also a key interest for the SRWFMP process.

City of Abbotsford Flood Recovery Works

Following the 2021 flood, the City of Abbotsford received flood recovery funding to repair flood and erosion damage in multiple areas. This included sediment removal, bank protection, dike repair and infrastructure repair. More recently, the City of Abbotsford received C$76.6 million (approximately US$56.7 million) in funding from the Province to support a suite of urgent works, known as the Barrowtown Pump Station Resiliency Project ("Project"). These works include completing critical improvements to improve flood resilience and improve fish passage ability at the Barrowtown Pump Station. The primary focus of the Project is to preserve and enhance the existing capability of the pump station to dewater Sumas Prairie East during heavy

runoff conditions. These works were discussed with SRWFMP partners and are short-term and focused on existing works. This Project does not affect or constrain the wider scope and vision of the SRWFMP or the Nooksack TFI. The Barrowtown Pump Station resiliency is one of the three elements of the urgent works for which the City has applied for financial support through the federal Disaster Mitigation and Adaptation Fund (DMAF) but was not successful.

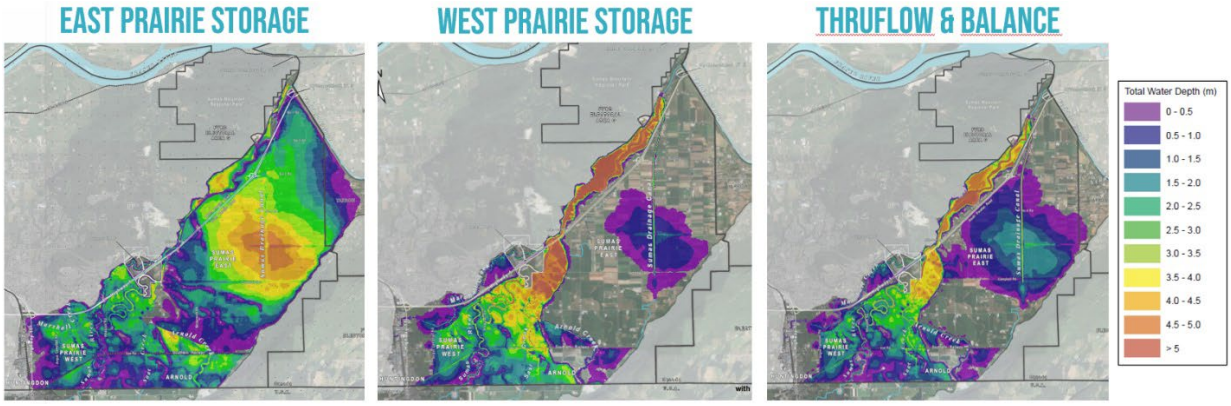


Figure 5. Panels showing inundation of the Canadian portion of Sumas Prairie during a potential future extreme flood event where warmer colors indicate deeper water (5 m = ±16'). Left panel ("East Prairie Storage" shows uncontrolled overflow into the former Lake Bottom. Middle panel ("West Prairie Storage") shows a reinforced dike/levee keeping all river flow out of Lake Bottom. Right panel ("Thruflow & Balance") shows the effects of adding an 8,000 cfs (225 m^3/s) pump station at Barrowtown and sharing the residual flood risk between Sumas Prairie East and Sumas Prairie West. NOTE: for illustrative purposes only, new modeling is currently underway within SRWFMP.

Key Uncertainties and Knowledge Gaps

Ecosystem Restoration

An essential first step in developing integrated flood management solutions is developing a habitat restoration strategy for the Sumas River corridor. Fish passage barriers, safe passage through pump stations, water quantity and quality are major limiting factors in the lower reach of the Sumas River, but a transboundary assessment of the Sumas River watershed – from the Fraser River upstream to key tributaries on the U.S. side, has never been conducted. A habitat restoration plan - identifying restoration goals and evaluating existing habitat and baseline environmental conditions - will provide critical context for identifying needed improvements that can be integrated into a flood and ecosystem management plan. A proactive—not reactive— approach to water quality and discharge of pollutants into surface waters during flooding is needed, particularly for the Sumas system.

Flow Split at Everson

The highly dynamic nature of sediment and high flows on the Nooksack River makes floodplain planning for the Everson overflow corridor and the Sumas Prairie exceptionally difficult. If flows go north during a flood, this decreases the flows to the west, and vice versa. Understanding the

trade-offs in flood risk associated with the flow split is critical. Increased understanding of the dynamic nature of the flow split would facilitate floodplain management planning and flood response for communities along the overflow corridor in Washington and is critical for developing an effective flood mitigation plan for the Sumas region. Better understanding is needed of the effects of existing infrastructure, as well as opportunities to restore habitat, improve fish survival and passage, and improve flood conveyance and flood storage in the Everson area. Extensive hydraulic modeling is currently being done and is needed to inform a comparative risk assessment for flooding on the lower Nooksack River and Sumas Prairie. Key issues currently limiting our understanding and ability to manage the flow split are sediment transport and storage dynamics, climate change, and downstream Nooksack River impacts.

Sediment Management

The most recent science on management of gravel bedded rivers of the coastal Pacific Northwest emphasizes the importance of giving the river more horizontal space to sustain sediment transport and other fluvial processes (Nelson et al., 2023). A "guided meander" river corridor width is the optimization of flood conveyance, channel migration, and riparian buffers in order to maximize flood protection and habitat value. A geomorphic analysis conducted in an unconstrained reach just upstream of the Everson overflow reach indicates that a corridor width of roughly 1500 to 2000 ft (500 to 600 m) may provide the majority of flood conveyance benefits, such that additional width may not add much value. The optimal width for habitat value is still being worked on. Sediment modeling is currently underway to predict the expected river response to the action of widening the erodible corridor to provide some verification of the geomorphic analysis and potential timeframe of channel evolution. Additional modeling is also being initiated to evaluate the impact of the potential increased sediment transport throughout the lower mainstem down to the delta in Bellingham Bay. Aggradation of the Nooksack River on and upstream of the Lummi Indian Reservation is an ongoing problem that is adversely impacting fishing, flooding, access, and withdrawals for the Lummi Bay salmon hatchery. Options for sediment storage in the Nooksack may need to be considered if the modeling indicates an increased rate of aggradation, particularly on and near to the Lummi Indian Reservation.

Climate Change

The anticipated climatic changes in the Nooksack, Sumas, and Fraser Rivers are substantial as they relate to precipitation, snowpack, sediment, flood magnitude, timing, and temperature. The interaction of these hydrologic and geomorphic parameters makes it difficult to predict future flood volumes with any certainty, especially at the location of the overflow. Due to the complex topography in the watershed and the mild maritime region climate, streamflow in the Nooksack River is highly sensitive to fluctuations in temperature. As the upper basin transitions

from a snow-dominant hydrology to a more rain-dominant hydrologic system, more variability is projected. Understanding changes to the frequency and magnitude of Atmospheric River Events (such as the ARE that occurred in November 2021) will be key. A fundamental question is what volume of water is anticipated to enter the overflow route during a 100-year event, a 200-year event, and under climate change conditions? That question, however, is very difficult to answer given the dynamically changing conditions on the Nooksack River system and difficulty measuring discharge with a changing riverbed, including within-event changes. In the case of Sumas Prairie, not only is there a need to plan for potential increased flood inflow scenarios from Nooksack River overflows, but there is also a need to plan for a Sumas River outflow at the Barrowtown Dam floodgates that may be limited if the Fraser River level is higher in winter. Flood mitigation options such as flood storage and/or flood conveyance will need to consider volume increase due to climate change. A range of projected flow estimates over time is needed to inform solutions.

V. Next steps / Opportunities

There are no easy solutions for managing such a complex and dynamic transboundary river system. The Nooksack and Sumas watersheds are the cultural backbone and territory of Tribes and First Nations, and home to residents of six cities in two countries. The Nooksack has three threatened salmonids and supports the treaty rights of Tribes, and supports the region's agricultural economy and culture. Past collaborative efforts have attempted for decades to coalesce around a shared strategy for managing flooding, and yet development in the floodplain continues and the region remains at grave risk of the next big flood. Given this complexity, the problem requires a multi-pronged approach: there is a role for improved flood warning system to inform emergency response, for flood protection works such as dikes and levees, and at the same time a need to retreat from the floodplains, and develop flood resilience strategies to minimize impacts and proactively plan for flooding. Despite the significant challenges the Nooksack and Sumas communities face, there remains great potential to regain a region with a healthy ecosystem that supports priority species and Indigenous cultures, a thriving agricultural economy, and is a safe place to live.

This report is intended to summarize the state of knowledge and inform long-term, multi-basin flood management strategies. The TFI technical table is tasked with determining what strategies are *feasible* to inform the decisions the policy table will have to make to determine what strategies are most *equitable*. Over the next year, the TFI technical table will work to align priorities of the SRWFMP and FLIP local processes and develop compatible timelines. The technical table will continue work to develop a cross boundary hydraulic model which will inform project scoping and develop a framework for an integrated risk assessment. In the

process, building critical relationships and sharing expertise to ensure long-term durable solutions.

Citations

Abbotsford Chamber of Commerce, 2022. *Canada's Agricultural Hub: An Economic Impact Analysis of Agriculture in Abbotsford.* Abbotsford. https://growthzonecmsprodeastus.azureedge.net/sites/92/2023/10/Canadas_Agricultural_Hub_-_An_Economic_Impact_Analysis_of_Agriculture_in_Abbotsford_May-25-2022-Report.pdf

Anderson S., C. Konrad, E. Grossman, and C. Curran, 2019. Sediment storage and transport in the Nooksack River basin, northwestern Washington, 2016-15: USGS Scientific Investigation Report 2019-5008, 43 p., https://doi.org/10.3133/sir20195008. ISSN: 2328-0328 (online)

Boyd, K., P. Pittman, A. Nelson, and T. Thatcher, 2019. Lower Nooksack River Geomorphic Assessment. Report prepared for Whatcom County Flood Control Zone District. https://www.whatcomcounty.us/DocumentCenter/View/39545/Lower-Nooksack-Geomorphic-Assessment-Final-Report-02112019

Chamber of Commerce Abbotsford, 2022. Canada's Agricultural Hub. An economic impact analysis of agriculture in Abbotsford 2022 Report. https://growthzonecmsprodeastus.azureedge.net/sites/92/2023/10/Canadas_Agricultural_Hub_-_An_Economic_Impact_Analysis_of_Agriculture_in_Abbotsford_May-25-2022-Report.pdf

Curry, C.L., Islan, S.U., Zwiers F.W., and S.J. Dery, 2019. Atmospheric rivers increase future flood risk in Western Canada's largest Pacific River. Geophysical Research Letters, 46, 1651-1661. https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018GL080720

Gillett N.P., Cannon A.J., Malinina E., Schnorbus M., Anslow F., Sun Q., Kirchmeier-Young M., Zwiers F., Seiler C., Zhang X., Flato G., Wan H., Li G., Castellan A. Human influence the 2021 British Columbia floods. Weather Clim. Extrem. (2022), Article 100441. https://www.sciencedirect.com/science/article/pii/S2212094724000033#bib1

Hutching, R.M. 2004. Mid-Holocene River Development and South-Central Pacific Northwest Coast Prehistory: Geoarchaeology of the Ferndale Site (45WH34), Nooksack River Washington: MA Thesis, Western Washington University, 160p.

Nelson, A.D., Collins, V.D., Payne, J.S, and T.B. Abbe, 2023. Proactive river corridor definition: Recommendations for a process-based width optimization approach illustrated in the context of the coastal Pacific Northwest. WIREs Water, 2024;e1711.

https://wires.onlinelibrary.wiley.com/doi/10.1002/wat2.1711

Paul, E. "Modeling 21st Century Peak Flows in the Nooksack River Basin in Northwestern Washington State Using Dynamically-Downscaled Global Climate Model Projections" (2023). WWU Graduate School Collection. 1161. https://cedar.wwu.edu/wwuet/1161

Pittman, P., 2019. Lower Nooksack River Geomorphic Assessment Appendix A Geologic and Geomorphic history of the Nooksack River. Report prepared for Whatcom County Flood Control Zone District. https://www.whatcomcounty.us/DocumentCenter/View/39541/Lower-Nooksack-Geomorphic-Assessment-APPENDIX-A

Reimer, C. Before we lost the lake, A Natural and Human History of Sumas Valley. Caitlin Press Inc. 255p.

Ross, P.S., Walters, K.E., Yunker, M. and B. Lo. 2022. A lake re-emerges: Analysis of contaminants in the Semá:th X̱ó:tsa (Sumas Lake) region following the BC floods of 2021. Raincoast Conservation Foundation. Sidney B.C. Canada. ISBN 978-1-9993892-6-0 www.raincoast.org/reports/flood-water/

Shead, R. 2004. Summary of Surface Water Quality Sampling on Sumas River and Tributaries. Abbotsford, British Columbia. https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/monitoring-water-quality/south-coast-wq-docs/sumas_riverwqmonitoring.pdf

WDFW Spawning Ground Survey Database, 2024. https://wdfw.wa.gov/fishing/management/sgs-data