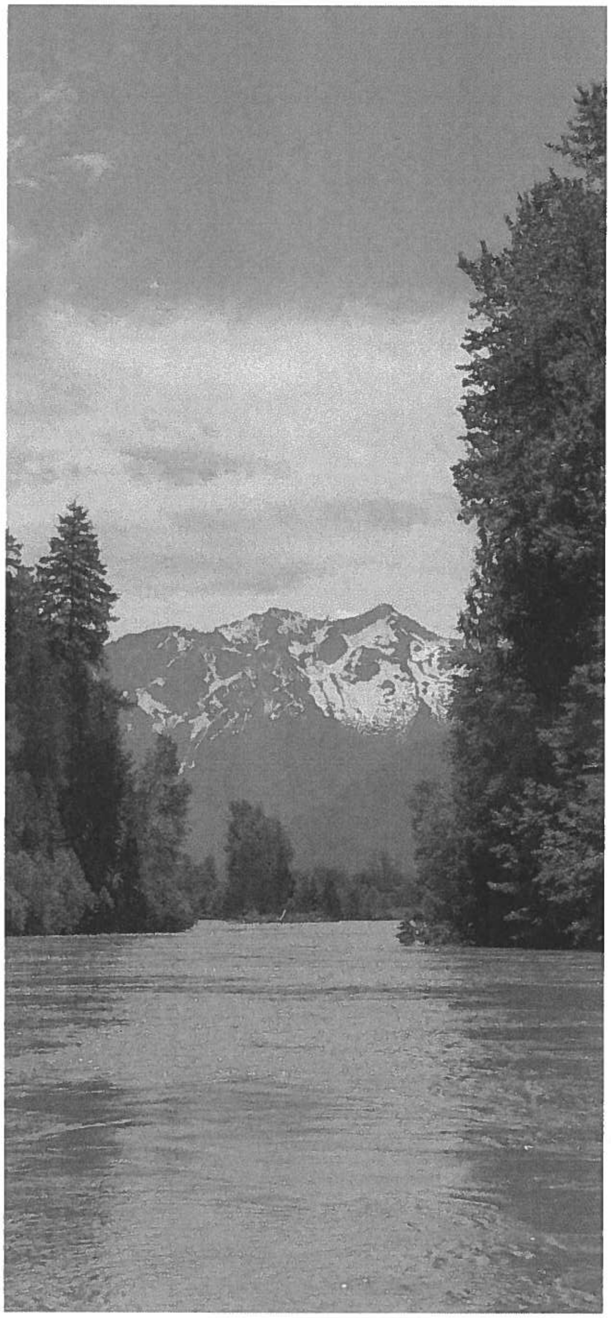

LILLOOET RIVER FLOODPLAIN MAPPING

FINAL REPORT

Prepared for:

VALLEY
DYKING DISTRICT

Pemberton Valley Dyking District Office
1381 Aster St
Pemberton, BC V0N 1B0

Prepared by:
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22 November 2018

NHC Ref. No. 3002903

nhc
northwest hydraulic consultants
water resource specialists

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DISCLAIMER

CREDITS AND ACKNOWLEDGEMENTS

Northwest Hydraulic Consultants Ltd. (NHC) would like to thank the Pemberton Valley Dyking District (PVDD) for initiating this study, making available extensive background information and providing advice and support through-out the project. Key PVDD representative was Mr. Steve Flynn, Operations and Maintenance Manager. Ryan Wainwright, Emergency Program Manager with Squamish Lillooet Regional District; Ernest Arman, COO with Lil'wat First Nation; and, Sarah Toews, Emergency Program Manager with Village of Pemberton, provided additional guidance.

The following NHC personnel participated in the project:

- Surveys (Wil Skitmore, Aaron Snyder, various field staff)
- Geomorphic Analysis (Andrew Nelson, Wil Hilsen, David McLean)
- Hydrologic Analysis (Joel Trubilowicz, Piotr Kuras, Malcom Leytham)
- Hydraulic Modelling (Vanessa Bennett, Chris Long)
- Mapping and GIS (Dawn Lasprugato, Madalyn Ohrt, Sarah North)
- Project Review (Neil Peters)
- Project Management (Monica Mannerström)

Highmark Land Surveying and Engineering Ltd. (Highmark) was retained as a subconsultant to assist with surveys of land features as required.

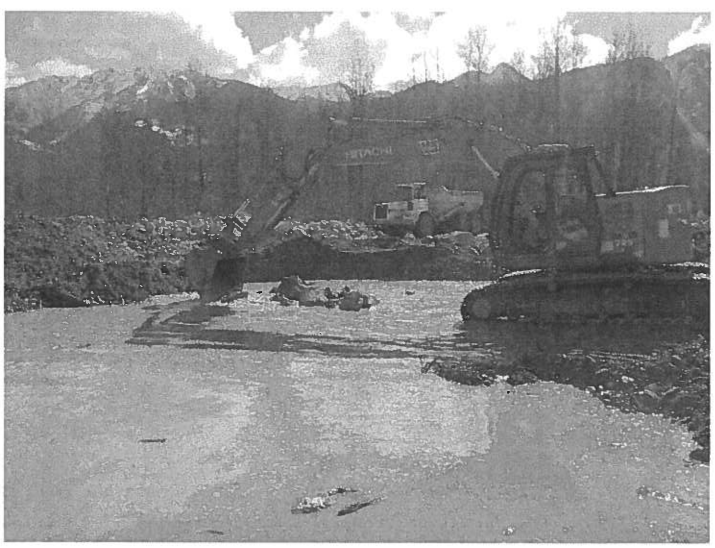
EXECUTIVE SUMMARY

Understanding Flood Hazards in the Pemberton Valley

The Pemberton Valley is prone to flooding - this was already recognized by early Lil'wat inhabitants thousands of years ago and European settlers as they started to arrive at the beginning of the last century. Flow records are available for the Lillooet River for almost 100 years and interestingly show an increase in flood peaks since about the late 1970's.

It is not unusual for British Columbian rivers to have long periods of above or below average floods, this is the result of normal climate variations. However, on the Lillooet this increase in peak flows has been accompanied by a shift in the timing of annual floods. Instead of generally being caused by snowmelt in the spring time, annual peak floods are now more consistently caused by heavy rains in the fall or early winter. The flood flows are the result of intense low-pressure weather systems, or atmospheric rivers. When originating over the Hawaiian tropics, these storms are often referred to as the Pineapple Express, bringing warm, high moisture air towards British Columbia's coastline. The storms may linger for several days and are particularly troublesome when preceded by early snowfall, leading to rapid melt in combination with heavy rains. This shift in timing of the annual flood peak may be permanent and climate change impacts are foreseen to further increase flood flows in the future.

In the 1940's and 50's, the Prairie Farm Rehabilitation Administration introduced measures to reduce flooding in the Valley. The Lillooet River was straightened, bypassing natural bends in several locations; some dikes were constructed and Lillooet Lake was lowered by modifying the lake outlet. In spite of the alterations, the river continued to flood. The Pemberton Valley Dyking District (PVDD) was formed and took on the upgrading and expansion of dikes along the Lillooet River and its main tributaries. Prior to and following the flood of record in 2003, with a peak flow of 1,490 m^3/s, PVDD has completed multiple projects in cooperation with federal, provincial and local governments, and First Nations. These projects have involved raising, widening and lengthening several dikes, protecting river banks from erosion, preventing log jams from building up and removing sand and gravel from the Lillooet River, Miller Creek, Birkenhead River and Pemberton Creek to help maintain sufficient channel capacity to convey flood flows. This work has significantly reduced flood impacts over the past several decades.



PVDD carrying out sediment removal to restore channel capacity.

In 2010, a large landslide occurred on the side of Mount Meager, about 65 km upstream from Pemberton. The slide caused a temporary channel blockage in Meager Creek and Lillooet River but fortunately the material gradually dispersed without resulting in a sudden outburst flood. Subsequently, PVDD commissioned the installation of an early warning system on the Lillooet River to alert against future channel blockages and potential outburst floods, should another large slide occur in the upper valley. Material from the slide is now making its way through the Lillooet River system, affecting the channel stability and the amount of flow the river can carry within its channel. This slide material, in combination with potential increases in flood peaks, means that the available floodplain mapping (prepared by the provincial government in 1990) and the updated dike design profile from 2002 are no longer valid.

Upper Lillooet River showing Meager Slide deposits in the river channel.

Floodplain Mapping – What Is Involved?

Floodplain mapping is highly useful for estimating the extent and depth of different magnitude floods, developing appropriate flood emergency response measures, and planning for future flood resistant development and infrastructure. PVDD, in consultation with other local governments and Lil'wat First Nation, recognized the need for updating the design profile and preparing up-to-date floodplain maps for the Valley. The Dyking District successfully applied for funding from Emergency Management BC, facilitating this important project to go ahead. Northwest Hydraulic Consultants Ltd. (NHC) carried out the work as described in the Lillooet River Floodplain Mapping Final Report, August 31, 2018. The project has made several major advances in knowledge and provides significant new tools to support flood management in the Pemberton Valley. The Final Report describes the work in detail, with main components and related benefits summarized here.

To support the hydraulic modelling and development of mapping, NHC developed a Digital Elevation Model (DEM) of the Valley, including the river channels. Floodplain topography was made available by the Province in the form of Lidar (Light Detection and Ranging) surveys; NHC surveyed by boat the bathymetry of the Lillooet River from Lillooet Lake to just upstream of the Forest Service Road Bridge and the tributary rivers. The two sets of surveys were converted to a consistent datum (CGVD2013) and combined in the DEM. Considerable effort was required to convert all historic information to this datum as various reference elevations have been used in the past.

NHC surveying on the river.

Considering the major channel changes that have taken place following the Mount Meager Slide, NHC carried out extensive fieldwork and geomorphic investigations to fully understand the Lillooet River sediment issues and their impacts, particularly those related to the changing flow capacity of the river channel. This work is described in the Geomorphic Atlas included as an appendix to the main report. Sediment supply will decrease over time but will remain high for several decades. The slug of coarse sediment moving down the river has increased channel instability in the upper river; the sand and fine gravel has already reached the depositional zone downstream of Ryan River confluence. Since 2011, the annual average channel bed elevation over the lower 35 km of the river has increased by about 0.4 m. As the coarse material enters the study reach, the channel bed will potentially infill an additional 0.5 m by 2025, further increasing flood levels.

NHC undertook hydrologic analyses to estimate the Lillooet River flows corresponding to the 50, 100 and 200-year flood events, including the 200-year flood incorporating projected climate change impacts by the end of the century. In view of the observed significant changes in timing and magnitude of peak flows, NHC based flood estimates on post-1975 flow records rather than the entire historical period. A 40+ year period is considered statistically significant for estimating the 200-year flood and resulted in much higher estimates than those previously developed by others.

The current 50-year flood estimate is slightly higher than the flood-of-record in 2003, and the current 200-year flood estimate is 39% higher than the value used for the 2002 profile update. Given the shift from spring freshet to fall/winter flood peaks, the higher design flows are considered to be more realistic than previous estimates and, therefore, the new estimates were used for updating the floodplain mapping and design profile. Previous studies assumed that the 50, 100 and 200-year tributary floods would occur during regional events with the Lillooet flood of the same return period, but that the timing of the peaks would differ. We took a different approach, instead estimating tributary flows (Ryan River, Miller Creek, Pemberton Creek, Green River and Birkenhead River) likely to coincide with the Lillooet design flows.

A numeric hydraulic model uses a DEM as input and then calculates water levels corresponding to certain inflows and boundary water levels, in this case Lillooet Lake. Past Lillooet studies used 1D hydraulic model software for simulating flood levels. Considerable improvements have been made to software products and computing power has increased significantly. NHC developed a leading-edge 2D model of the rivers and floodplain. The model has several advantages over previous 1D models, allowing for more detailed representation of flood waters. The model was calibrated and validated to observed water levels and flows and then used to simulate the 50, 100, 200 year and 200 year + climate change floods.

The simulated flood profiles allowed comparison with surveyed dike crest elevations to estimate the flows when dikes may start to overtop. Some overtopping is likely at the 50-year flood and the present diking will not adequately protect against the 200-year flood. The present work generated animations of floods progressing through the valley as the result of dike overtopping and breaching. This information is particularly useful for planning emergency response. In some locations warning time is minimal and the animations form a key tool for planning. The model will allow simulation of potential future up-grades to specific dikes such as the "Miller-Lillooet-Pemberton Ring Dike" and assessment of impacts to adjacent areas.

Three types of map products were produced:

- Designated floodplain maps depicting 200-year flood levels plus a freeboard allowance of 0.6 m.
- Flood depth maps for the 50, 100 and 200-year floods.
- Flood hazard maps showing a Hazard Rating based on flood depths and flow velocities.

The designated flood maps show the extents of flooding and include Flood Construction Levels (FCLs), the minimum level for construction. The Village of Pemberton, the Squamish Lillooet Regional District and Lil'wat First Nation have the authority to designate the maps as official floodplain mapping for their areas. The flood extents are fairly similar to the 1990 maps but FCLs are considerably higher due to: 1) the increased 200-year flood flow; 2) the reduced channel flow capacity due to the Meager slide; and, 3) the more accurate modelling methods applied. The flood depth and hazard maps are primarily intended for emergency response planning.

Moving Forward

The Pemberton Valley is now one of relatively few communities in BC with up-to-date floodplain maps, providing valuable opportunities for improving flood safety and emergency response in the Valley. By sharing the results and educating key authorities, stake holders and the public, PVDD will help reduce potential loss-of-life and flood damages during future extreme flood events.

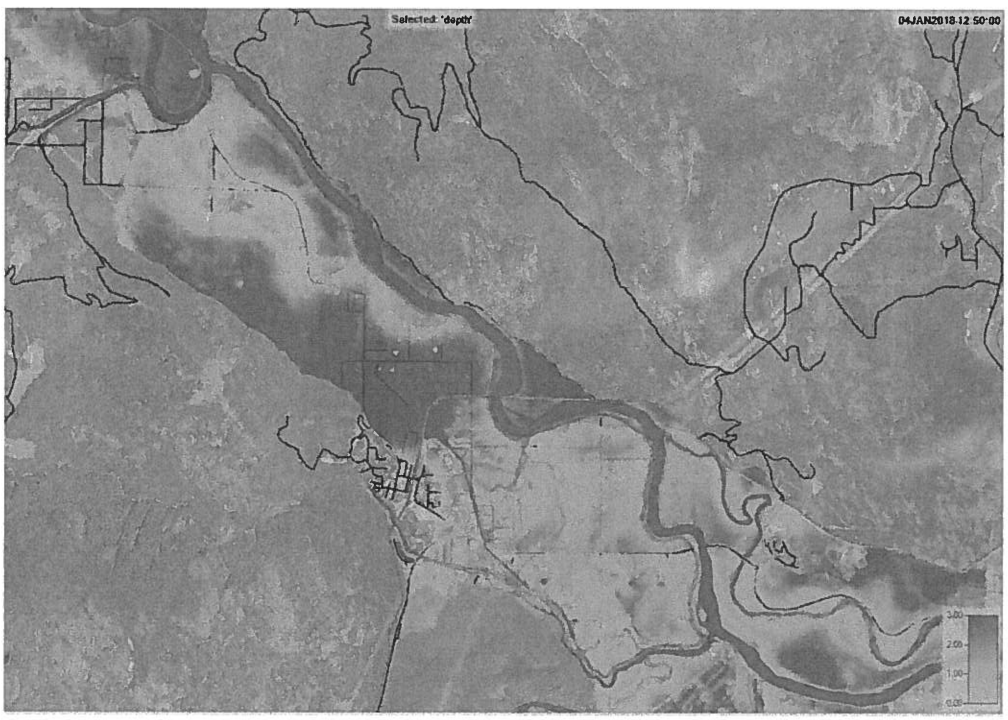
Planning new development away from high hazard areas and implementation of the Lillooet River updated FCLs will lead to more flood resilient development. Access and egress routes requiring improvement can readily be identified and the location of temporary evacuation areas determined. Substantial dike upgrades are likely to be costly and a dialogue regarding tolerable flood risk should be initiated. Consideration should also be given to relocating or floodproofing existing housing and other development in extreme flood hazard areas.

As the material from the Meager Slide moves through the river system, it is critical that the current sediment management program be intensified. Preferably, DFO and the province should grant a standing agreement for regular removals of sand and gravel from key locations in the river. The feasibility of installing a sediment trap upstream of the Forest Service Road Bridge should be explored.

It is clearly important that WSC continues to maintain their primary gauge on the Lillooet River near Pemberton and that the stage-discharge relationship be kept up-to-date. Gauges on the tributaries should be reinstalled, the Birkenhead gauge being particularly important. The water level gauge installed by NHC at the Forest Service Road Bridge provides important emergency notification in the event of an upstream channel blockage and should be monitored and maintained. The provincial River Forecast Centre needs to be aware of the increased flood vulnerability of the Valley.

We recommended that tributary 200-year floods also be modelled to develop corresponding FCLs on the tributaries. Modelling the Birkenhead River is a priority for the Lil'wat First Nation.

The Lillooet River channel is highly dynamic and the hydraulic model and mapping will need to be updated over time. Considering the ongoing aggradation, the river channel should be monitored and re-surveyed every 5-10 years and the hydraulic model updated as required. During future flood events, high water marks should be obtained to allow for future model calibration.



Progression of 200-year Lillooet River flood. Still image from model animation.