CHAPTER 7 PRIMARY RECOMMENDATIONS

Chapter 3 through to Chapter 6 provide detailed recommendations at the end of each chapter for those study components. The reader is referred to each of those chapters for a complete list of recommendations as these are not re-summarized here. This chapter provides the primary recommendations from this study with additional detail provided to assist in any future work. The first recommendation listed, update of the operational guidelines, is a preeminent recommendation as it is required to help ensure the flood hazard for the design event is not greater than that presented in the report and accompanying maps.

7.1 Critical Study Assumption: Modifications to the OLRS Operating Plan

The floodplain maps produced from this study are based on inflows projected to the middle of this century. Magnitudes of the design events are expected to exceed the capacity of the existing infrastructure if operational rules are not adjusted to account for the changing climate. Preliminary modifications to the OLRS Operating plan and guidelines were developed to mitigate projected future increases in floods. If these modifications, or similar mitigations, are not implemented, then the resulting flood flows and levels of the design events are expected to be more severe than mapped.

The preliminary modifications were based solely on flood control. Prior to implementation, any changes to the operational plan is expected to require review initially with the Okanagan Nation Alliance and Canadian Okanagan Basin Technical Working Group (COBTWG) and then with a wider stakeholder group. Given the currently projected rate of change in floods due to climate change, review and subsequent implementation of revised operational rules is recommended within the next five years. The Raven ORB model can be used to explore and optimize different OLRS operation schemes for current and projected conditions. At the time of this future review, any updates to climate projections should be reviewed to assess the most up-to-date expectations on future climate.

The climate projections used for this study followed the most recent, accepted projections available; that is, World Climate Research Programme (WCRP) Coupled Model Intercomparison Project Phase 5 (CMIP5)[1], which was undertaken by the WCRP in support of the IPCC 5th Assessment Report[2]. Climate models have recently been updated with Coupled Model Intercomparison Project Phase 6 (CMIP6) [3]. Release of these results is scheduled for 2020; the IPCC 6th Assessment Report is due for release in 2022[4].

7.2 Okanagan Lake Dam and Mainstem Dams

This study did not include an assessment of the consequence of dams overtopping, malfunctioning, dam failure, or the mainstem dams not being operated as designed.

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[1] https://www.wcrp-climate.org/wgcm-cmip/wgcm-cmip5 , accessed 31 March 2020.

[2] https://www.ipcc.ch/report/ar5/syr/ , accessed 31 March 2020.

[3] https://www.wcrp-climate.org/wgcm-cmip/wgcm-cmip6 , accessed 31 March 2020.

[4] https://www.ipcc.ch/report/sixth-assessment-report-cycle/ , accessed 31 March 2020.

The 2017 freshet resulted in peak lake levels in Kalamalka and Okanagan lakes that exceeded their previously estimated 200-year ARI level (1991 floodplain mapping), and were the highest levels that have occurred since the dams were built (AE, 2017b). Temporary flood barriers (sandbags) on the west side of Okanagan Lake Dam were necessary during the 2017 freshet peak to contain water within the lake and prevent flow around the west side of the main dam and over the (lower) adjacent land (see Photo 1-2). Based on the Lidar data used in this study, the elevation of the adjacent land (~343.12 m CGVD2013) to the west of the dam is lower than the dam crest, and the water level at the time of the 2017 Lidar (343.479 m CGVD2013), which was 0.36 m higher than ground. Preliminary simulation of the maximum flow that could reach the Okanagan River downstream of the dam if the temporary barriers failed, is approximately 275 m^3/s. This is more than double the design flood from Okanagan Dam used for the floodplain mapping of this reach (Table 3-32).

The scope of the current study did not include dam or dike breach analysis. Typically dam breach analysis is conducted as part of a dam safety analysis by the dam owner and is not incorporated in floodplain mapping or mitigation analysis. While the simulation of flow around the dam is preliminary and should not be used for any assessment, it highlights a risk that is recommended to be evaluated by the dam owner. The following is a list of dam-related study recommendations:

- Low elevation land to the west and east of Okanagan Lake Dam should be evaluated along with the risk of overflow during flood events. Mitigation measures should be identified and planned for as appropriate.
- Develop formal high-water operating rules and/or emergency plans for each reservoir.
- Risk of dam operations (e.g. blockage or malfunction) that could lead to rapid and/or uncontrolled rise in lake levels, or rapid drawdown and release to the downstream channel should be assessed.
- Infrastructure upgrades should be investigated for each dam with two objectives:
  - Increasing outflow capacity from Okanagan and Kalamalka lakes so that rapidly rising water levels can be responded to more quickly than is currently possible; and,
  - Increasing the capacity of the Okanagan River (e.g. reactivation of side channels, lower floodplain levels, set back dikes) for fish habitat and to increase flow conveyance and also dissipate flood flows. Opportunities that improve fish habitat should be prioritized.
- The current Raven ORB model coupled with hydraulic models of the dams could be used for future Dam Safety reviews, including simulation of the PMF with some model refinement. This can aid in assessing dam breach scenarios, reviewing the mainstem dam consequence classifications (CDA, 2013), and improving emergency response plans.
- As larger flood events become more common and the climate and hydrology of the basin change, it is likely that infrastructure upgrades will become necessary. It should be expected by dam owners that their infrastructure will have to be reassessed and potentially upgraded, possibly multiple times over the coming decades, as climate of the Okanagan region continues to change.

- Further refinement of the rating curves for each dam is recommended to improve reliability in the understanding of discharge through the structures during emergency spills. Limited rating curves, consisting of a one gate open scenario, currently exist for the flow control gates at the outlet of Kalamalka-Wood, Okanagan, Skaha, and Vaseux lakes (WaterSmith Research Inc & Streamworks Consulting Inc, 2014). While total outflow is currently monitored with the use of near real-time discharge data from downstream gauges, this does not allow for such well-informed operations in the case of an outage (during which the real-time data may not be available), which could potentially be needed during an emergency. The real-time gauge data is also reliant on rating curves specifically developed for the river, which may shift and are preliminary until reviewed and published by WSC, with the discharge data reported by the gauge being uncertain during operation.

7.3 Climate Data and Flood Forecasting

The following recommendations are provided for climate monitoring and flow forecasting:

- Automating high-elevation climate stations for which the data is currently manually collected or on a volunteer observer network:
  - It was identified that the ECCC Vernon Silverstar (1128584) is missing most of the critical temperature and precipitation data from the pre-freshet/freshet periods (April-June) for 2016-2019 due to the manual data collection being intermittent. This station's data is being used in the development of climate grids by NRCan[1] and PCIC[2], and being the only higher elevation EC station in the Okanagan Valley, it influences the interpretation of high elevation precipitation and temperature in the development of the climate grids. As a result of the missing station data, the climate grids for 2016 and 2017 were erroneous (as identified through comparison to SWE data from high elevation snow pillows, which are not directly used in climate grid generation) and could not be used to simulate these freshets with the hydrologic model.
- Include SWE data directly in the generation of future climate grids.
- Installing additional high-elevation climate stations with the number and distribution throughout the ORB based on an assessment of the spatial variability of climate and apparent gaps.
- Improve lower elevation snow monitoring and include this data in flow forecasting models.
- The Raven ORB model could be used for improved water supply forecasting in the basin; however, it is expected that over time, current forecasting methods will be inadequate due to changing peak timing and the approach to forecasting will need to be re-examined in the

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[1] https://cfs.nrcan.gc.ca/projects/3, accessed 31 March 2020.

[2] https://www.pacificclimate.org/, accessed 31 March 2020.

future. This could involve further exploration into improving long-term forecasting of inflows to the ORB.

- It is recommended that the influence of the Similkameen-Okanogan confluence on Osoyoos Lake levels be simulated with a hydraulic model, and that these results be used to develop a three-dimensional relationship between Similkameen River flow, Okanogan River at Oroville flow, and Osoyoos Lake water level. This relationship could then be used to link a Similkameen hydrologic model to the Raven ORB hydrologic model.

7.4 Mainstem Lakes Data Collection and Further Study

The wave results in this study are limited by the accuracy of the data used. Assessing the impacts of wind and waves on the mainstem lake shorelines could be improved in the following ways:

- Bathymetric surveys (particularly in the nearshore) could improve the accuracy of the nearshore wave results; the available bathymetry for several lakes is particularly coarse, including the narrowing of Osoyoos Lake at Highway 3. This data would improve site specific assessments (but could be collected as such assessment are conducted) in addition it would improve any future revisions to the current study. Site specific assessment is recommended for any locations that appear to vary from the referenced generalized shoreline profile or for sizable developments.
- Implementation of wind and wave buoy data collection on Okanagan Lake. Wave data was not available for this study and was simulated without model calibration; wind data was used from Penticton and Kelowna along with short term wind data collected on the lake in a past study (Spence and Hedstrom, 2015).
- Landslide generated tsunamis have been documented in Okanagan Lake over the last 80 years and can result in runup in excess of that calculated for the wind generated wave events. More detailed study of potential landslide zones, the generation and propagation of tsunamis, and subsequent runup zones should be conducted and added to the floodplain maps. Further work is recommended in assessing tsunami hazard in the Okanagan Valley overall, and that this be provided at minimum as information on floodplain maps or included in FCLs where relevant.

7.5 River and Dikes

The Okanagan River dikes generally contain large floods, but these could fail through stability and seepage mechanisms and can breach even if not overtopped. Where vulnerabilities exist is where the dikes are overtopped and where non-gated culverts are present. The open culverts are a source of floodwater onto the floodplain and can contribute a significant amount of water that can spread a large distance during a long flood. During high flows, particular attention should be paid to the dikes to ensure they are not overtopping, eroding, and that piping through / under the dike is not occurring. If the dike should fail, a large amount of water could access the floodplain. It should be noted that while non-gated culverts may increase flood risk on the landside of the dikes, they may also act to reduce dike geotechnical failure risk by reducing the differential head across a dike.

Dike assessments and surveys were not completed as part of this study but are recommended for future work. A dike vulnerability assessment would help identify low and weak spots in the dikes and show the available freeboard. Dike crest surveys could be used to update the dike crest heights used in the modelling to support future dike investigations for the Okanagan Basin.

7.6 Flood Event Monitoring

HWMs should be collected during all flood flow events (i.e. floods in excess of the 10-year flood). This information is useful for model calibration and validation, which should be done following any large flood event. The HWM's should be taken along the entire profile of the modelled reach with sufficient spacing to capture any substantial breaks in slope (i.e. such as upstream and downstream of all hydraulic structures and any constrictions or change in slope). The HWM's for a particular flood event should be collected at the same flow, ideally near the peak of the flood event. The HWM can be staked during the flood and surveyed after it recedes as long as the duration is not so long following the flood that the HWMs maybe damaged or moved.

7.7 Floodplain Mapping, Applications, and Website

Recommendations for future work include:

- Keep the study and website live and up-to-date and continue to share the information on flood hazard with local communities through in-person workshops and discussions to ensure the information is available and accessible. These workshops help the community through dissemination of information about the hazard, identifying what matters to the community and stakeholders, educating people on the issues and options, as well as identifying and building momentum to proceed with further flood risk reduction measures.
- Develop a comprehensive risk reduction plan. This plan should take a risk-based approach to flood mitigation, include stakeholder priorities, be developed for the short, medium, and long term, consider climate change, and strive for consistency between jurisdictions. Key steps in plan development are:
    - Assessment of existing structural and non-structural flood mitigation measures;
    - Assessment of flood risk to identify areas of high risk and in greatest need of further flood mitigation, and to inform prioritization of mitigation measures; and,
    - Identification of structural and non-structural risk mitigation measures and development of an actionable plan to implement the measures.

Re-evaluate and maintain studies associated with the plan including floodplain mapping, risk assessment, and mitigation planning to reflect changes in risk related to hazard likelihood or consequence. Flood hazard maps should be reviewed at least every 10 years and updated if there are changes to conditions such as the design flood, channel geometry, new flood hazards, dike construction, or floodplain development, as recommended by EGBC (APEGBC, 2017).

REFERENCES

Acres International Ltd. (1986). *Osoyoos lake control structure*. Report to Washington State Department of Ecology and British Columbia Ministry of Environment.

AE (2017a). *Regional District of Okanagan-Similkameen Area “F” OCP Update Technical Background Report*. Associated Environmental Consultants Ltd. [online] Available from: http://www.rdosmaps.bc.ca/min_bylaws/planning/F_OCP_Review_2017/Background_Technical_Report_.pdf (Accessed 27 March 2020).

AE (2017b). *Review of 2017 Flood Response: Okanagan Lake Regulation System and Nicola Dam, prepared for Ministry of Forests, Lands, Natural Resource Operations & Rural Development*. Associated Environmental Consultants Ltd.

AIDR (2017). *Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia - Handbook 7*.

Alexander, C. A. D., Hyatt, K., and Symonds, B. (2013). *The Okanagan Fish/Water Management Tool (v.2.4.000): Guidelines for apprentice water managers.* Prepared for Canadian Okanagan Basin Technical Working Group, Kamloops, BC. 129 pp. [online] Available from: https://essa.com/explore-essa/projects/the-okanagan-fish-water-management-tool.

Anon (1996). *Emergency Program Act*.

APEGBC (2017). *Flood Mapping in BC, APEGBC Professional Practice Guidelines, V1.0*. The Association of Professional Engineers and Geoscientists of British Columbia, Burnaby, BC. 54 pp.

Arino, O., Perez, J. R., Kalogirou, V., Defourny, P., and Achard, F. (2009). *GLOBCOVER 2009*. European Space Agency, Frascati, Italy. 3 pp.

Asquith, W. (2011). *Univariate distributional analysis with L-moment statistics using R* (PhD thesis). Texas Tech University.

Associated Engineering (2012). *Okanagan Lake Dam Structural Integrity and Seismic Analysis*. Ministry of Forests, Lands and Natural Resource Operations. 165 pp.

Associated Engineering (2016). *Regional District of Central Okanagan Regional Floodplain Management Plan: Phase 1. Final Report.* [online] Available from: https://www.regionaldistrict.com/media/204180/Floodplain_Phase1.pdf.

Associated Environmental (2019a). *Climate Data Expansion to Encompass US/Canada Similkameen, data update, no report.*

Associated Environmental (2019b). *Okanagan Climate Data Updating Project, Report to the Okanagan Basin Water Board.*

Associated Environmental (2020). *Okanagan Hydrologic Models for Long-term Water Planning & Management* (2018-8215.000.008). Okanagan Basin Water Board, Vernon, B.C. 143 pp.

Ausenco-Sandwell (2011). *Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use: Sea Dike Guidelines*. Report prepared by Ausenco-Sandwell for BC Ministry of Environment. 59 pp.

Barnes, H. H. (1967). *Roughness Characteristics of Natural Channels*. U. S. Government Printing Office, Washington.

BC (2016). *British Columbia Emergency Management System*.

B.C. Environment (1991). *Report on Frequency Analyses of Flood Flows and Levels for Okanagan Valley Mainstem System* (S511 S5211). B.C. Environment Water Management Division Hydrology Section, Okanagan, BC. 13 pp.

BC Ministry of Agriculture, and Agriculture and Agri-Food Canada (2010). *Okanagan Water Demand Model (OWDM)*. [online] Available from: https://www.obwb.ca/wsd/models/okanagan-water-demand-model.

BC Ministry of Environment (2019). Bathymetric Maps Query. Fish Inventories Data Queries (FIDQ). [online] Available from: http://a100.gov.bc.ca/pub/fidq/viewBathymetricMaps.do (Accessed 22 March 2019).

BC MoE (2011). *Climate Change Adaption Guidelines for Sea Dikes and Coastal Flood Hazard Land Use, Guidelines for Management of Coastal Flood Hazard Land Use*. BC Ministry of Environment.

BC MOE, Environmental and Engineering Service Water Investigations Branch (1976). *Vaseux Lake - Bathymetric Plan of Lake*. [online] Available from: http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=1404.

BC MOE, Environmental and Engineering Service Water Investigations Branch (1979). *Skaha Lake - Bathymetric Plan of Lake*. [online] Available from: http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=1374.

BC MOE, Environmental and Engineering Service Water Investigations Branch (1981). *Osoyoos Lake - Bathymetric Plan of Lake*. [online] Available from: http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=1265.

BC Water Resources Service (1974). *Summary Report of the Consultative Board, including the Comprehensive Framework Plan. Report prepared for the Canada-British Columbia Okanagan Basin Agreement*.

BCFWR (2018). *Addressing the New Normal: 21st Century Disaster Management in British Columbia*.

Bean, S., and Oldrich, H. (2011). North Beach Rock Slide, Summerland, BC Movement Monitoring and Analysis. *Geohazards*, 104.

Bergstrom, S. (1995). The HBV Model. In V.P. Singh (Ed.), *Models of Watershed Hydrology* (pp. 443–476). Water Resources Publications, Highlands Ranch, CO.

Booij, N., Haagsma, Ij.G., Holthuijsen, L.H., Kieftenburg, A.T.M.M., Ris, R.C., van der Westhuysen, A.J., and Zijlema, M. (2004). *SWAN User Manual SWAN Cycle III Version 40.41*. Delft University of Technology, The Netherlands.

Brunner, G. W. (2016). *HEC-RAS River Analysis System. Hydraulic Reference Manual. Version 5.0*. Davis, CA.

CDA (2013). *Dam Safety Guidelines 2007 (2013 Edition)*. 88 pp.

Chow, V. T. (1959). *Open Channel Hydraulics*. McGraw-Hill Book Company, New York.

Craig, J. R., Brown, G., Chlumsky, R., Jenkinson, W., Jost, G., Lee, K., Mai, J., Serrer, M., Snowdon, A. P., Sgro, N., Snowdon, A., and Tolson, B. A. (2020). Flexible watershed simulation with the Raven hydrological modelling framework. *Environmental Modelling & Software*, 104728. doi:10.1016/j.envsoft.2020.104728.

Craig, J. R., and the Raven Development Team (2019). *Raven user's and developer's manual (Version 2.9)*. 182 pp. [online] Available from: http://www.civil.uwaterloo.ca/jrcraig/Raven/Main.html (Accessed 13 March 2019).

Curry, C. L., Islam, S. U., Zwiers, F. W., and Déry, S. J. (2019). Atmospheric rivers increase future flood risk in Western Canada's largest Pacific river. *Geophysical Research Letters*. doi:10.1029/2018GL080720.

DHI Water & Environment (2010). *Okanagan Basin Water Accounting Model, Final Report. Prepared for Okanagan Basin Water Board.* [online] Available from: https://www.obwb.ca/obwrid/docs/338_2010_OBWAM%20Final%20Report.pdf.

Dobson, D. (2004). Chapter 13: Hydrology and Watershed Management. *Okanagan geology, British Columbia (2nd Edition (Ed. by M. A. Roed and J. D. Greenough)*. Sandhill Book Marketing.

Ecora (2019a). *Comprehensive Engineering Assessment of the OLRS Drainage Works- Version A* (GK-17-625-MOF). Prepared by Ecora for Ministry of Forests, Lands, Natural Resource Operations & Rural Development.

Ecora (2019b). *Swan Lake Dam Operations Plan* (GK-18-729-MOF). BC Ministry of Forests and Lands, Natural Resource Operations and Rural Development. 124 pp.

EGBC (2018). *Legislated Flood Assessments in a Changing Climate in BC, Version 2.1*. Engineers & Geoscientists British Columbia, Burnaby, BC. 192 pp.

EurOtop (2018). *Manual on wave overtopping of sea defences and related structures. An overtopping manual largely based on European research, but for worldwide application.* Van der Meer, J.W., Allsop, N.W.H., Bruce, T., De Rouck, J., Kortenhaus, A., Pullen, T., Schüttrumpf, H., Troch, P. and Zanuttigh, B. [online] Available from: www.overtopping-manual.com.

EXCIMAP (2007). Flood mapping: a core component of flood risk management - Atlas of Flood Maps: Examples from 19 Countries, USA and Japan. European Commission - Environment. [online]

Available from: http://ec.europa.eu/environment/water/flood_risk/flood_atlas/ (Accessed 13 August 2018).

FBC (2016). *Lower Mainland Flood Management Strategy: Phase 1 Summary Report*.

FEMA (2013). *Analysis and Mapping Procedures for Non-Accredited Levee Systems, New Approach, Federal Emergency Management Agency (FEMA)*. Federal Emergency Management Agency.

Ferguson, H. L., Foweraker, J. C., Hall, P. L., Halstead, E. C., Hunter, H. I., Leach, T. A. J., Le Breton, E. G., and et al. (1974). *Technical supplement I to the final report on water quantity in the Okanagan Basin*. Office of the Study Director, Penticton: Canada British Columbia Okanagan Basin Agreement. 553 pp pp.

Fisheries and Oceans Canada (2019). CHS Digitial Data Portal. Licence Request Portant. [online] Available from: https://inter-j01.dfo-mpo.gc.ca/registry-registre/orderMap-commanderCarte?lang=eng (Accessed 22 March 2019).

FLNRORD (2018). *Flood Hazard Area Land Use Management Guidelines, originally Ministry of Water, Land and Air Protection, Province of British Columbia, May 2004, amended January 2018 by the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD)*. Ministry of Forests, Lands, Natural Resource Operations and Rural Development.

Flood Control Division, River Bureau, Ministry of Land, Infrastructure and Transport (MLIT) (2005). *Flood Hazard Mapping Manual in Japan*. Ministry of Land, Infrastructure and Transport. 87 pp. [online] Available from: http://www.icharm.pwri.go.jp/publication/pdf/2005/flood_hazard_mapping_manual.pdf (Accessed 16 December 2013).

Goda, Y. (2000). *Random Seas and Design of Maritime Structures*. 2nd ed. World Scientific.

Government of British Columbia (2019). *Modernizing BC's Emergency Management Legislation*. [online] Available from: https://www2.gov.bc.ca/assets/gov/public-safety-and-emergency-services/emergency-preparedness-response-recovery/modernizing_bcs_emergencymanagement_legislation.pdf.

Hamilton, A. S., Hutchinson, D. G., and Moore, R. D. (2002). Estimating winter streamflow using a conceptual streamflow model. *Journal of Cold Regions Engineering*, 14(4), 158–175.

Hawkins, E., and Sutton, R. (2010). The potential to narrow uncertainty in projections of regional precipitation change. *Climate Dynamics*, 37, 407–418. doi:10.1007/s00382-010-0810-6.

Hicks, D. M., and Mason, P. D. (1998). *Roughness characteristics of New Zealand rivers*. NIWA (Ed.). Water Resources Publications, LLC, Christchurch, NZ.

Higman, B., Shugar, D. H., Stark, C. P., Ekström, G., Koppes, M. N., Lynett, P., Dufresne, A., Haeussler, P. J., Geertsema, M., Gulick, S., Mattox, A., Venditti, J. G., Walton, M. A. L., McCall, N., Mckittrick, E., MacInnes, B., Bilderback, E. L., Tang, H., Willis, M. J., Richmond, B., Reece, R. S., Larsen, C., Olson, B., Capra, J., Ayca, A., Bloom, C., Williams, H., Bonno, D., Weiss, R., Keen, A., Skanavis, V., and Loso, M. (2018). The 2015 landslide and tsunami in Taan Fiord, Alaska. *Scientific Reports*, 8(1), 12993. doi:10.1038/s41598-018-30475-w.

Hornik, K. (2016). *The R FAQ*. [online] Available from: www.r-project.org.

Hyatt, K. D., Alexander, C. A., and Stockwell, M. M. (2015). A decision support system for improving "fish friendly" flow compliance in the regulated Okanagan Lake and River System of British Columbia. *Canadian Water Resources Journal/Revue canadienne des ressources hydriques*, 40(1), 87–110.

Ichinose, G. A., Anderson, J. G., Satake, K., Schweickert, R. A., and Lahren, M. M. (2000). The potential hazard from tsunami and Seiche waves generated by large earthquakes within Lake Tahoe, California-Nevada. *Geophysical Research Letters*, 27(8), 1203–1206. doi:10.1029/1999GL011119.

IJC (2013). *International Joint Commision in the matter of the application of the State of Washington for approval to construct a control structure near the outlet of Osoyoos Lake Supplementary Order of Approval*. International Joint Comission. 8 pp. [online] Available from: https://ijc.org/sites/default/files/2018-08/Docket%20108%20Supplemental%20Order%202013-01-29.pdf.

KWL (2014). Creek Hydrology, Floodplain Mapping and Bridge Hydraulic Assessment - Floodplain Development Permit Area, Flood Construction Level Development and Use.

KWL (2017). *District of Squamish Integrated Flood Hazard Management Plan - Final Report, October 2017*. Prepared by Kerr Wood Leidal Associates Ltd. for District of Squamish. 251 pp. [online] Available from: https://squamish.ca/assets/IFHMP/1117/20171031-FINAL_IFHMP_FinalReport-compressed.pdf (Accessed 3 May 2018).

Løvholt, F., Pedersen, G., Harbitz, C. B., Glimsdal, S., and Kim, J. (2015). On the characteristics of landslide tsunamis. *Philosophical transactions. Series A, Mathematical, physical, and engineering sciences*, 373(2053), 20140376. doi:10.1098/rsta.2014.0376.

Martel, J.-L., Mailhot, A., and Brissette, F. (2020). Global and Regional Projected Changes in 100-yr Subdaily, Daily, and Multiday Precipitation Extremes Estimated from Three Large Ensembles of Climate Simulations. *Journal of Climate*, 33(3), 1089–1103.

Matott, L. S. (2017). *OSTRICH – An Optimization Software Toolkit for Research Involving Computational Heuristics Documentation and User ' s Guide*. State University of New York at Buffalo, Buffalo, NY. 79 pp. [online] Available from: https://www.eng.buffalo.edu/~lsmatott/Ostrich/OstrichMain.html.

McFall, B. C., and Fritz, H. M. (2016). Physical modelling of tsunamis generated by three-dimensional deformable granular landslides on planar and conical island slopes. *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 472(2188), 20160052. doi:10.1098/rspa.2016.0052.

McNeil, R. I. (1974). *Factors affecting the level of Osoyoos Lake* (File 307580-1). Water Investigations Branch.

Micovic, Z., Hartford, D. N. D., Schaefer, M. G., and Barker, B. L. (2016). A non-traditional approach to the analysis of flood hazard for dams. *Stochastic Environmental Research and Risk Assessment*, 30(2), 559–581. doi:10.1007/s00477-015-1052-2.

Ministry of Environment and Climate Change Strategy (n.d.). Bathymetric Maps of Surveyed Lakes - Data Catalogue. [online] Available from: https://catalogue.data.gov.bc.ca/dataset/bathymetric-maps-of-surveyed-lakes (Accessed 14 March 2019).

Ministry of Environment, Lands and Parks Water Management Division (1992). *A Design Breif on the Floodplain Mapping Study - Okanagan River* (35100-30/310–0000). Province of British Columbia, Ministry of Environment Lands and Parks, Water Management Branch, Flood Hazard Identification Section, Victoria, B.C. 55 pp.

MOELP (1999). *Guidelines for Management of Flood Protection Works in British Columbia*. Province of British Columbia, Ministry of Environment, Lands & Parks.

MOELP, and MSRM (1978). *Swalwell (Beaver) Lake Reservoir Survey and Storage Compliation*. Ministry of Environment, Land and Parks and Ministry of Sustainable Resource Management. [online] Available from: http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=1388 (Accessed 20 March 2019).

MWLAP (2004). *Flood Hazard Area Land Use Management Guidelines*. Province of British Columbia, Ministry of Water, Land, and Air Protection. 72 pp.

Nash, J. E., and Sutcliffe, J. V. (1970). River flow forecasting through conceptual models part 1 - A discussion of principals. *Journal of Hydrology*, 10(3), 282–290.

Natural Resources Canada (2020). Earthquakes Canada, GSC, Earthquake Search (On-line Bulletin),. [online] Available from: https://earthquakescanada.nrcan.gc.ca/stndon/NEDB-BNDS/bulletin-en.php (Accessed 27 March 2020).

Neilsen, D., Bakker, M., Van der Gulik, T., Smith, S., Cannon, A., Losso, I., and Warwick Sears, A. (2018). Landscape based agricultural water demand modeling – a tool for water management decision making in British Columbia, Canada. New Title. *Frontiers in Environmental Science*, 6, 74.

NHC (2008a). *Chehalis Lake landslide preliminary site inspection and survey*. Memorandum. Prepared by NHC for the Ministry of Environment. 1–11 pp.

NHC (2008b). *Flood Risk Evaluation and Flood Control Solutions, Phase 1.* (34920). Report prepared by Northwest Hydraulic Consultants for City of Prince George.

NHC (2014). *Simulating the Effects of Sea Level Rise and Climate Change on Fraser River Flood Scenarios* (GS14LMN-035). Report prepared by Northwest Hydraulic Consultants for BC Ministry of Forests Lands and Natural Resource Operations (included as Appendix 1 to FLNRO report). 202 pp.

NHC (2016). *North Alouette and South Alouette Rivers Additional Floodplain Analysis: Phase 2 - Technical Investigations Completion Report*. Report prepared by NHC for the City of Maple Ridge. 46 pp.

[online] Available from: https://www.mapleridge.ca/DocumentCenter/View/8145/North-and-South-Alouette-Rivers-Floodplain-Study?bidId= (Accessed 6 December 2018).

NHC (2018). *Lillooet River Floodplain Mapping Final Report* (NHC PN3002903). Report prepared by Northwest Hydraulic Consultants for Pemberton Valley Dyking District. [online] Available from: https://www.pvdd.ca/assets/pdf/resources/LillooetRiverFloodMapping_FinalReport.pdf.

NHC (2020a). *British Columbia Extreme Flood Project, Regional Flood Frequency Analysis – Technical development report and manual to complete a regional flood frequency analysis* (Bulletin 2020-1-RFFA, NHC PN3004476). Report prepared by Northwest Hydraulic Consultants Ltd. (NHC) for the British Columbia Ministry of Forests, Lands, Natural Resource Operations, and Rural Development.

NHC (2020b). *Okanagan Mainstem Floodplain Mapping Project* (NHC PN3004430). Report prepared by Northwest Hydraulic Consultants Ltd. (NHC) for the Okanagan Basin Water Board (OBWB).

Northwest Hydraulic Consultants (NHC) (1987). *Flood control analysis for Similkameen River multi-purpose dam feasibility study. Report to Seattle District US Army Corps of Engineers.*

NRC/PSC (2018). *Federal Flood Mapping Framework Version 2.0*.

PEP (1999). *Flood Planning and Response Guide for British Columbia*.

Polar Geoscience, Ltd. (2012). *Projected water sypply and use in the Okanagan Basin (2011-2040) – Okanagan Basin Water Accounting Model results. Phase 3 Okanagan Basin water supply and demand project.* Prepared for the Okanagan Basin Water Board. [online] Available from: https://obwb.ca/wsd/wp-content/uploads/2014/07/OWSD_Phase3_Scenarios.pdf.

Riglin, L. D. (1977). *The perpetual landslide Summerland, British Columbia* (MSc thesis). University of British Columbia. [online] Available from: https://doi.library.ubc.ca/10.14288/1.0052706 (Accessed 27 March 2020).

Roberts, N. J., McKillop, R. J., Lawrence, M. S., Psutka, J. F., Clague, J. J., Brideau, M.-A., and Ward, B. C. (2013). Impacts of the 2007 Landslide-Generated Tsunami in Chehalis Lake, Canada. In C. Margottini, P. Canuti, and K. Sassa (Eds.), *Landslide Science and Practice: Volume 6: Risk Assessment, Management and Mitigation* (pp. 133–140). Springer, Berlin, Heidelberg [online] Available from: https://doi.org/10.1007/978-3-642-31319-6_19 (Accessed 26 March 2020).

Roed, M., and Fulton, R. (2019). Okanagan Geology South: Geologic Highlights of the South Okanagan Valley, British Columbia.

Schertzer, W. M., and Taylor, B. (2009). *Assessment of the capability to compute evaporation from Okanagan Lake, other mainstem lakes and basin lakes and reservoirs using the existing database* (WSTD contribution no. 08-547). Environment Canada Water Science and Technology Directorate (WSTD). [online] Available from: https://www.obwb.ca/obwrid/docs/332_2009_Lake Evaporation Report.PDF.

Septer, D. (2006). *Flooding and Landslide Events Southern British Columbia 1808-2006*. Ministry of Environment British Columbia. [online] Available from: http://www.env.gov.bc.ca/wsd/public_safety/flood/pdfs_word/floods_landslides_north.pdf.

Sobie, S. R., and Murdock, T. Q. (2017). High-resolution statistical downscaling in southwestern British Columbia. *Journal of Applied Meteorology and Climatology*, 56(6), 1625–1641.

Spence, C., and Hedstrom, N. (2015). Attributes of Lake Okanagan evaporation and development of a mass transfer model for water management purposes. *Canadian Water Resources Journal / Revue canadienne des ressources hydriques*. doi:10.1080/07011784.2015.1046140.

Steacy, S. (2005). Introduction to special section: Stress transfer, earthquake triggering, and time-dependent seismic hazard. *Journal of Geophysical Research*, 110(B5), B05S01. doi:10.1029/2005JB003692.

Stein, R. S. (2003). Earthquake Conversations. *Scientific American*, 288(1), 72–79.

Stockner, J. G., and Northcote, T. G. (1974). Recent limnological studies of Okanagan Basin lakes and their contribution to comprehensive water resource planning. *Journal of the Fisheries Board of Canada*, 31, 955–976.

Summit Environmental Consultants (2010). *Study 7 (Part 1): Demonstration of factors that govern Osoyoos Lake levels during high water periods*.

Summit Environmental Consultants Inc. (2010). *Okanagan water supply and demand project: Phase 2 summary report.* Report prepared for the Okanagan Basin Water Board. [online] Available from: https://www.obwb.ca/wsd/wp-content/uploads/2011/02/339_2011_summary_report.pdf.

Summit Environmental Consultants Inc. (2013). *Okanagan Hydrologic Connectivity Model Summary Report. Prepared for the Okanagan Basin Water Board*. [online] Available from: https://www.obwb.ca/newsite/wp-content/uploads/2013/09/ohcm_final_report.pdf.

Summit Environmental Consultants Ltd. (2005). *Okanagan Basin Water Supply and Demand Study: Phase 1*. [online] Available from: https://www.obwb.ca/fileadmin/docs/Supply_Demand_Phase1.pdf.

Summit Environmental Consultants Ltd. (2013). *Okanagan Hydrologic Connectivity Model: Trout Creek Watershed Groundwater Integration. Report prepared for the Okanagan Basin Water Board.* [online] Available from: https://www.obwb.ca/obwrid/docs/357_OHCM_TroutGW_Final_Report.pdf.

Symonds, B. (2018). *Okanagan River: Adaptive management success stories. Presented at the Adaptive management for large-scale water infrastructure workshop*. New Orleans, Louisiana.

Tannant, D. D. (2011). *Geohazards in the South Okanagan*. University of British Columbia. [online] Available from: https://doi.library.ubc.ca/10.14288/1.0102564 (Accessed 27 March 2020).

Trivett, N. B. A. (1984). *Lake Okanagan evaporation study* (Canadian Climate Centre Report No. 84-2). Atmospheric Environment Service, Downsview, Ontario.

United Kingdom Department for Environment Food and Rural Affairs (2014). *Framework and tools for local flood risk assessment*. [online] Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/316280/Local_flood_risk_assessment_-_project_report.pdf.

US Army Corps of Engineers (2002). *Coastal Engineering Manual (CEM): Engineer Manual 1110-2-1100*. US Army Corps of Engineers, Washington, D.C. (6 Volumes) pp.

Van der Gulik, T., Neilsen, D., and Fretwell, R. (2010). *Agriculture Water Demand Model. Report for the Okanagan Basin.* [online] Available from: https://www.obwb.ca/wsd/wp-content/uploads/2015/11/500300-3_agric_water_demand_model-okanagan_report.pdf.

Voight, B., Janda, R. J., Glicken, H., and Douglass, P. M. (1983). Nature and mechanics of the Mount St Helens rockslide-avalanche of 18 May 1980. *Géotechnique*, 33(3), 243–273. doi:10.1680/geot.1983.33.3.243.

WaterSmith Research Inc & Streamworks Consulting Inc (2014). *Okanagan Lake Regulation System Hydrologic & Hydraulic Capacity Review*. Prepared WaterSmith Research Inc and Streamworks Consulting Inc for BC Ministry of Forests, Lands and Natural Resource Operations - Public Safety & Protection Branch: Okanagan Shuswap Natural resource District. 193 pp.

Werner, A. T., Schnorbus, M. A., Shrestha, R. R., Zwiers, F. W., Dayon, G., and Anslow, F. (2019). A long-term, temporally consistent, gridded daily meteorological dataset for northwestern North America. *Scientific Data*, 6(180299). doi:10.1038/sdata.2018.299.

Wittneben, U. (1986). *Soils of the Okanagan and Similkameen Valleys* (52). BC Ministry of Environment, Victoria, BC. 238 pp. [online] Available from: http://www.env.gov.bc.ca/esd/distdata/ecosystems/Soils_Reports/bc52_report.pdf.