Okanagan Dams and Reservoirs – Past, Present, and Future

A White Paper on

Issues, Concerns and Recommendations for Dam and Reservoir Management in the Okanagan Region

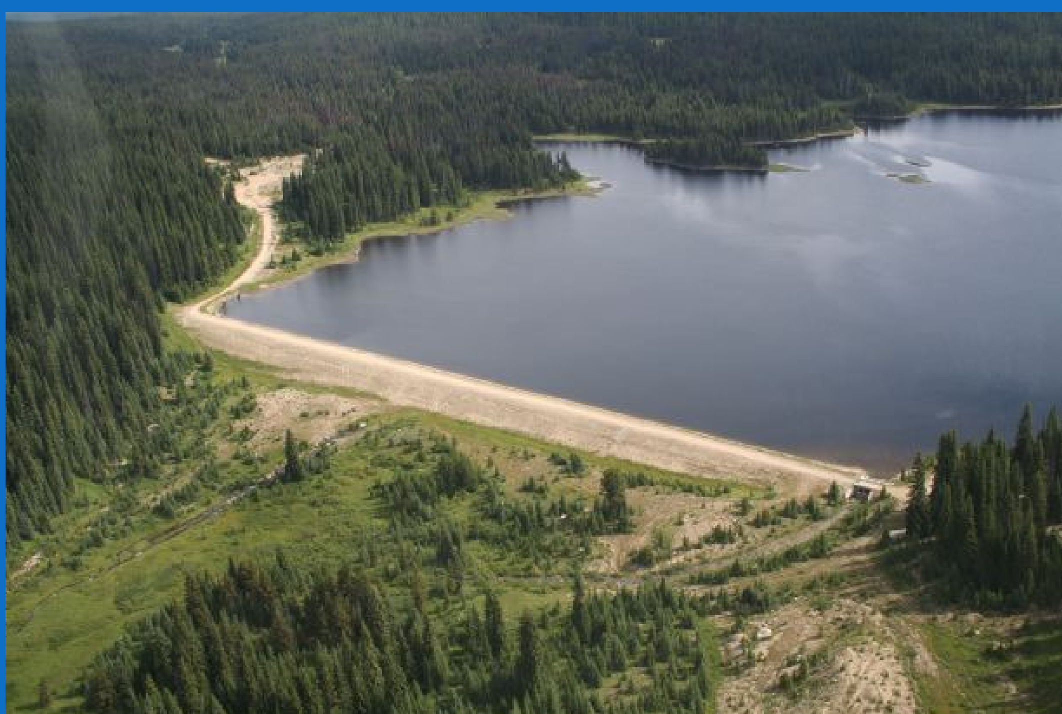
Submitted by

Okanagan Dams and Reservoirs Committee

of the

Water Stewardship Council (Okanagan Basin Water Board)

March 2021



Fish Hawk Dam within Graystoke Provincial Park (Photo credit – Black Mountain Irrigation District)

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EXECUTIVE SUMMARY

The fundamental challenge facing all dam owners, managers, and regulators in the Okanagan is to facilitate a smooth and seamless transitioning from an immutable past to an uncertain future given that we presently live amidst a complex array of ever-changing financial, regulatory, and knowledge constraints as well as shifting climatic conditions and socio-cultural norms.

Purpose and Scope

In 2018, the Water Stewardship Council (WSC) of the Okanagan Basin Water Board (OBWB) formed a Committee to examine future issues related to *Okanagan Dams and Reservoirs*. The mandate was to identify opportunities for improved water resources planning and sustainability, consistent with the objectives of the OBWB, and in so doing, to review the current state and future direction of dam and reservoir management in the region. The OBWB operates within the scope of the Supplementary Letters Patent granted to the three Regional Districts in the Okanagan and does not have legislative authority or complete autonomy (Appendix A). The Committee limited the scope of its inquiries into matters within the purview of the OBWB. The Committee focused its attention mainly on the mid to upper elevation dams and reservoirs owned and operated by Okanagan municipalities, water purveyors, and private owners for water supply or conservation purposes. Excluded from consideration were the large dams and reservoirs operated and managed by the Province of British Columbia (the 'Province') even though these flow-control structures on the valley-bottom lakes and rivers are hydrologically inter-connected with the uplands.

As of 2019, 205 freshwater dams in the Okanagan were listed with the BC Ministry of Forests, Lands, Natural Resource Operations & Rural Development (FLRNORD) as being subject to the application of the ***Dam Safety Regulation* (DSR)**. Another 64 dams were listed as either decommissioned (5), not yet constructed (43), or breached (16). An unknown number of unregulated dams are not listed because they are classified as 'minor' due to their small height and storage volume. A detailed report that follows this Executive Summary provides information on the consequence classification of dams as well as additional information on the history, regulation, and management of dams in the Okanagan.

James Lake Reservoir and Saddle Dam

(Photo credit: Bob Hrasko)

Dam Ownership and Regulatory Framework

Freshwater dams in British Columbia are regulated by the Province in two primary ways: (1) an approved water licence is required to allow for storage of water under the ***Water Sustainability Act*** (WSA); and (2) dam design, construction, maintenance, and operation must adhere to the ***Dam Safety Regulation*** (DSR). From an administrative standpoint, the dam itself is simply a structure that enables the water license to become operational. A dam owner is defined loosely as the person who holds or did hold (or should have held) the water license, or in the absence of a license, the person who owns the land upon which the dam is located. It is the responsibility of the dam owner to ensure the safe condition and operation of their dam, including outlets and protection facilities, while the Province provides oversight via the DSR. For many dams in the Okanagan that were constructed for municipal waterworks purposes, it is the responsibility of the individual or local government (e.g., regional district, municipality, or improvement district), via their elected officials, to ensure compliance with the DSR while meeting the terms and conditions defined in the water license.

Historical Context

Dams on the Okanagan waterscape are the products of over a century of decisions and actions driven initially by the need to control water for purposes of agricultural production and economic growth, and more recently, to serve rapid urbanization. The earliest investments in dam development were made by private interests within a largely unregulated system of water management using construction and quality control practices of the day. The consequence of dam failure to downstream populations was usually not a consideration because there were very few people and buildings on the landscape. These realities of the past have led to a range of present-day challenges, such as (i) dam infrastructure in various stages of physical condition and compliance with today's expected standards; (ii) a current system of dam oversight (stemming from some recent dam failures in BC) that is highly regulated and strictly enforced; (iii) structural modifications and updates to dams that in some cases were undocumented, inadequate or illegal; and (iv) progressive shifts in the utilization of reservoirs for multiple purposes (e.g., flood mitigation, environmental flow augmentation, recreational use, wetland habitat) that were likely not anticipated during their original construction. Private owners of small dams, in particular, are vulnerable to financial stress because compliance with the DSR may require costly dam improvements or expensive dam decommissioning options. It is, perhaps, not surprising that dam owners are reluctant to initiate preemptive or remedial actions on their infrastructure voluntarily because the effort and costs are borne by the dam owner exclusively, whereas the broader society typically benefits from the dam and reservoir.

Present Issues and Concerns

Consideration of the present and future state of dams and reservoirs in the Okanagan must be framed within a broader discussion of sustainable water resources management in the region. Dams and reservoirs provide flexibility for water storage and release timing (e.g., during times of crop stress and urban demand), but they are not a panacea that will solve all water supply problems. Important factors that underpin such discussions include population growth and urban development, a changing climate (resulting in warming temperatures, reduced snowpack, and earlier freshet), expansion of agriculture and changes in the type of crop production, land use and land cover changes (driven by forestry, wildfire, pine beetle infestation, and urbanization), environmental flow needs and conservation flows, impacts to aquatic and riparian habitat, and shifts in socio-economic conditions and personal attitudes that may alter public perceptions of water use and conservation (i.e., demand management).

Climate change is predicted to have multiple effects on the hydrology of the region, including: (1) less snow accumulation (and hence water shortage in the snowpack at mid and high elevations); (2) more rain-on-snow events leading to flashier runoff events in the spring; (3) earlier arrival of the spring freshet with higher peak discharges; and (4) longer, hotter growing seasons extending into the autumn (much past the date of most water licenses).

The following questions and issues identified through the work of the Committee are particularly relevant when considering the future of dams and reservoirs in the Okanagan:

a) Is existing water storage capacity adequate to accommodate future growth and development? Are new reservoir management strategies needed? Are there opportunities to develop additional, cost-effective, upland storage capacity?
b) How will climate change affect water resources management in the region, and what are the implications for the long-term operations of dams and reservoirs (directly and indirectly)?
c) The existing upland dams and reservoirs offer many benefits to society and represent significant water supply assets that are critical to agriculture and economic well-being. Are these assets adequately serviced, maintained, and financed for the long term? If not, what are the ramifications and policy changes needed?
d) What proportion of dams in the Okanagan are operated and maintained in compliance with the DSR? Is there awareness and understanding of the potential risks and liabilities of not adhering to the DSR?
e) Does everyone (i.e., dam owners, water managers, elected officials, and the general public) understand the magnitude of physical, economic, and social consequences of an upland dam failure?
f) Are land-use and emergency planners appreciative of the dam breach hazard in terms of potential valley-bottom inundation areas, and is the risk being managed (mitigated) adequately?
g) Dams are managed by owners quite independently of each other. Are there appreciable benefits to a coordinated, systematic management control approach to achieve objectives such as reliable water supply (redundancies), environmental flow needs, or flood mitigation?
h) Does the management of dams and reservoirs in the Okanagan consider and account for the traditional knowledge and values of Indigenous Peoples?
i) What role should OBWB play in long-term planning and support for dam owners in the Okanagan?

General Findings

A detailed Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis was conducted, and subsequent discussions among Committee members and other experts led to several observations concerning dams and reservoirs in the Okanagan.

Perhaps the most important observation is that there is increasing complexity in dam ownership and operations, being driven by competing interests and demands. In the past, the upland dams served a singular interest – storage for community waterworks and agricultural irrigation in the late summer months. Today, the value of dams to communities is much broader, including, for example, year-round public recreational amenities, late summer supplementary flows for environmental benefits, and ecological services. As the Okanagan population continues to increase and transition from rural to urban interests, the utility of dams and reservoirs is being redefined. The notion of dam 'ownership' is implicitly becoming broader, reflecting societal community interests, whereas the legal liability and management requirements remain with individuals and water purveyors. The long-term impact of these changes is increased complexity and constraints on dam ownership and operations, with no apparent mechanisms for cost-sharing amongst all beneficiaries.

The development of additional upland storage can offer greater operational flexibility in the future to respond to the hydrologic effects of climate change as well as to service environmental flows during dry periods. An estimated 133 x 10^3 mega-litres (ML) of water are stored annually in upland reservoirs, but a total of 226 x 10^3 ML has been licensed (see Dobson, 2008, Table 2.5 and Table 2.4, respectively), suggesting that only about 60% of already-identified reservoir capacity has been developed. An updated assessment of water licenses in the Okanagan indicates that the total licensed volume with storage may be closer to 161 x 10^3 ML (see Appendix D), which suggests that more than 80% of the licensed allocation has been constructed and developed. Thus, there remains some limited opportunity for reservoir expansion although new locations for reservoirs may need to be found and new licenses may need to be allocated. Developing additional upland storage is very expensive and involves many, often competing interests. Moreover, expanding reservoir storage provides only temporary relief to a long-term water supply problem driven by perpetually increasing water demand due to population growth, agricultural expansion into higher elevations, and economic development. **The broader challenge for the future is finding the ability to live within our means.**

The total amount of potential storage available in upland reservoirs is small in comparison to the annual recharge in Okanagan Lake, and therefore managing water releases from upland reservoirs to mitigate flood damage downstream (and along lakeshores) may not be an effective strategy, although local flood damage on creeks and streams may be partly mitigated. The primary advantage of dams and reservoirs is to hold back water for use in the dry season. One of the challenges in this regard is forecasting near-future weather and runoff conditions (i.e., weeks to months) and managing releases accordingly. This will require expanded networks of hydrometric stations and other measurement techniques (*in situ* and remotely sensed), as well as QA/QC and storage of data for rapid retrieval from a public database.

Reservoirs are critical components of our water supply and economic infrastructure and should be maintained and financed accordingly. Many dams are approaching a point in their life expectancy where major physical improvements are required (e.g., low-level outlet replacement, spillway reconstruction, upgrading ancillary controls, geotechnical reassessments, and improvements). Whereas initial construction was often subsidized by capital grants from senior governments, upgrades today are normally at full cost to water utility customers. The need for re-investment is often not evident to local government decision-makers until major repairs or improvements are mandated. Municipalities with large tax bases are in better positions, via asset reviews, to manage this challenge, whereas individual landowners with small dams face a range of complex constraints that often preclude appropriate investments in long-term maintenance strategies. Even when the funding is available, the process for obtaining permits and approvals can be onerous with little guidance or support from provincial agencies.

In terms of risk management, the BC ***Dam Safety Program***, in collaboration with water industry organizations (e.g., the Canadian Dam Association), offers a high level of technical support to dam owners. Although many municipal dam owners recognize the importance of properly trained staff and take full advantage of training programs, there remain dams in the Okanagan (usually of low consequence classification) that do not meet expected maintenance standards.

Recommendations arising from the deliberations of the Okanagan Dams and Reservoirs Committee are listed below (in no particular order of importance) and described in greater detail in the main body of the White Paper.

- The OBWB should ***initiate and lead (with local and provincial governments) discussions to explore and implement financial mechanisms in support of long-term infrastructure maintenance and sustainable dam and reservoir operations***.
- The OBWB should continue to ***lobby the provincial and federal governments to expand regional capacity for measuring and modelling hydro-climatic trends into the near and distant future***.
- The OBWB should ***encourage, commission, and co-sponsor a range of scientific and technical studies focused on the future role of dams and reservoirs within a valley-wide water management strategy*** that also considers, for example, water conservation, environmental flows, and zoning by-laws.
- The OBWB should ***collaborate with local Indigenous Peoples*** in hopes of incorporating their perspectives and needs into a valley-wide reservoir management strategy with a targeted solution that properly recognizes the contextual nuances of dams owned by the First Nations.
- The OBWB should ***collaborate with local governments and the Province to explore possible mechanisms to achieve efficiencies and economies of scale associated with coordinated reservoir operation*** under a 'one operator' model for sub-watersheds that have multiple dam owners.
- The OBWB should ***collaborate with the Province and water industry organizations to address evident gaps in existing outreach (education) programs*** offered by a range of national and international organizations.
- The OBWB ***should investigate the extent to which the land surrounding existing and yet-to-be-developed reservoirs could be protected from future development, privatization, and lease arrangements (in the case of Crown Land)***.

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DISCLAIMERS

The material presented in this document is intended for general information purposes only. It does not replace official government documents and regulatory guidelines, which should always be consulted as the primary source of information. The ideas expressed within the document reflect group opinion and are not necessarily held firm by any individual committee member, their organizations, or the members of the Water Stewardship Council or Okanagan Basin Water Board.

ABSTRACT

Dams and reservoirs are an integral part of the waterscape of the Okanagan region, developed historically to address the need for water during the hot, dry summers primarily for agricultural production. Much of this water-supply infrastructure is aging and in need of upgrades. Today's regulatory environment imposes strict requirements on how dams and reservoirs are operated and maintained, driven in part by heightened awareness of risks associated with recent dam failures in BC and elsewhere. Thus, dam owners face significant financial challenges to meet new regulatory requirements as well as to ensure that the water-supply infrastructure that they are responsible for will serve future needs. These needs, in turn, are continually changing due to pressures imposed by climate change, population expansion, and shifting public attitudes and values. The expansion of existing dams or the development of new dams is an option that must be evaluated in the context of water conservation initiatives and demand management strategies that are often cheaper, less risk-prone, and more sustainable over the long term. A list of recommendations and actionable items is proposed for consideration by the Okanagan Basin Water Board in hopes of ensuring a sustainable water future for the Okanagan region.

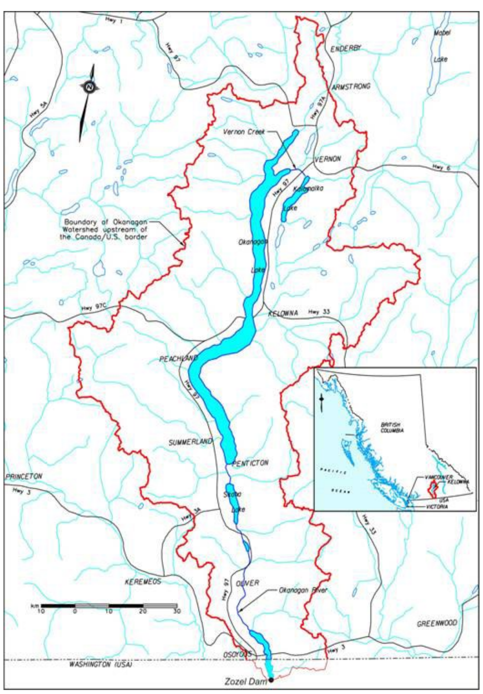
1. INTRODUCTION

Some people view dams as essential infrastructure in a modern water supply system. Dams are critical to the reliable delivery of water to customers during dry periods, and they serve as the foundation for economic development. Others oppose dams because of their environmental impacts on watersheds and aquatic ecosystems. These views are accompanied by socio-cultural considerations and implications. Most people, however, don't think about dams—the benefits, risks, and costs—much like they don't think about where the water at their tap comes from.

The history of dam construction and reservoir management in the semi-arid Okanagan Valley arose due to the need to augment natural water supplies during the hot summer months to enable agricultural production. Without irrigation, the land could not support many of the crops that are grown in the region, especially tree fruits and market-garden vegetables.

Most of the water that flows into the creeks and streams originates on the upper plateaus that surround the valley bottom, ultimately serving to recharge and sustain the main stem lakes and aquifers (Figure 1). Noteworthy in this regard is the fact that the total annual inflow from all the streams feeding the main stem lakes is relatively small in comparison to the total volume of water stored in those lakes. Okanagan Lake, for example, has a volume of about 24.6 cubic kilometres, whereas the average annual inflow (outflow) is only 0.6 cubic kilometres per year (about 2.5%). Approximately one-third of the inflow is contributed by Mission Creek. It is not surprising, then, that no major hydroelectric power generating facilities exist in the Okanagan simply because there are no rivers with large enough sustained flows to warrant the investment.

(a)



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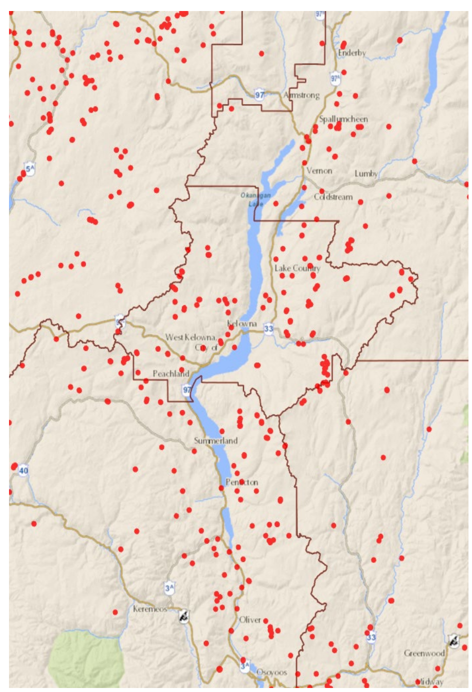

***Figure 1**: (a) Map of the Okanagan watershed showing basin outline and major rivers and streams. (b) Location of dams (red dots) in the Okanagan and surrounding region (Source: iMapBC 2020).*

The majority of the annual discharge occurs during the annual freshet (Figure 2), coinciding with a relatively short snowmelt period (approximately 6-8 weeks) and the beginning of the growing season (April-June). The summer and fall, in contrast, are characterized by low-flow conditions supplied mainly through baseflow (i.e., groundwater) and surface runoff generated by the occasional rain shower. Water storage in the form of upland reservoirs made sense to early settlers, as it does now, to capture and hold a portion of the spring freshet runoff for later use. This enables a slow but sustained release of water during the summer and fall when dry conditions are common and demand is the greatest. Thus, the existing dams have become a critical component of the water-supply management infrastructure in the Okanagan.

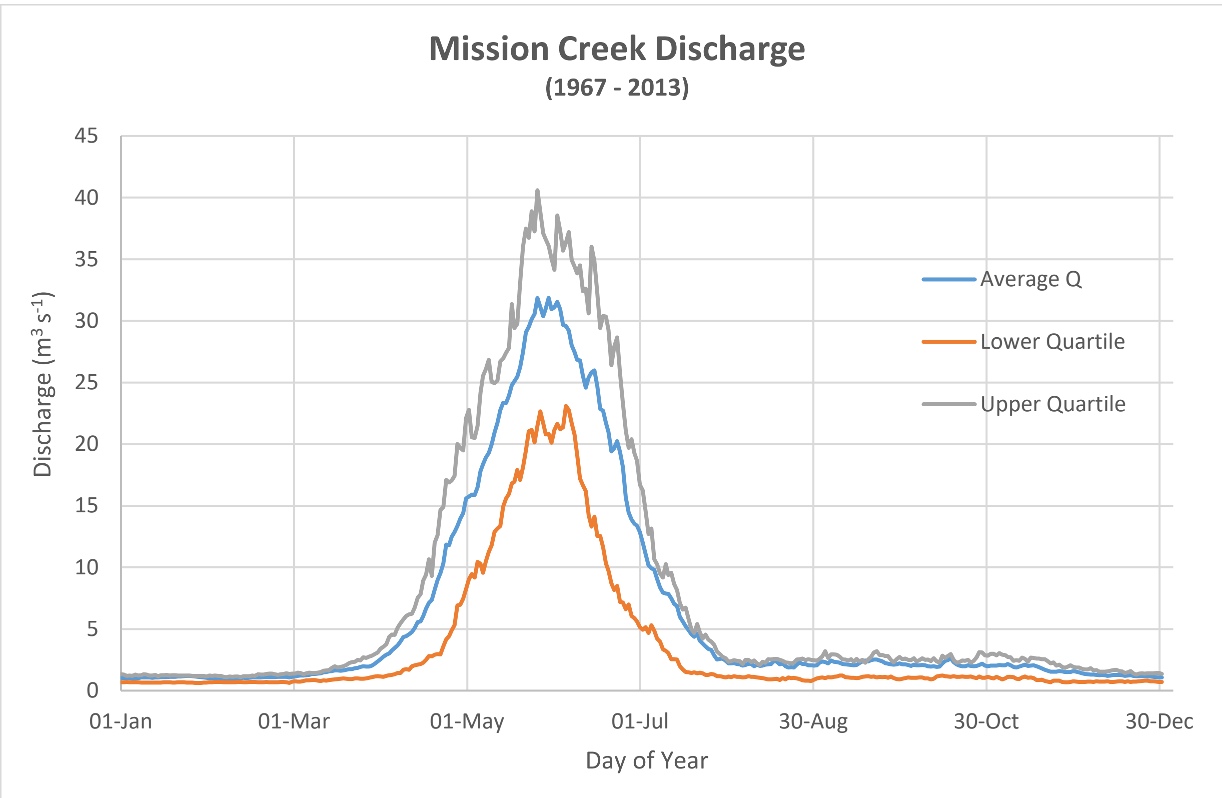

***Figure 2**: Annual discharge hydrograph for Mission Creek showing the relative importance of spring freshet from late April through early July. Data from Water Survey of Canada (Station 08NM116 near East Kelowna).*

Despite the large water volume in Okanagan Lake, the annual recharge (or useable storage) is equivalent to only 1.5-2 m of water, of which approximately 0.5-0.9 m is lost through evaporation during the warm summer months. Thus, contrary to public perception, the large volume of water in the main stem lakes is

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largely inaccessible from a water resources perspective because removing water in excess of the upper 1+/- m of the lake would result in mining the water supply. (The term 'mining' refers to extracting water from a lake or aquifer in an unsustainable manner, beyond its capacity to be recharged naturally and reliably.)

In contemplating a sustainable water future, Okanagan communities often ask whether additional water storage in the form of reservoirs controlled by new or expanded dams will become necessary or even possible as water demand continues to increase. Water conservation and lost water management (i.e., leak management) has proven to be the most cost-effective long-term strategy for mitigating increased water demands, but what other options are there? It seems prudent to explore water enhancement opportunities, in addition to water conservation, that enable more flexible and efficient resource management strategies. However, the question of whether it is reasonable to build new dams or expand existing storage reservoirs in the Okanagan has not been addressed in a way that takes into account all the complexities involved.

The main purpose of this White Paper is to inform a broader discussion about Okanagan dams and reservoirs that considers issues of safety, risks to life and infrastructure, regulatory requirements, legal liability, operational efficiencies, environmental considerations, social license, and shifting contexts in which dams and reservoirs are managed. The intent is to provide sufficient information for decision-makers to plan for a sustainable water future in the Okanagan that considers alternative options and accounts for financial constraints, cultural norms, and inter-generational equity.

2. SCOPE and CONTEXT

In framing this White Paper, the Okanagan Dams and Reservoirs Committee (ODRC) of the Water Stewardship Council (WSC) conducted a scoping exercise that first identified the primary target audience for the report. This was essential because the general topic of 'dams and reservoirs' is very broad, spanning a range of issues and scales from local to global. It was critical to identify who the intended (and likely) readership would be in order to restrict the report to those issues and concerns over which the Okanagan Basin Water Board has potential influence.

A great deal has already been written on the topic of dams, and there is much recent activity worldwide concerning dam management, especially dam decommissioning in the U.S. (and recently in the Province of British Columbia). Even though there may be significant overlap with dam management concerns in the Okanagan, many issues are not directly relevant to the region (e.g., hydroelectric power generation by mega-dams). To be effective and useful, **the White Paper was restricted to those issues and recommendations that are within the purview of the Okanagan Basin Water Board (OBWB).** The OBWB was the target audience; see Appendix A for a brief overview of the OBWB mandate and authority. This implies providing recommendations for actionable items at the level of local and regional governments, and to a much lesser extent, provincial and federal authorities.

It is intended that the information provided in the White Paper will assist Board members and staff in making decisions that promote sustainable water resource management in the Okanagan watershed and enable the OBWB to fulfil its mandated objectives. In this context, a conscious decision was made by ODRC members not to deal extensively with issues that are under the jurisdiction of (and are being addressed by) provincial and federal agencies such as dam safety, cross-border treaty negotiations, and hydroelectric power generation. **The focus of the White Paper is the upland reservoir systems that control water supply to the valley bottom for agricultural and municipal purposes** (Figure 3)**.** This paper does not address the mainstem lakes or the major flow control structures on the Okanagan Lake and River System, which fall under the authority of, and are managed by, the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD).

(a)  (b) 

***Figure 3**: (a) Mission Lake, breached dam and remaining lake – Mission Creek Watershed (Photo credit: Bob Hrasko); and (b) A flow control structure on the valley bottom – Penticton Dam controlling outflow from Lake Okanagan to the Okanagan River (Photo credit: Bernard Bauer).*

The OBWB provides regional leadership and facilitates effective communication about inter-jurisdictional water issues in the Okanagan, which involves coordinating and enabling partnerships between the provincial Ministries, First Nations, Okanagan-based governments, and water stakeholders. With most of the upland reservoirs and watersheds in the valley situated on Crown Lands, all parties must be at the table and their voices heard. The White Paper will ideally assist the OBWB and its partners to identify, understand, and improve complicated inter-jurisdictional water issues related to managing the upland reservoir systems.

To assist the reader in understanding the complex challenges related to dams, **four hypothetical scenarios** were developed to provide insight into the broad array of issues that dam owners face depending on the size and purpose of the dam and reservoir. **These are presented in boxed inserts scattered throughout the White Paper and can be read independently**. Each scenario is based on a true situation encountered in the Okanagan, although the content has been generalized and anonymized. The objective of these scenarios is to highlight many of the tensions and conflicts that arise when trying to manage a dam, most of which are context-specific, despite a regulatory environment that is intended to be comprehensively applicable. Awareness and appreciation for such complexities are important when contemplating the future role of dams in the waterscape of the Okanagan Valley.

3. A HISTORICAL PERSPECTIVE ON WATER MANAGEMENT AND DAMS IN THE OKANAGAN

Human occupation of the Okanagan Valley by Indigenous Peoples extends back to time immemorial (roughly to the beginning of the last deglaciation, beginning approximately 14,000 years ago). The pressures on the land base were minimal, and water was used for multiple purposes but not managed or controlled in any substantial fashion.

Widespread immigration by European and North American settlers into the Okanagan began in the mid-to-late 1800s, spurred initially by the Gold Rush and a need for sustainable food sources to feed the mine worker population. Most of the early permanent settlers were cattle ranchers with large herds that required extensive grazing lands. However, the rapid decline of the Gold Rush yielded a shift from cattle ranching to agriculture, mainly in the form of orchards that required a dependable source of water. Land speculators parcelled the land, installed crude irrigation systems, and planted fruit trees while marketing the bounty of the Okanagan to English, Scottish, and Irish aristocrats with wealth and resources to invest. Immigration was strongly encouraged by politicians who were also land speculators in many cases.

Early Water Management Works

The oldest water licences in the Okanagan date to the mid-1870s. Early settlers used ingenuity and creativity to access water, relying on human hands and animal labour. Remnants of the original waterworks (e.g., hand-dug canals, wooden trestles, and hillside ditches) are still visible in the landscape if you know where to look (Figure 4). Realization of the need for water storage to meet crop demands in the summer growing season came quickly to these early irrigators. The simplest approach was to build crude dams across streams or at the outlets of headwater lakes to increase storage capacity during snowmelt runoff. Access to the upper watersheds was by foot or horseback because roads and trails did not exist. Wood from local trees and nearby soils was used as construction materials. For the most part, these crude dams satisfied immediate needs with little thought given to long-range planning. However, as individuals and co-operatives organized themselves into water irrigation districts, there was a need for dam improvements and storage expansion. Funds were limited and privately sourced. The Province occasionally provided financial support to individual water purveyors who found themselves in dire straits, but there was no formal assistance program dedicated to infrastructure development.

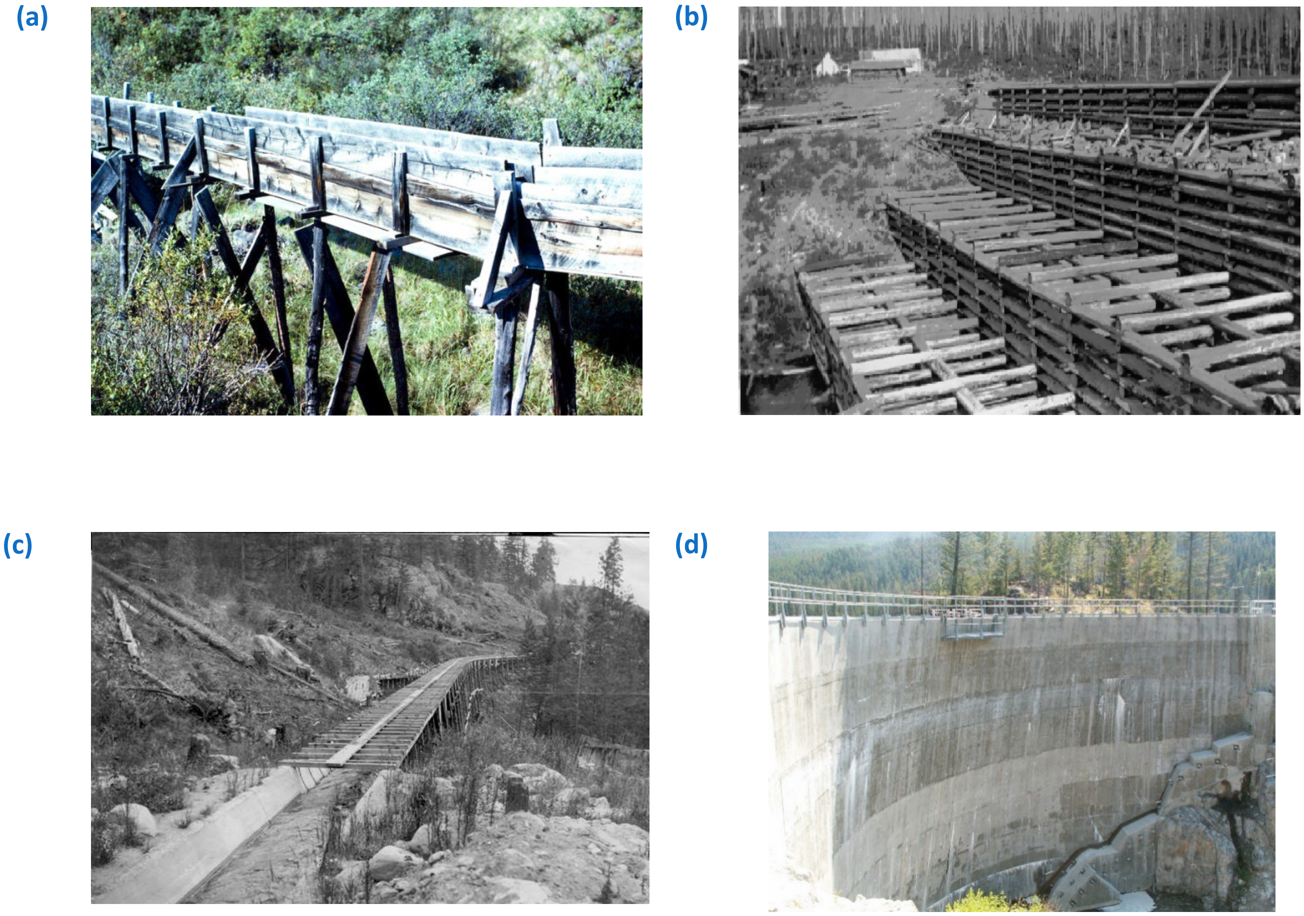

__Figure 4: (a)__ Wooden flume for conveying water from a stream to a plot of land for irrigation (Royal BC Museum, I-18355); __(b)__ Log-crib dam under construction at Postill Lake, east of Kelowna, circa 1911. (Kelowna Museum Photo No. 10, 347); __(c)__ Okanagan flume and trestle (Kelowna Public Archives – Photo #1569); __(d)__ Thirsk Dam, is a concrete arch dam near Summerland originally constructed in 1940 and raised in 2007-08 to store additional water from the Trout Creek watershed. (photo credit – Bob Hrasko)

A concerted effort by irrigation districts in the Okanagan during the 1960s led to the signing of a federal-provincial funding program called the ***Agricultural Rehabilitation Development Act*** (ARDA). This program provided opportunities for irrigation districts to apply for funding support to undertake water system improvements where the costs were shared equally by the federal government, the Province of BC, and the irrigation district applying for support. The ARDA program resulted in a major dam redevelopment program where most irrigation districts were able to rebuild or upgrade their dams to new government standards. The infrastructure upgrades enabled an increase in net storage volumes to avoid future water shortages similar to the crisis experienced during the 1929-1931 drought years. The result of this program of investment is, in many cases, the dams and reservoirs that are in use today.

The Situation Today

The situational context is much different today than it was in the past. Climate change and extensive logging have altered the natural hydrological pathways through which water is delivered to and stored on the landscape. There is less snow accumulating at high elevations than before. The snowpack is prone to melt faster and earlier in the growing season. Summers are predicted to become hotter and drier with more variable weather conditions. More annual precipitation will be delivered in the form of rainfall rather than snow, which implies that the natural storage capacity of the winter snowpack at higher elevations will be reduced. Thus, there is a pressing need to understand the opportunities and challenges associated with reservoir management as a potential climate change adaptation strategy.

Concurrently, the demand for water in the Okanagan region has continued to increase, mostly due to expanding population pressures that have driven intensive housing development and a slow but persistent shift of water uses away from agricultural production to urban uses (e.g., commercial/industrial, lawn watering, golf course irrigation). Thus, there is less water available to meet increasing demands during late summer when it is needed the most, and, ironically, more water than is ideal during the spring, leading to flooding challenges that are increasingly prevalent with population growth. The situation has been further complicated by gradually shifting cultural values that speak to the desire to be(come) better stewards of the environment by maintaining (or enhancing) healthy ecological systems and respecting water as a sacred entity. Nowhere is this more forcefully pronounced than in the Syilx Nation *siwlkʷ* Declaration, which treats water as a relative that connects all life (Appendix B).

The implications for upland reservoir management in the future are manifold. Instead of one clear management objective—i.e., retaining water in the reservoirs at full pool levels for as long as possible to satisfy the demand during the late summer, dry period—there are now multiple objectives that dam managers need to consider, often with conflicting outcomes. The need to attend to supply issues remains paramount, but reservoir managers are occasionally asked to alter releases in a manner that mitigates potential flooding impacts downstream, if possible, and sustains environmental flows during critical fish spawning, rearing, and incubation periods. At the same time, there are regulatory pressures regarding dam safety, especially concerning dams that may pose significant risks or consequences to downstream infrastructure and communities. In many instances, the dams were constructed long before there was much development downstream. With population growth, the dam failure consequence classification for many dams has changed through time, through no fault of the dam owner. It is important to develop new methods to optimize dam operations to accommodate multiple objectives. This will require more sophisticated monitoring and system management as well as input from the First Nations and the general public on whether there should be shared responsibilities (and liabilities) with dam and reservoir operations and maintenance. If there are broad societal benefits from dam operations by way of flood protection, recreation and ecosystem integrity, is it reasonable to expect the dam owner (individual or local government) to be solely responsible for the costs of maintaining the dam, especially if those benefits were not considered as part of the original decision to approve and build the dam?

SCENARIO 1 – VINEY WATERMAN

Viney Waterman purchased some acreage with a small dam and reservoir in 1979. The earliest record of the dam dates back to 1920 when a conditional water licence was issued, which was finalized in 1925. The engineer's report describes the structure as an "earth dam with a concrete core, 201' long, 5' to 9' high, 350' of 20" metal flume and ditches." The name on the licence was changed (in pencil) in 1929, and the next notation in the provincial file occurred in 1962, stating that the storage rights were abandoned and cancelled. However, around this time, an orchard adjacent to the reservoir began using the water to irrigate their trees and unofficially assumed operation of the reservoir.

A recent inspection of the dam on Viney's property identified structural issues and also revealed the fact that there was no storage licence attached to the dam and reservoir. Viney was caught off-guard. The realtor that sold him the property did not say anything about water issues or concerns, and Viney did not think to ask because he assumed that the orchard was responsible for maintenance of the structure given that they were making beneficial use of the water. After the inspection, the Dam Safety Officer encouraged Viney to decommission the dam, which is an expensive and involved proposition. Viney saw great value in terms of ecosystem services that the reservoir provided. During extended periods of drought, the reservoir supported waterfowl, deer, bears, and a wide array of insects, reptiles, and amphibians (e.g., painted turtle, snakes, tiger salamander, spade-foot toad). Surely these things are important and of significant value, so Viney was not inclined to remove the dam. The Dam Safety Officer subsequently requested a formal engineering review. Accordingly, Viney upgraded the dam and built a new spillway to accommodate the 1-in-1000-year flood, at considerable personal expense. In addition, modifications were made to reduce the impounded live storage volume to less than 10,000 m^3 to re-classify the structure as a 'minor' dam that is not subject to regulation. After a long delay, a formal decision on reclassification was made, but Viney can't help wondering why it was so complicated and expensive to maintain (or remove) a dam that fundamentally provides healthy ecosystem functions.

Lessons Learned: Owners of dams (as well as prospective owners) should become informed about the responsibilities and liabilities they assume with a dam, regardless of whether it is subject to the ***Dam Safety Regulation*** (see below) or not. There is currently no requirement for an existing dam owner to inform a potential new owner of the responsibilities/liabilities related to the dam, although the real estate industry could play an important role in this regard. The provincial mandate is to ensure public safety, which drives many decisions about how identified deficiencies need to be addressed. This scenario illustrates that there can be considerable expense associated with owning a property with a dam on it, even if the reservoir is not used for water-supply purposes. A range of values associated with a reservoir typically extend beyond just domestic or agricultural water use (e.g., ecosystem enhancement, recreational utility), but the costs to maintain the dam and to sustain those affiliated benefits are not shared by society.

4. DAM TYPES AND REGULATIONS – A PRIMER

Most of the large freshwater dams and storage reservoirs in the Okanagan watershed are located on the upper plateaus, and these dams are typically under the management of municipalities, regional districts, and improvement districts (i.e., local governments). However, there are also many smaller dams, some of them owned and operated by individual ranchers and farmers. As of 2019, there were 205 freshwater dams in the Okanagan, currently in operation, that are potentially subject to the ***Dam Safety Regulation* (DSR)** (https://www.bclaws.ca/civix/document/id/complete/statreg/40_2016). Another 64 dams in the provincial database (maintained by the Ministry of Forests, Lands, Natural Resource Operations & Rural Development) are listed as either decommissioned (5), not yet constructed (43), or breached (16).

A **dam** is defined (for this White Paper) as a structure that restricts, impedes, or diverts the downstream flow of water in a creek, stream, or river. Some dams are used to manage mine tailings and sewage sludge, but they are not considered herein. Dams vary in design and construction from large concrete structures with automated monitoring and gate controls to small earthen or wooden check dams. The action of beavers, landslides, log accumulations, and ice jams also may create a dam, but these natural dams are not the focus here. A **reservoir** is a body of water impounded by a dam. It can be in the form of a lake or pond along the stream course or an artificial off-stream impoundment area. The maximum size and storage capacity of a reservoir is related to the height of the dam and the geometry of the basin upstream of the dam (Figure 5).

(a) (b)

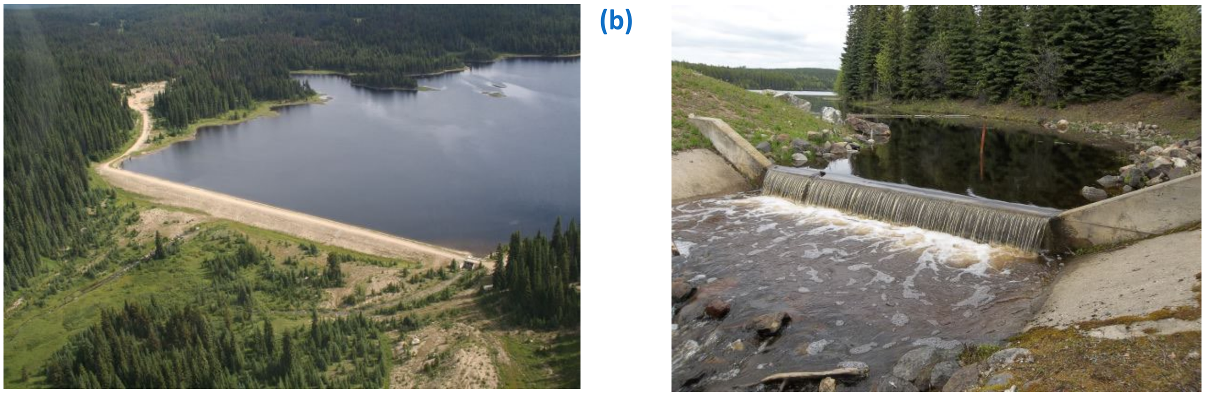

***Figure 5**: (a) Graystoke Dam showing spillway channel, access road (left) and outlet structure (right). This is a large earthen dam that is 430 m long and 18 m high with a storage volume of 5100 megalitres (ML). (Photo credit: Bob Hrasko). (b) Small broad-crested weir on Moore Lake that serves as the spillway for an earthen dam and for measuring discharge into Bulman Creek. Photo credit: Bernard Bauer).*

Dams are regulated under the ***Water Sustainability Act* (WSA)** in two ways: (1) a license must be authorized to allow diversion and storage of water under the Act; and (2) dam design, construction, maintenance, and operation must adhere to the DSR.

Figure 6 shows how the DSR applies to dams of varying height, live storage capacity, and failure consequence. The height of a dam is measured from the crest to the lowest elevation defining the live storage capacity (LSC). The LSC of the reservoir is that portion of total reservoir storage that would drain away if the dam was fully breached, leaving only the 'dead' storage in the lowest portions of the reservoir upstream of the dam. Similarly, it is the volume of water that can be accessed by the dam owner by way of the low-level outlet (LLO) in the dam. If the LLO is installed at the same elevation as the base of the dam, the live storage would be the same as the total volume. However, if the LLO is located above this elevation, then the LLO is less than the total storage because there is dead storage beneath the LLO. Low-level outlets are often elevated to improve water quality so that sediments are not sucked into the intake. Reservoir sedimentation will eventually infill the dead storage, therefore requiring ongoing maintenance (e.g., dredging or sluicing).

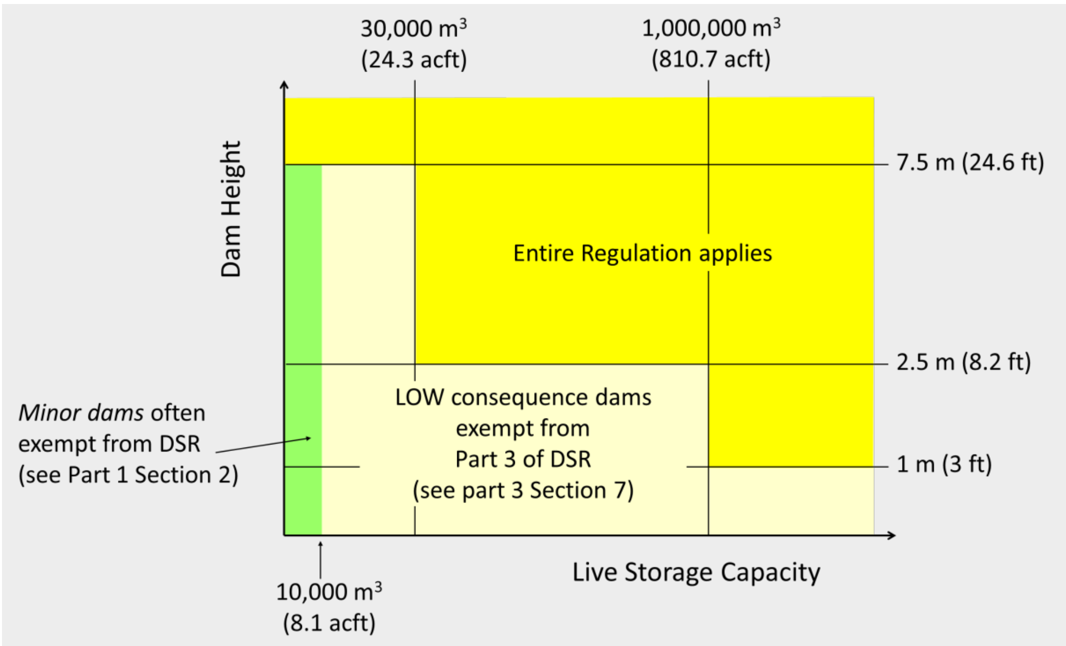

Figure 6: *Application of the BC* ***Dam Safety Regulation*** *(Modified from https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/dam-safety/2018_01_17_-_regulated_dam_graph_-_final.jpg*

In general, any barrier constructed for the purposes of water diversion and storage that is greater than 7.5 m high or stores more than 10,000 m^3 must meet the requirements of the DSR. Dams that impound less than 10,000 m^3 of water are exempt from the DSR as long as they are also less than 7.5 m high, and these structures are referred to as 'minor' or unregulated dams. Minor dams are exempted from the requirements of the DSR except where the comptroller of water rights or a water manager believes the dam is or may become potentially hazardous to public safety, the environment, or land or other property.

Schedule 1 of the ***Dam Safety Regulation*** deals with dam classification. Assessments are made on the basis of 'consequence of failure', which refers to the losses or damages that are likely to be caused by the failure of the dam. The impacts or losses to: (a) human life; (b) environmental and cultural values; and (c) infrastructure and economics are evaluated (see Appendix C). Depending on the consequence classification, the requirements for monitoring, reporting, and review increase considerably. Additional information may be found at https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/laws-rules/dam-safety-regulation.

Table 1: *Consequence classes of listed dams in the Okanagan*

Failure Consequence Class	Regulated Dams Subtotal	Unregulated Dams Subtotal	Dams Total
Extreme	6	-	6
Very High	32	-	32
High	41	-	41
Significant	45	3	48
Low	49	28	77
Unclassified	-	1	1
Dam Totals	**173**	**32**	**205**

In the Okanagan, fewer than 50% of the dams are classified with a failure consequence rating of 'high', 'very high', or 'extreme', as shown in Table 1. Approximately 16% of the dams are unregulated or minor dams.

A dam "owner" is defined in the ***Dam Safety Regulation*** as,

(a) the following persons:
  (i) a person who is a licensee in relation to a licence for the dam;
  (ii) a person who must under the Act, but does not hold a licence for the dam;
  (iii) a person who was a licensee in relation to a licence for the dam immediately before the suspension, cancellation, termination or abandonment of the licence, and
(b) if there is no person to whom paragraph (a) applies, the following persons:
  (i) an owner, as defined in the Act, of the land on which the dam is located;
  (ii) a person who had the dam constructed.

These definitions imply that at least one individual or entity has legal responsibility for almost every dam in BC, whether they hold an active water licence or not. Even if a licensee applies to abandon their water licence, responsibility for the dam persists until the dam is decommissioned to the satisfaction of the Dam Safety Officer such that there are no longer any downstream risks from the dam. The same holds true for someone who owns or purchases property with a dam on it—they are, by default, the dam owner because they inherit the water licence, which is appurtenant to the property. Appendix D contains a listing of all current water licences with dams in the Okanagan along with technical information in the form of an Excel spreadsheet that accompanies this White Paper.

Dam owners are solely responsible for the safety of their dams, which includes inspection/monitoring, maintenance/upkeep, rehabilitation, safety assessments, maintaining documentation, reporting, and fulfilling all regulatory requirements. In some cases, dam emergency plans are to be implemented and updated depending on the consequence classification of the dam.

The ***Dam Safety Program*** **(DSP)** provides oversight for dam construction, operations, maintenance, and surveillance. The DSP is delivered through a distributed model, administered jointly via designated dam safety officers based in Victoria and eight FLNRORD regional offices throughout the province. Additional safety officers are employed by the BC Oil and Gas Commission (OGC) under the direction of the DSP. The DSP is responsible for the enforcement of legislation, policies and procedures, delivery of dam-owner education programs, reporting progress on program objectives, satisfying information system needs, and leading a community of practice for dam safety. Dam safety officers in Victoria are generally responsible for the regulation of major dams (> 9 metres) throughout the province, while regional dam safety officers regulate the remaining dams. Dam safety officers with the OGC are responsible for dams that are owned by oil and gas lease holders, including major dams. The program receives significant support from the FLNRORD compliance and enforcement branch and from partner agencies such as Emergency Management BC.

5. THE RISK OF DAM FAILURE

The earliest known dam failure in the Okanagan Valley occurred in 1907. Since then, more than 20 dams have failed, with four occurring since 2010. This illustrates that dam failures are not hypothetical occurrences. Fortunately, no loss of life was associated with any of these failures, although extensive property and environmental damage have occurred (Figure 7). Approximately half of the dam failures occurred between 1921 and 1947, during a period of rapid expansion in the number of dams built on the upland areas of the Okanagan watershed (Tannant, 2017).

Nearly all dam failures occurred between mid-April and mid-June, coinciding with the yearly peak in stream flow. The hazard is greatest when an above-average snowpack occurs and in years when cooler temperatures are experienced in March and April. When hotter weather returns or intense spring rainstorms occur, these combine with late-season snowpack and saturated ground conditions to create very high discharge events that can result in dam failure. Climate change may further increase these peak stream flows, and dams once believed to have sufficient spillway capacity (Figure 8) may need to be upgraded.

While most dams have stood safely for over fifty years, dams deteriorate with age, and the hydrologic conditions of the watershed above the dams can change over time. These factors, combined with increased development along creeks and alluvial fans below the dams plus climate changes, can increase the risks from dam failures. Most old dams have been upgraded and improved over time, and better systems are now in place for dam safety management. Regular physical dam inspections and adequate maintenance are critical factors in reducing dam failure risks. A significant improvement in the identification of potential safety hazards was realized when the Province required regular Dam Safety Reviews for dams of High, Very High, and Extreme consequence classifications. This involves, in part, a thorough review of the original design schematics that may not now meet today's engineering standards.

Figure 7: *The failure of a very small dam in the uplands triggered a debris flow that emanated from Testalinden Creek canyon (upper centre of photo) and destroyed five homes and caused overall losses and compensation to land owners estimated at $20 million (Tannant 2017). (Photo credit: Dwayne Tannant).*

***Figure 8**: Dam on Isintok Reservoir – Summerland, showing the dam crest and off-road vehicle tracks eroding the surface. (Photo credit: Bob Hrasko)*

6. FUTURE CHALLENGES

The previous sections have alluded to the complexities and realities of dam and reservoir management within a complex regulatory environment that is subject to changing public norms and expectations regarding integrated water supply systems. This section examines in greater detail what are considered to be the most significant challenges that dam owners and water managers will face in the near future. To accomplish this, the ODRC followed a traditional Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis, and the results were synthesized and combined into the following five challenges:

- the water management uncertainties created by climate change;
- contemporary expectations placed on dam owners brought about by changing land-use patterns, especially the public safety risks related to urban development near watercourses and floodplains in the valley bottom;
- the high cost of future dam maintenance and improvements, and how this will be distributed amongst the benefitting parties (e.g., water users, recreation, environmental enhancement, flood prevention);
- the feasibility of increasing upland reservoir storage in the future; and
- changing water licencing regulations – competition for available water and storage capacity versus priority of licence ownership and beneficial use.

6.1 The Uncertainty of Climate Change

Climate change projections for the Okanagan suggest that there will be a progressive shift in runoff patterns toward an earlier freshet with larger peak discharges (see Okanagan Basin Water Demand and Supply Project – Phase 1 (https://www.obwb.ca/wsd/). The discharge hydrograph for Mission Creek during the 2018 spring freshet (Figure 9) is consistent with this trend.

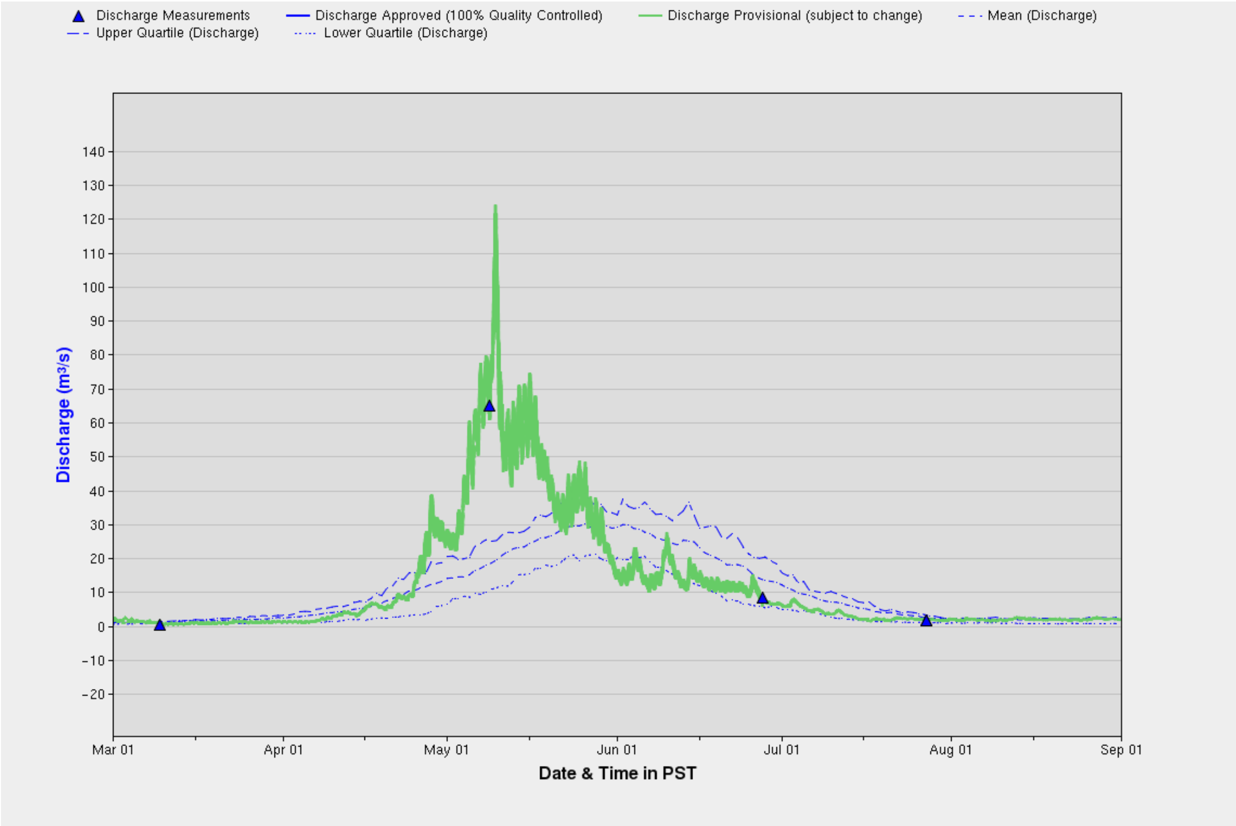

***Figure 9**: Mission Creek discharge hydrograph for the 2018 spring freshet (green line) relative to the long-term mean (with upper and lower quartiles). Note that the peak discharge during the freshet was much larger than the mean discharge, and the arrival date was approximately one month earlier. By early June, however, the discharge was below the long-term lower quartile. Data from Water Survey of Canada (Station 08NM116 near East Kelowna).*

Reduced snow accumulation in the mid-to-upper elevations implies that there will be less water stored on the landscape (Figure 10), which is normally released slowly during the spring and early summer months as the alpine regions gradually warm. The thinner, warmer snowpack will have reduced thermal inertia, and rain-on-snow events will lead to faster snowmelt. The spring season is, therefore, likely to be characterized by flooding events that are flashier and more damaging to infrastructure. In contrast, extended dry periods in the late summer will pose severe challenges for water supplies throughout the valley, which will be a primary factor in: (a) optimizing reservoir management strategies; and (b) considering whether to expand existing storage capacity by increasing dam heights or finding new locations where dams might reasonably be emplaced.

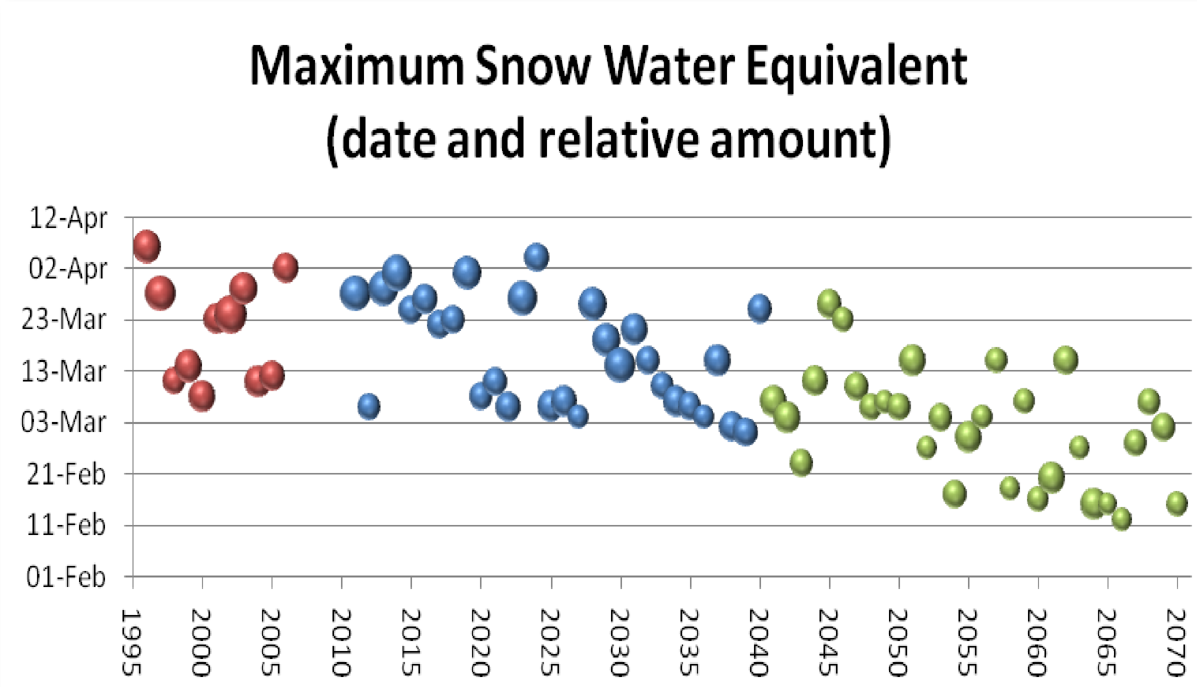

Figure 10: *MikeSHE model projections of peak snowpack timing based on CGCM A2 (global circulation modelling scenario) showing the shift from mid-March currently (red balloons) to late February (green balloons) by 2070. Balloon size is proportional to snow water equivalent stored in the snowpack, which will decline over the next 50 years. (Source: OBWB, 2008)*

Dam operations can be optimized to reduce the impacts of high runoff years by draining the reservoirs in advance of the spring freshet and storing some of the excess runoff in the reservoirs to reduce peak discharges during the flooding period. Later in the summer, during the dry period, the stored water can be released to enhance environmental flows and minimize stress (and mortality) on fish populations. In addition, irrigation demands, domestic supplies, and commercial uses of water can be augmented. However, to be effective, reservoir management requires timely access to data and reliable model forecasting because there are inherent risks to draining reservoirs early (to accommodate flooding downstream) if the reservoirs can not be re-filled during the final stages of the freshet. This is a difficult balancing act for many operators.

SCENARIO 2 – 21ST CENTURY UTILITY

21st Century H_2O Utility is a large water purveyor that sources its water from a local creek that sometimes runs dry during hot summers. Decades ago, an upper watershed dam was built for the purposes of diverting and storing water in a large, off-channel reservoir during the spring runoff. The stored water is released from June through September to satisfy irrigation demands and domestic purposes downstream.

The utility tracks many parameters in their water distribution system, including daily and annual water consumption as well as peak flows. The parameters recorded in the upper watershed include stream flow, dates of changes in the release flow rate of water from the dam, the volume of water passing over the dam spillway, the volume of water passing through the dam outlet gates, annual water production from each upper sub-watershed above the reservoirs, and date of first release each season. The date of first release is weather-related and tied directly to when the snowpack has melted completely and can no longer supply water to the creek. The utility is concerned that this first release date seems to be occurring earlier and earlier in the year. The worry is that existing reservoir storage may not be sufficient to supply water for the longer and hotter dry seasons that climate models predict will occur with increasing frequency.

In looking at the records, the Manager noticed that water demand has actually decreased by 20% over the past 20 years. The decrease is apparent both in the peak summer water demands and in the total annual water demand by the customer base. The reasons for the decline in water demand reflect a range of policies and procedures put in place to enhance water conservation, including:

- *improved irrigation equipment, practices, and scheduling;*
- *shifting crop types (e.g., vineyards replacing forage crops);*
- *metering and pricing;*
- *improved customer education and outreach regarding water use efficiencies;*
- *leak repair.*

The utility supports agriculture and understands the economic benefits afforded to a region with a strong agricultural base. In the past five years, the water utility has been pressured to expand water for agriculture, specifically for vineyards and cherries. The utility is allowing expansion of the water system to the new plantings but is concerned with the loss of late spring snowpack, the fast growth of the agricultural industry, and the limited water supply.

The water from reservoirs that is currently in excess of the utility water demand is sometimes used to supplement environmental flows during very dry summers. However, this may not be possible if water demand increases and reservoir expansion does not. Having excess storage water in reservoirs above what is needed in an average year allows for flexible management and reduced conflict during times of water stress. The key challenge is to obtain reliable data and to track trends that can be used to inform decision-making and to document historical patterns to anticipate future needs. In the absence of detailed data sets to track past trends and predict future needs, the business case for expanded reservoir storage is difficult to make to the rate-payer base.

Lessons Learned: You cannot manage what you do not measure. The value of reliable long-term data cannot be overstated. At a time when the climate is rapidly changing, water managers and local governments must have access to data to make truly informed decisions. However, because of climate non-stationarity and changing demand scenarios, the data are most useful in predictive models rather than simple trend-line extrapolations. Without robust data, the economic impacts of an ill-informed decision can be catastrophic in the long term.

Historically, there has always been enough natural flow to recharge existing reservoirs on an annual basis, although annual spilling or full pool levels are not guaranteed. The 100+ year history of water stewardship in the Okanagan has allowed a robust system of water supply to evolve, even though water shortages are common, and severe drought conditions were declared in 2003 (OBWB, 2008) and most recently in 2021. Many of the major water purveyors have developed redundancy in their water sources to mitigate the risk of relying on a single source. Much is being done in a proactive and progressive fashion by way of drought planning and coordination, and public outreach campaigns are beginning to instill a public ethic of water conservation. A major study informing Environmental Flow Needs in the Okanagan was recently completed (ONA, 2020), and this knowledge will assist in managing water more efficiently in critical streams as well as informing new water licence allocations, as required by the BC *Water Sustainability Act.* The Okanagan Water Supply and Demand Project (Summit Environmental Consultants Inc., 2010) provides a good baseline to understand the hydrology of the Okanagan watershed as well as consumptive use patterns, and new hydrological models are being developed.

Despite these recognized strengths, there are also many weaknesses that can be identified with respect to the impact of climate change. A key concern is the lack of quantitative information on evapotranspiration (ET) and snow sublimation from the watershed and evaporation (E) from the mainstem lakes. Of the annual amount of precipitation that falls in the Okanagan (approximately 647 mm) approximately 81% (524 mm) is lost via evapotranspiration (Summit Environmental Consultants Inc., 2010), so ET is a critical component of the water balance (Figure 11). However, the losses due to ET are estimated by models rather than by actual measurements, and there is considerable uncertainty about the true value of annual ET as a fraction of annual precipitation (a value that changes from year to year). Notably, if the uncertainty is of the order of 10%, which is not unreasonable, then the error in ET is of the same order of magnitude as all the other terms in the water balance combined (e.g., river flow, groundwater flow, consumptive use, irrigation withdrawals, etc.).

ET is strongly influenced by land cover such as forest, grassland, or asphalt/concrete, and therefore it will become necessary to project land-use patterns into the future to understand how the land cover will change and affect ET (Figure 12). Where is urban development likely to occur? How will forests be managed to support timber harvesting and wildfire management, which works on cycles of 50-100 years? And what are the impacts of major forest fires or pine beetle infestations? Similarly, relatively little is known about soil moisture and how soil cover influences surface runoff and infiltration. And perhaps most critically, there are insufficient data on the hydro-climatic conditions in the Okanagan (especially at mid- and high-elevations) to fully understand and reliably model the regional impacts of global climate change (i.e., the down-scaling challenge).

In light of these climatic uncertainties and increasing consequences of dam failure, regulators are requiring increased conservatism in dam design, at a very high cost to water users.

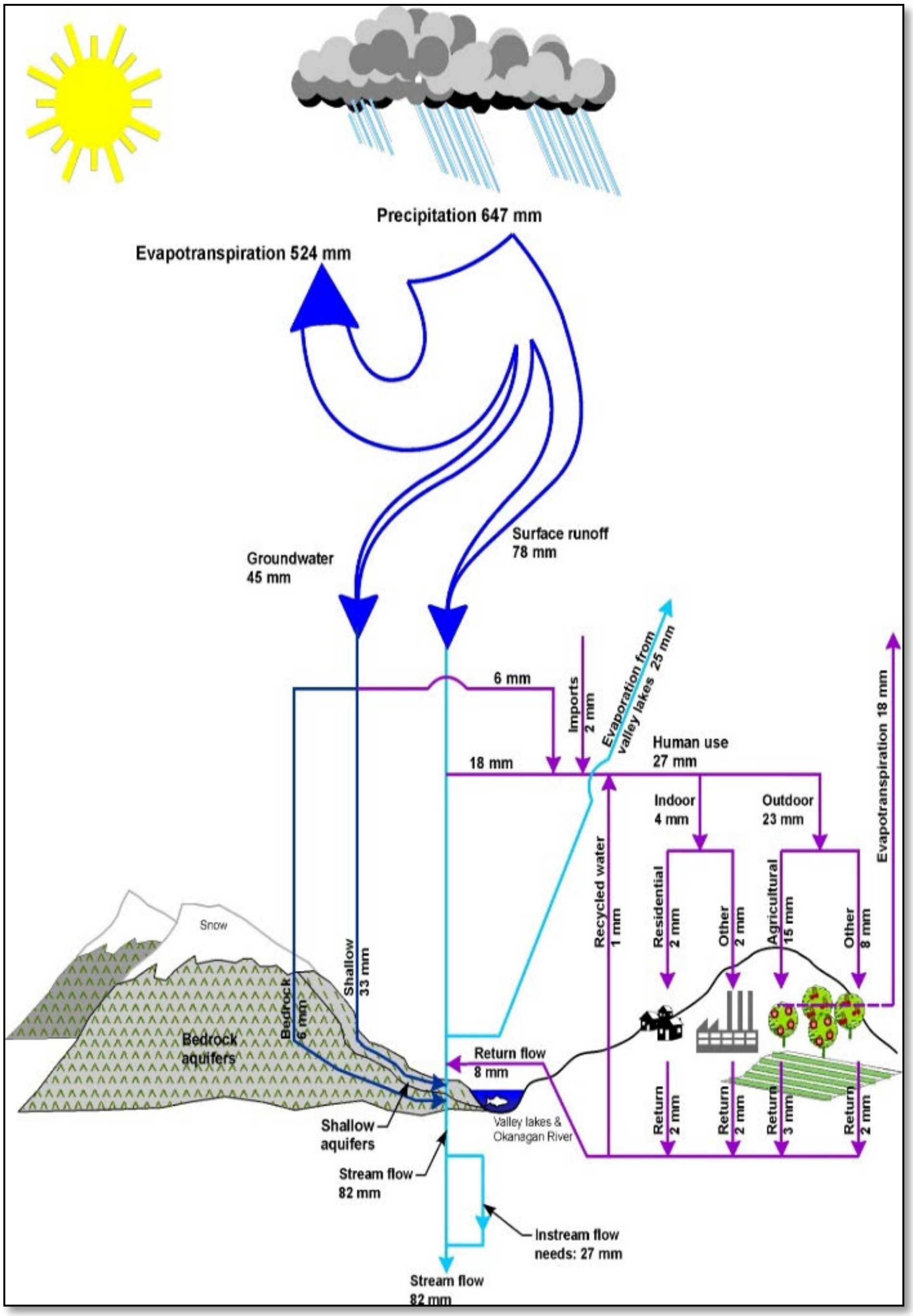

***Figure 11**: Main components of the annual water balance of the Okanagan watershed showing natural inputs and outputs as well as human demand. (Reproduced with permission from OBWB, 2008).*

(a)  **(b)** 

***Figure 12**: (a) Mission Lake (left) is located within a relatively undisturbed landscape within Graystoke Provincial Park; and (b) Ideal Lake Reservoir is within an area where the forest has been heavily logged around the reservoir, partially due to pine-beetle kill. Such land-use changes have implications for the local water balance primarily by influencing the rate of evapotranspiration, sublimation, and snowpack depth. (Photo credit: Bob Hrasko)*

6.2 Pressures of Population Growth and Urban Development

The population of the Okanagan is predicted to increase from about 350,000 in 2010 (according to a 2015 report by the Okanagan Valley Economic Development Society) to about 450,000 in 2040, depending on the expected growth rate. According to Statistics Canada, Kelowna (the largest urban centre in the Okanagan with a population of 152,000 in 2016) is the fastest-growing city in British Columbia and the fifth fastest-growing metropolitan area in Canada with a growth rate of 1.8% (https://worldpopulationreview.com/world-cities/kelowna-population). Since 2016, the growth rate has increased to about 2% for each of the subsequent three years, with similar rates of increase in Vernon and Penticton.

The consequences of rapid population expansion and urban development for water resources management are numerous. At the most fundamental level, an increase in the number of people implies greater water demand, not simply for domestic purposes but for all associated uses that drive economic well-being. Declines in per capita use due to conservation strategies will not outpace the increased demand driven by the increasing number of users. Whether this population lives in high-density residences or sprawling suburban acreages is a matter of personal preference and wealth, but the type of housing development and style of municipal infrastructure planning will have direct implications for water demand. In addition, cities are comprised not only of residential dwellings but of large buildings, factories, schools, golf courses, playgrounds, and parks, all of which have a need for water.

The indirect challenges posed by rapid urban development for dam and reservoir management are also pronounced. Whereas development along the valley-bottom creek corridors in the early 1900s was sparse and dominated by agricultural fields with little infrastructure, today there is an ever-densifying mix of residential, commercial, and institutional development. Most upland reservoirs were developed with a single purpose – irrigation - with little consideration for changing land use downstream. The construction standards of the day could not have anticipated the scale of future development valley-wide. Nevertheless, infrastructure development and population growth downstream of dams inevitably lead to a change in the consequence classification or risk rating of the dam. The current dam owner must comply with changes to consequence ratings, typically at significant expense, even though the owner may have little input or control over planning and zoning downstream. The costs are inherited by virtue of dam ownership in a constantly changing landscape of urbanization.

Potential consequences of a dam breach, a worst-case scenario for the upper reaches of a typical watershed in the valley, might result in the following:

- Rapid release of water from the reservoir over a period of several hours;
- Extensive flooding and property damage along the creek corridor, with potential for loss of life (human, livestock, wildlife);
- Severe erosion of channel margins in the steeper reaches of the creek resulting in mobilization and transport of massive quantities of soil, rocks, trees, and debris that would be deposited downstream;
- Loss of road access to the dam to initiate emergency repairs;
- Damage to road crossings along the creek, including roads, water, sewer, power, gas, and communications;
- Restricted access to creek corridor by emergency responders, including access for emergency vehicles;
- Loss of domestic, irrigation, and firefighting water supply;
- Immediate and multi-year economic losses to businesses, including agriculture;
- The creation of a debris plume entering Okanagan Lake causes environmental damage and severely degrades recreational and cultural First Nations values of the lake as well as the drinking water quality for communities that draw water from the lake.

Compared to the situation in the early 1900s, a dam breach today will have substantially more severe consequences primarily due to expanding population and intensified land-use in the valley bottom and up-stream corridors.

On the positive side, there is a comprehensive ***Dam Safety Program*** in place, and provincial dam safety officers have been active in providing stringent oversight in the wake of the Cannon Creek, Testalinden, and Mount Polley dam failures. Although this was initially met with resistance, the culture among dam owners has improved with the realization that the regulations are being applied uniformly and consistently. Dam safety training is available, and most local operators and engineering staff responsible for dams have received such training.

Nevertheless, there remain significant weaknesses in the current system of dam management. Many dam owners are still unaware of (or prefer to ignore) the full extent of their responsibilities for ensuring dam safety, and in general, community-level public servants (e.g., elected officials, planners, emergency responders, land developers) lack a deep understanding of the regulations, risks, and responsibilities. Most small dam owners do not have the requisite expertise to undertake dam safety inspections or to make required modifications, so there is a reliance on qualified professionals at considerable expense. The ***Dam Safety Program*** appears to be under-resourced with too few dam safety officers covering very large regions.

6.3 Inflationary Pressures and Budgeting for the Future

Increasing costs are a reality for all of society. However, inflationary pressures over the last few decades have affected dam owners in disproportionate ways. Historically, the majority of dams in the Okanagan were built at a time when design and construction standards were different, and the costs of materials and labour were relatively cheap. Older structures may be coming to the end of their useful life spans and will require rehabilitation or upgrading, at considerable expense. A primary driver of this trend has been the result of more stringent regulations put in place for public and environmental protection. The burden of responsibility and costs associated with meeting regulations is placed on the dam owner, who must, in turn, hire qualified professionals such as registered engineers and geoscientists to certify compliance. Municipal dam owners can rely on their tax bases and ratepayers to absorb these expenses, but private dam owners are often financially challenged to meet the requirements. Even if a private dam owner would prefer to decommission their dam rather than pay the costs necessary to maintain or upgrade them, decommissioning is a costly and complicated process.

The costs associated with expanding reservoir storage and building new dams or increasing the height of existing dams can be significant. Often a range of studies needs to be completed in association with an application for a new water licence that includes storage, and extensive consultation with First Nations is mandatory. Furthermore, there is no current equitable cost-sharing arrangement when the water (and reservoir) may have multiple uses that serve public interests (e.g., recreation, flood control, conservation flows).

SCENARIO 3 – TADPOLE POND

Following the amalgamation of the operations of a number of small water purveyors, Blue City assumed responsibility for all operations, liabilities, and capital expenditures as well as all water was contacted by the BC Dam Safety Program, indicating that one of the medium-sized concrete dams acquired in the merger was identified to have deficiencies. There were geotechnical issues, and the structure was in urgent need of costly upgrades. In part, this judgement was driven by rapidly expanding urban development downstream of the dam, which changed the 'consequence classification' of the structure from Low to Very High, following a recent dam safety review by an independent expert.

The Blue City Engineering Department conducted a risk analysis that showed quite clearly that: (a) there was no need for the water storage capacity behind the dam (because of the redundancies from other, more reliable sources that were recently acquired); and (b) it would cost more to upgrade the dam and maintain it into the future (projected over 25 years) than to decommission the dam and remove its footprint on the landscape. The City was also aware that house insurance premiums are typically higher for properties downstream of a dam, which would no longer be an issue if the dam were removed entirely.

Blue City proceeded with the decommissioning option, but it did not go as expected. During the design phase for decommissioning, an environmental review conducted by a qualified biologist found that the reservoir supported a small population of endangered frogs. Indeed, one shallow section of the reservoir had turned into a wetland with thriving populations of bull-rushes and aquatic vegetation that hosted populations of insects, invertebrates, amphibians, and birds. A group of local residents had organized a wildlife viewing society and had built a series of trails and a boardwalk along the fringes of what they referred to as 'Tadpole Pond.' Water-level fluctuations in the reservoir were never extreme enough to endanger the integrity of the wetland, and a recent wetland mapping exercise classified Tadpole Pond as a permanent feature with considerable habitat value.

Blue City was now faced with a serious management challenge. The fiscally responsible course of action was to decommission the dam and return the landscape to its pre-dam state; ideally a park or green-belt with considerable recreational benefit to local residents. Yes, it would be costly, but it was a one-time investment in the future. However, securing the permits to decommission the dam would not be an easy task because many other branches of government—those protecting environmental conditions—would become involved, and they, in turn, would require expensive studies as to how the damage to critical habitat could be mitigated, if at all. More importantly, the wildlife viewing society was already organizing marches and posting signs about how decommissioning of the dam would destroy valuable environmental conditions and directly impact property values.

These new developments altered the parameters of the original risk analysis, and a reassessment concluded that the decommissioning option was more expensive (both financially and politically) than originally anticipated. A third option was therefore developed whereby a reduction in the size of the reservoir impounded by a smaller, low-consequence dam would minimize risk to habitat, urban development, and operational costs. In the end, the reservoir was combined with an urban park setting with considerable amenity value. However, Blue City will need to accept that there will be ongoing costs to operate and maintain the dam in perpetuity.

Lessons Learned: When estimating the values of a reservoir, all values need to be considered, not just the water supply use. Changes to legislation and regulations, such as species at risk, can override the original purpose of the works resulting in additional unintended long-term costs to a water supplier. The example illustrates how responsibilities for dam management are assumed by a water supplier and not shared equitably among all benefiting parties.

6.4 To Expand or Not to Expand…That is the Question

Net expansion of reservoir storage capacity seems like an obvious strategy to mitigate the challenge of inadequate water supplies during the dry summer months. However, it is not immediately obvious whether new reservoir locations can be found in the Okanagan or whether existing dams can be increased in height to expand reservoir storage above the dam. There are questions about engineering feasibility, project costs versus benefits, regulatory requirements, and public support for building new dams. There is a general opinion among water experts that most of the ideal sites have already been identified and occupied, leaving little opportunity for expanding valley-wide storage in new locations. Based on estimates presented by Dobson (2008) as part of the Okanagan Water Demand and Supply Project (Phase 2) completed in 2010 (https://www.obwb.ca/wsd/), approximately 133 x 10^3 ML of water are stored annually in developed upland reservoirs. However, a total of 226 x 10^3 ML of storage has been licensed, suggesting that about 60% of reservoir capacity has been developed to date, and there is the capacity to expand if financial resources allow. An updated accounting of water licences with storage appears in Appendix D, suggesting that only about 161 x 10^3 ML of storage has been licensed, which increases the percentage of already developed storage to about 82%. Even if viable expansion potential exists or new dam sites can be found, it is not a foregone conclusion that the reservoirs will fill annually given the impact of climate change on the local water balance.

Loss of land due to reservoir filling is very contentious, especially when First Nations traditional territories are impacted or individual landowners are displaced. The construction of new dams could lead to substantial environmental impacts and destruction of natural habit. Public opposition can be anticipated, especially with respect to sensitive fish-bearing streams and First Nations cultural values. Dam owners would prefer to exclude the public from open access to reservoirs, in part to maintain water quality by restricting activities that may contaminate the water (e.g., boating, camping, mud-bogging, installation of lake-side septic systems), but also to avoid legal liability. Others view this as an infringement on their public rights to access and utilise Crown Land.

Large dams (i.e., greater than 2 x 10^3 ML) have essential ‘economies of scale’, but they have large foot-prints. Small dams with minimal impacts on land resources are unlikely to be built in the current fiscal environment given the costs associated with maintenance and monitoring to satisfy regulatory requirements. Large dams, if developed, should serve many functions to make them cost effective, and thus there would likely be competing objectives and interests (e.g., irrigation water supply, flood control, environmental flows, recreation, run-of-river power generation). On a positive note, given a decade of tightening regulatory requirements, it seems likely that current policies and regulation will remain largely unchanged in the near future, and therefore dam owners may enjoy a period of relative certainty with respect to norms and expectations governing dam and reservoir management. Nevertheless, the cost of operating and maintaining dams is significant, and appropriate long-term budgets are needed sooner rather than later.

SCENARIO 4 – CITY OF GREEN VALE

The City of Green Vale is contemplating water management changes in their community, motivated by the potential impacts of climate change on their water supply and increasing water demands due to the growth of residential homes and shifting agricultural practices. Everything points to the need for a new dam on the Riparian River.

The construction of a dam will be expensive and requires significant advance planning. Clearly, there is a need to understand the hydrology of the watershed, if only to be certain that the unlicensed natural flows in the upper reaches of the Riparian River will be sufficient to fill the reservoir to capacity on an annual basis. A hydrometric station was installed on the lower reaches of the Riparian River about 15 years ago, and there are a few other stations operated and maintained by the Water Survey of Canada in neighbouring watersheds. Having no expertise in hydrological modeling on their staff, the City of Green Vale hired a local consulting company (HydroHeads, Inc) to undertake a study. The report took nine months to complete, and it concluded that there is 'probably' enough flow in the system to fill the reservoir every 3 out of 5 years. There is considerable uncertainty around the projections because the available data time series are too short to make reliable projections into the future. Moreover, the required 'stationarity' of the time series that underpins the statistical analysis is not dependable because of shifting climatic patterns. It is a substantive and professional report, but it doesn't provide a firm conclusion on whether the reservoir will fill, if constructed, nor does it provide guidance on whether to proceed with the project or not.

During the preliminary stages of the project, the Water Manager at the City of Green Vale contacted the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) to determine whether the Province would consider a new water licence application with storage. Ms. Awesome answered the call and informed the Water Manager at the City that a new water licence application will need to be submitted and approved, followed by a formal technical plan submission for the dam design accompanied by a preliminary report (from the proponent) that includes information such as:

- *Proposed location of new dam;*
- *Extent of proposed reservoir with details on dam height, length, crest width, and maximum storage volume;*
- *Extent of the footprint of proposed dam and reservoir on timber resources;*
- *Potential impacts from dam and reservoir on; fish, fish habitat, wildlife, wildlife habitat, review of species-at-risk;*
- *Potential impacts from dam and reservoir on downstream; fish, fish habitat, wildlife, wildlife habitat, review of species-at-risk;*
- *Potential impacts of proposed dam/reservoir on any existing utility corridors;*
- *Presence/absence of any First Nations archeological sites within the project footprint;*

Ms. Awesome advises that the process could take a long time and the earlier that the three local Indigenous Bands, whose interests may be impacted by dam construction, are brought into the discussion, the better. Evidently, ArcheoLogo Consulting has done a lot of this type of work, and they are able to address any requirements under the Heritage Conservation Act through a potential Archaeological Impact Assessment.

Ms. Awesome also advises the Ministry of FLNRORD to be involved right away as there may be many steps that are not clearly defined by the process online. She also notes that the Canadian Department of Fisheries and Oceans needs to be involved as they likely have concerns relating to the project over and above what the FLNRORD Ecosystems department does.

Ms. Awesome is a fountain of knowledge, and she advises that water licences are applied for online through FrontCounterBC using the website. The Water Manager first signs up for a BCEID account. Once that is done, then the process to complete the water licence application is set out step-by-step in the application form. When the application is completed, the Water Manager can submit it to a local FrontCounterBC office along with the specified application fee.

Lessons Learned: Constructing a new dam is only one option to address increasing future water demands. Before deciding on that option, a water supplier should investigate all possible alternatives. A comprehensive water conservation program and unaccounted-for water investigation can have significant benefits in reducing demands and deferring the need for additional supplies. Considerable time and expense, as well as comprehensive consultation with affected First Nations communities, will be required before a decision can be made on whether a new dam and additional storage is the right option. Finally, there are many steps in the permitting process and many different branches of government to consider. The earlier approving bodies can be brought into the discussions (concept exploration), the better.

Despite the benefits of managed reservoir releases, there are many challenges associated with expanding reservoir storage that go beyond geotechnical concerns. A larger dam and reservoir system implies a likely change in associated risks of failure. There are differences of opinion regarding whether the dam owner or society in general (or both) should be absorbing the costs affiliated with a change in consequence classification. Under current regulations, however, it is the dam owner who is responsible, even if there are societal benefits that accrue to the dam and reservoir.

6.5 The Shifting Waterscape – Priority Interests and Beneficial Use

Water in semi-arid locations is, by definition, a finite resource, constrained by the limited capacity of the hydrologic cycle to meet the ever-increasing demands from humans. Many streams and creeks in the Okanagan region are already fully allocated with respect to the legal right to extract water by registered users with active licences. Agriculture plays a critical role in this supply-demand dynamic because it is the largest user of water in the valley and because most of the dams and reservoirs currently active in the Okanagan were built to serve irrigation demands in orchards and fields. For this reason, many agricultural producers claim some form of priority access to stored water, and their arguments are buoyed by public sentiment that favours local production and food self-sufficiency, at least in principle.

As the population in the valley expands, there is increasing pressure to re-purpose agricultural land for vineyards, commercial ventures, and urban development. In response, agricultural production is moving into previously unirrigated lands, often at higher elevations and in more northerly locations, which are now seen as viable given a warming climate. This is changing the map of water demand in the Okanagan in two ways: (1) there is new or more intense water demand in locations where historically there was little or no demand; and (2) in areas that have experienced intensive urbanization, there has been a need to shift beneficial use (see Appendix E) from agriculture to domestic and commercial purposes while also increasing supply to serve expanding needs. The situation has been complicated further by the requirement in the ***Water Sustainability Act*** (WSA) to consider environmental flow needs (EFNs) when considering new water licence applications.

The WSA uses a "First-in Time, First-in-Right" (FITFIR) system of priority access to water, but the WSA also ranks water use purposes (with similar FITFIR dates) from highest to lowest as follows: domestic, waterworks, irrigation, mineralized water, mining, industrial, oil and gas, power, storage, conservation, and land improvement, which is slightly different from the original BC *Water Act* (1909), which privileged mineral trading above irrigation but otherwise maintains the same general order of priority purposes. The FITFIR system of allocating water through licensing has, in theory, the advantage of preventing the potential 'drift' of licences from one use to another. However, existing practice is not always consistent with these principles, and there are instances when water allocated for one use may be used for different purposes. This is the case, for example, with water purveyors who hold multiple licences and who serve both rural and urban users within their districts.

The largest licences with the oldest priority dates tend to be those originally dedicated to agricultural purposes, but more efficient water use in the sector has led to under-utilization of the fully licensed allocation in many non-drought years. As urban development expands into the service areas of the water purveyor, water use can shift from agriculture to domestic. Since water is managed in bulk, there is no easy way to determine just how much water within an irrigation district goes to one use or another unless all end-users are metered and monitored (with appropriate record-keeping and reporting, which some utilities currently do). Repurposing of allocated water may occur when municipalities amalgamate or absorb historically small irrigation districts, thereby assuming ownership of the water licences and infrastructure. There are advantageous economies of scale associated with such amalgamations, but there can be negative outcomes as well. Water Utilities must apply to have the licence purpose changed if the licences do not match their needs. Water Utilities are also required to report their annual water usage per licence to FLNRORD. This reporting is one mechanism by which the province could assess the degree to which licensed allocations are being used for the specified purpose on the licence, but the capability to monitor and regulate such licence 'drift' uniformly is under-resourced.

7. FUTURE OPPORTUNITIES

Water managers in the Okanagan Valley have overcome significant challenges in the past, mostly with respect to the engineering and financing of upland storage and water distribution systems. The previous section has suggested that the challenges of the future are likely to be much more complex and nuanced.

Nevertheless, the future presents a wide variety of opportunities for improved water resource management in the years ahead, should society decide to come to terms with them and prioritize them. These opportunities need to be acted upon by appropriate parties and authorities. Under the current water governance structure as it pertains to dams and reservoirs in BC, the 'appropriate party' is either the dam owner (whether a municipality, private landowner or otherwise) or the Province, noting that the Province also owns dams. There may well be some areas where the OBWB is positioned to take on a leadership role, especially with regard to education, outreach, brokering of collaborative efforts, policy development, research projects, and provision of small grants.

The following sections summarize some of the opportunities that were identified in the SWOT analysis and should be considered for improving our ability to manage water in the Okanagan.

7.1 Living with Climate Change

- Improve our monitoring and modelling capacities to predict water supply and demand in the future with greater reliability. To do so, it will be essential to:
    - enhance our capacity to measure a range of variables that feed into hydrologic and supply-demand models (e.g., soil moisture, groundwater aquifer characteristics, evapotranspiration and sublimation, snowpack depth and density, etc.),
    - build stronger relationships with university researchers to enhance modelling capacity,
    - improve long-range forecasting and downscaling methods, so that dam operators are less reluctant to release water early in the season (to mitigate flooding) in favour of keeping maximum storage in anticipation of drought.
- Develop 'synoptic' climatologies for the Okanagan that define the characteristic conditions leading to extreme flooding events (e.g., wet autumn, rapid onset of freezing, followed by warm spring) or extreme drought, and use these as ways to forecast future conditions (in ways that complement numerical model predictions).
- Use the power of computational models to develop revised flood frequency and drought frequency predictions that go beyond standard statistical approaches based on extreme events and the assumption of stationarity in time series.
- Continue to develop 'demand-side management' strategies to reduce per-person use in the Okanagan, which is in excess of 600 L/day on average (Summit Environmental Consultants Inc., 2010).

- Develop a better understanding of temperature stressors to aquatic ecosystems as critical constraints on fish mortality in the context of reservoir release strategies.

7.2 Mitigating the Impacts of Population Growth and Urban Development

- Improve existing dam breach inundation models to take into account the likelihood of debris flow initiation downstream, which can cause far more damage than a flood alone, as occurred in the Testalinden dam failure.
- Continue to implement education programs for dam owners, land-use planners, emergency program operators, and elected officials.
- Improve climate and runoff modelling capacity to enable better reservoir inflow forecasting.
- Develop policies for watershed land use, development, and recreation, with a high priority given to dam safety where appropriate.
- Use OBWB mechanisms to initiate and implement Okanagan-wide initiatives that improve dam and reservoir management.
- Sponsor research into linkages between upland reservoirs and valley-bottom land use planning.
- Provide a coordinated approach and direct financial resources to the development of consistent risk assessments.

7.3 Dealing with Inflationary Pressures and Budgets

- Funding mechanisms such as the Agricultural Rehabilitation and Development (ARDA) program were put in place to assist with infrastructure upgrades, and a similar program could be established to assist with the costs of upgrading all dams regulated under the DSR with prioritization of high-consequence dams given the potential risks to downstream communities.
- Contingent valuation of ecosystem services provided by dams and reservoirs could be integrated into financial assessments of overall costs of building or not building new dams or decommissioning existing dams to provide a more accurate metric to assess the worth of a project.
- An increased focus on the urgency of climate change and its implications in recent years has created an environment in which an educated public may be ready to engage in a broad conversation about the trade-offs of developing (or not) new water storage versus water conservation and demand management.
- The issue of reservoir expansion and dam construction may stimulate ideas about alternative storage solutions such as groundwater injection that may be more cost effective and less environmentally destructive.

7.4 Exploring Reservoir Expansion

- Partnerships with First Nations can be established to accommodate First Nations objectives and cultural values, for example, with respect to environmental flows and fisheries.
- Recent LiDAR data of the Okanagan watershed can be used to accurately assess the natural capacity to expand reservoir storage (existing and new).
- An optimization modelling exercise can be undertaken to yield improvements in water-use efficiencies on a system-wide level that focuses specifically on dam operations to satisfy multi-objective criteria (e.g., when to fill or spill; when to release for EFN versus human demand).
- Work to establish coordination of operations, maintenance, and surveillance (OMS) activities between different dam owners in the same sub-watershed to reduce OMS costs and allow reallocation of a larger budget for infrastructure upgrades.
- Work to coordinate the timing and release rates of water in sub-watersheds with multiple dams and reservoirs so that water resources in the Okanagan can be managed in a coordinated fashion (optimize peak flood flow reduction and EFN).
- Allow reservoir operators to meet objectives over multiple years rather than on an annual basis.
- Assess whether storage volume in upper-elevation reservoirs is sufficient to affect flood mitigation efforts on main-stem lakes (and thereby implement basin-wide optimization strategies or not).
- Consider whether multiple dams on the same river can be used to cascade water from high-elevation reservoirs to mid-elevation reservoirs to manage EFN releases more efficiently.
- Water Sustainability Plan can be developed for sub-watersheds with reservoir storage to accommodate shared beneficial uses as guided by societal values.

7.5 Prioritizing the Value of Water

- Develop a system of meaningful collaboration between dam owners, government agencies, and various user groups and stakeholders, including environmental advocates and First Nations, to avoid future conflict over stored water during times of stress.
- Explore the possibility of establishing a Water Sustainability Plan, as defined in the WSA, that includes dam and reservoir operations as a mechanism to mitigate the negative impacts of dry season conditions. This could build on recent efforts to coordinate regional Drought Plans across the Okanagan.
- Explore the viability of a system of Water Reserves (e.g., for Agriculture and Environmental Flow Needs) that have the advantage of securing long-term access to water by sector rather than by individual licensees.
- Establish a fund that pays for some dam decommissioning costs should a licence be abandoned because the owner deems it no longer useful or cost-effective to maintain. A cost-sharing approach involving public money and dam owner contributions could be explored.
- Recommend changes to the practice that requires site visits to view the decommissioning of works (especially dams) prior to the abandonment of a water licence with associated dam works.

8. CONCLUSIONS AND RECOMMENDATIONS

Dam and reservoir management in the Okanagan will become increasingly complex in the future because of changes to the hydrologic cycle induced by climate change and by population growth in the region. Moreover, the ever-changing nature of human consumption patterns, attitudes, and values tied to water in the Okanagan will pose additional challenges. A pressing issue facing many dam owners is financing infrastructure upgrades to meet the requirements of the ***Dam Safety Regulation*** as urban development alters the consequence classification and increases the failure risks associated with individual dams. Dams vary in size, construction, and use, so guidelines for dam safety and cost-effective management are dam specific, with greater challenges faced by small dam operators because they cannot benefit from the economies of large-scale operations.

Over the longer term, the question of reservoir storage expansion looms large. There are compelling arguments, both for and against such an ‘engineered’ solution to water management in the Okanagan. Additional reservoir storage assists in capturing more of the spring runoff and thereby improving the capacity to provide water supply during the long, hot summer. If carefully managed, this additional supply may also provide a means to address environmental flows, especially in systems that may be prone to running dry. There is also limited potential to mitigate local flood damage during the spring freshet. Many other environmental and recreational benefits may accrue to large reservoir lakes. However, by installing flow-control structures such as dams and weirs on creeks and streams, the natural flow hydrograph is altered with the potential to significantly impact the natural aquatic ecosystem downstream in ways that can cause irreparable change. In addition, expanding reservoir storage is, in many regards, a short-term fix to a long-term problem. We may satisfy our immediate thirst for water, perhaps for a few decades, but the challenge in the future will always be to live within our means. **The Okanagan watershed has only so much water to provide, thus serious consideration has to be given to what a sustainable future implies for the demand side of the problem.**

A key question that the Okanagan Dams and Reservoirs Committee asked during its deliberation is “who is thinking about solutions to the many challenges faced by dam owners and water managers?” Finding solutions will require thoughtful leadership, collaboration, and a significant commitment of resources. For the most part, solutions to water supply issues in the region are beyond the purview and authority of individual dam owners. Yet dam owners will likely be responsible for implementing province-wide regulatory or policy changes. Basin-level leadership that bridges the provincial and local jurisdictions is the only sensible approach, working closely with dam owners to ensure practicality and fairness of the solutions.

The following recommendations have arisen from Committee discussions, and they are directed specifically at actionable items that the OBWB could initiate or undertake, either directly or indirectly, through collaborative networks. There is no implied ranking or order of importance.

1. *The OBWB should* ***initiate and lead (with local and provincial governments) discussions with the goal of exploring and implementing financial mechanisms in support of long-term infrastructure maintenance and sustainable dam and reservoir operations****. Guidelines for best fiscal management practices are needed (possibly in the form of a Dam Owners Financial Toolkit). Options for distributing the costs associated with dam ownership equitably among the full range of benefitting stakeholders should be investigated in a way that explicitly includes broader societal benefits (e.g., environmental flows, wetlands, species at risk). Given that owners of small dams are particularly challenged financially, without the benefit of economies of scale, a fund should be established either regionally or provincially to provide assistance with the costs associated with mandatory regulatory requirements (e.g., dam safety reviews, upgrades, site monitoring, formal inspections, decommissioning studies).*

2. *The OBWB should continue to* ***lobby the provincial and federal governments to expand regional capacity for measuring and modelling hydro-climatic trends into the near and distant future****. Such projections are essential for the proper operational management of dams and reservoirs, and adequate lead time is essential to make timely decisions on releases. Options should be explored to incorporate and re-distribute publicly the broad range of data that dam owners collect and routinely report to the Province (for purposes of water license management). The City of Kelowna data management initiative may be instructive in this regard. In parallel, the OBWB should ensure that recent initiatives to expand the hydrometric network in the Okanagan continue so as to include the optimal number of stations required for supporting valley-wide water supply-demand management.*

3. *The OBWB should* ***encourage, commission, and co-sponsor a range of scientific and technical studies focused on the future role of dams and reservoirs within a valley-wide water management strategy*** *that also considers, for example, water conservation, environmental flows, zoning by-laws, and First Nations perspectives, knowledge, and rights. Dams and reservoirs are recognized as integral and essential components of our water supply infrastructure, but they are not a panacea for all present and future water challenges in the Okanagan. An obvious opportunity presented by the recently acquired LiDAR data set of the Okanagan watershed is to assess the potential for reservoir expansion and new reservoirs valley-wide with much greater accuracy than was previously possible.*

4. *The OBWB should* ***collaborate with local governments and the Province to explore possible mechanisms to achieve efficiencies and economies of scale associated with coordinated reservoir operation*** *under a 'one operator' model for sub-watersheds that have multiple dam owners. Amalgamation is one option that has been implemented successfully in the central Okanagan. New water license applicants could be referred to larger water purveyors nearby, but some means of communication is required that currently does not exist. The intent is to alleviate many of the challenges faced by small dam operators.*

5. *The OBWB should* ***collaborate with the Province and water industry organizations to address evident gaps in existing outreach (education) programs*** *offered by a range of national and international organizations (e.g., Canadian Dam Safety Association, International Commission on Large Dams, Association of State Dam Safety Officials). The objective is to ensure a high level of awareness amongst Okanagan dam owners, land-use planners, emergency service providers, real estate agents, and*

landowners regarding risks and responsibilities associated with dam ownership and management in our region specifically.

6. *The OBWB **should investigate the extent to which land surrounding existing and yet-to-be-developed reservoirs could be protected from future development, privatization, and in the case of Crown Land, lease arrangements that would restrict future reservoir development**. This will also have a positive impact on water quality and assist water purveyors in maintaining high-quality water for consumptive uses downstream. It also facilitates the potential future expansion of the storage capacity of the reservoir. Restrictive covenants on the land titles surrounding the reservoir may be one possible mechanism to accomplish this objective.*

9. REFERENCES

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APPENDIX A: Okanagan Basin Water Board – Objects and Purpose

The Okanagan Basin Water Board (OBWB or Board) is made up primarily of elected local government representatives appointed from each of the three regional districts (North, Central, South) in the Okanagan region. Each regional district appoints three Board members (Directors). The appointments of non-elected representatives fill the remaining three spots that make up the twelve-member Board, one each from the Water Stewardship Council, the First Nations Alliance and the Water Supply Association of B.C.

While the overall mandate of the Board is to view the Okanagan Basin as one entity to be managed as a whole, regardless of political boundaries, the elected representatives are often inclined to adopt a more parochial view. This is understandable given that every representative is accountable to his or her regional district council and constituents. Consequently, the issues that usually gain the most traction with the Board are those common to each of the three regional districts, rather than those concentrated in one location. A good example of this is the invasive mussel issue, which has galvanized support from the Board and, subsequently, municipal councils up and down the valley.

A comprehensive description of the OBWB authority and mandate may be found at:
https://www.obwb.ca/newsite/wp-content/uploads/obwb_governance_manual_2016.pdf.

The objects and purpose of the OBWB are as follows (OBWB Governance Manual, SLP Appendix II):

3. The objects and purpose of the Board shall be:

- *(i)* *to organize or receive proposals from private interests, local organizations or agencies and all levels of governments concerning water resources utilization and management in the best interests of man;*
- *(ii)* *to define problems and determine such factors as priorities, economic feasibility, responsibility, necessary support legislation and required action;*
- *(iii)* *to provide communication and coordination between various levels of government and government agencies involved with water resources utilization and management;*
- *(iv)* *to present proposals and recommendations to appropriate agencies, being municipalities or governments, according to jurisdiction and responsibility;*
- *(v)* *to participate financially or otherwise, in such surveys, investigations or projects on behalf of municipalities, electoral areas or regional districts as may be authorized by the participating regional districts.*
- *(vi)* *The Board shall be the regional authority referred to in Recommendation 1(b)83 of the Comprehensive Framework Plan attached to and forming part of the Canada-British*

Columbia Okanagan Basin Implementation Agreement and the Board shall act as the coordinating agency in the implementation of any of the recommendations of the Comprehensive Framework Plan of the Okanagan Basin Study involving the regional authority.

(vii) The Board may advise any municipality or regional district and any Provincial Department or Agency that any proposed action, regulation or bylaw is contrary to the recommendations of the Comprehensive Framework Plan of the Okanagan Basin Study or any recommendation of the Board made pursuant to sub-paragraph (iv).

(viii) to participate in and to undertake an aquatic weed control program under a cost-sharing agreement with the Province.

The OBWB established the Water Stewardship Council (WSC or Council) as a technical advisory committee to enhance the effectiveness of OBWB recommendations and to provide a communication channel to water stakeholders. The WSC does not have delegated authority, and it reports directly to the OBWB. The work of the WSC recommends only those actions that can be undertaken within the bounds of the OBWB mandate. It is appropriate, therefore, that the work of the Okanagan Dams and Reservoirs Committee be targeted to the Board and consist of information and recommendations consistent with its objects.

APPENDIX B: Syilx Nation *siwɬkʷ* Declaration

SIWɬKʷ **- WATER**

siwɬkʷ is a part of us and a part of all life.

siwɬkʷ must be treated with reverence and respect. Our relationship with *siwɬkʷ* is not taken lightly; we are responsible to ensure that our relation can continue to maintain the health and resiliency of our *tmxʷ ulaxʷ* and *timixʷ* .

siwɬkʷ is the lifeblood of our *tmxʷ ulaxʷ* and our *timixʷ* and we as Syilx People recognize *siwɬkʷ* as a sacred entity and relative that connects all life.

siwɬkʷ comes in many forms and all are needed for the health of *tmxʷ ulaxʷ* and for the *timixʷ* .

siwɬkʷ is our most sacred medicine: *siwɬkʷ* nourishes, replenishes, cleanses, and heals. Any use of *siwɬkʷ* should be an act of reverence and a commitment to our responsibilities to all life: now and to come, as Syilx People.

siwɬkʷ comes from the sky and the highest places yet it never willfully rises above anything. It will always take the lowest path in its humility, yet of all the elements, it is the most powerful.

Our sacred *siwɬkʷ* water teaches us that we have great strength to transform even the tallest mountain while being gentle, soft, and flexible.

siwɬkʷ will always find a way around obstructions: under, over and through. It teaches us that anything is possible.

siwɬkʷ movements, pathways, resiliency and power teach us who we are and who we can be as people

https://www.syilx.org/wp/wp-content/uploads/2016/11/Okanagan-Nation-Water-Declaration_Final_CEC_Adopted_July_31_2014.pdf

APPENDIX C: Dam Classification according to the Dam Safety Regulation

Item	Column 1	Column 2	Column 3	Column 4	Column 5
	Dam failure consequences classification	**Population at risk**	**Consequences of failure**		
			Loss of life	**Environmental and cultural values**	**Infrastructure and economics**
1	low	none[1]	no possibility of loss of life other than through unforeseeable misadventure	minimal short-term loss or deterioration and no long-term loss or deterioration of (a) fisheries habitat or wildlife habitat, (b) rare or endangered species, (c) unique landscapes, or (d) sites having significant cultural value	minimal economic losses mostly limited to the dam owner's property, with virtually no pre-existing potential for development within the dam inundation zone
2	significant	temporary only[2]	low potential for multiple loss of life	no significant loss or deterioration of (a) important fisheries habitat or important wildlife habitat, (b) rare or endangered species, (c) unique landscapes, or (d) sites having significant cultural value, and	low economic losses affecting limited infrastructure and residential buildings, public transportation or services or commercial facilities, or some destruction of or damage to locations used occasionally and

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Item	Column 1 **Dam failure consequences classification**	Column 2 **Population at risk**	Column 3 **Consequences of failure** **Loss of life**	Column 4 **Environmental and cultural values**	Column 5 **Infrastructure and economics**
				restoration or compensation in kind is highly possible	irregularly for temporary purposes
3	high	permanent[3]	10 or fewer	significant loss or deterioration of (a) important fisheries habitat or important wildlife habitat, (b) rare or endangered species, (c) unique landscapes, or (d) sites having significant cultural value, and restoration or compensation in kind is highly possible	high economic losses affecting infrastructure, public transportation or services or commercial facilities, or some destruction of or some severe damage to scattered residential buildings
4	very high	permanent[3]	100 or fewer	significant loss or deterioration of (a) critical fisheries habitat or critical wildlife habitat, (b) rare or endangered species, (c) unique landscapes, or (d) sites having significant cultural value, and	very high economic losses affecting important infrastructure, public transportation or services or commercial facilities, or some destruction of or some severe damage to residential areas

Item	Column 1	Column 2	Column 3	Column 4	Column 5
	Dam failure consequences classification	**Population at risk**	**Consequences of failure**		
			Loss of life	**Environmental and cultural values**	**Infrastructure and economics**
				restoration or compensation in kind is possible but impractical	
5	extreme	permanent[3]	more than 100	major loss or deterioration of (a) critical fisheries habitat or critical wildlife habitat, (b) rare or endangered species, (c) unique landscapes, or (d) sites having significant cultural value, and restoration or compensation in kind is impossible.	extremely high economic losses affecting critical infrastructure, public transportation or services or commercial facilities, or some destruction of or some severe damage to residential areas

1. *There is no identifiable population at risk.*

2. *People are only occasionally and irregularly in the dam-breach inundation zone, for example stopping temporarily, passing through on transportation routes or participating in recreational activities.*

3. *The population at risk is ordinarily or regularly located in the dam-breach inundation zone, whether to live, work or recreate.*

APPENDIX D: Storage Licence Analysis for the Okanagan Watershed

Estimates of the total storage volume behind dams in the Okanagan are surprisingly difficult to obtain as the province does not keep track of this number directly. There is information available on dams (as regulated structures) that can be obtained from the provincial Dam Safety Program, but as discussed in reference to Table 1 in this report, the list does not include all dams listed as 'minor' or 'unregulated.' Moreover, it is often difficult to extract information on storage capacity as opposed to licenced storage, although technical details on the type of dam, construction date, and location are usually available. Thus, estimating the design total storage volume from information derived from the dam inventory would require significant manual labour, but would likely yield the most accurate information on actual (or developed) storage (with the caveat that not all dams are in the inventory).

A published summary of water storage associated with Okanagan dams and reservoirs appears in a report by Dobson (2008: https://www.obwb.ca/wsd/data/water-management-use) that is supplementary to the ***Okanagan Water Supply and Demand Project*** (Summit Environmental Consultants Inc., 2010). Table 2.4 of the Dobson (2008) report provides a summary of water licence volumes for waterworks, irrigation, and storage for 57 major water suppliers as well as all 'other' licences (lumped into one category) in the Okanagan as of September 2007. The total volume of licensed storage was 225,831 ML relative to a total volume of licensed withdrawals of 434,907 ML. The methodology for arriving at these numbers was not discussed in detail, nor were spreadsheets provided for all the licences downloaded from the provincial database. Rather, the reported values were aggregated according to water supplier and hydrological nodes to serve the modelling requirements of the Supply and Demand Project. The report notes that 17 of the largest water purveyors accounted for about 80% of the total licensed volume in the region, and in order to determine how much of the licensed storage was actually constructed or developed (and used annually), an in-person survey of those major purveyors was undertaken. The responses from the survey indicated that the largest 36 upland reservoirs accounted for 132,589 ML of water storage annually (Table 2.5 in Dobson report), which is consistent with the fact that not all licenced water is utilized to full capacity or that all storage allocations have been fully developed.

For the purposes of this White Paper, it was decided that the licenced storage estimates should be updated to the latest available information and quality controlled to provide the most accurate estimate of storage volume currently available. The methodology used is outlined in detail below.

1. Water Licence Data Acquisition

All BC water licences are publicly accessible from the BC Data Catalogue website (https://catalogue.data.gov.bc.ca/dataset/water-rights-licences-public#edc-pow) maintained by the Ministry of Forests, Lands Natural Resource Operations and Rural Development (MFLNORD) – Water

Management. This is a province-wide Spatial Database Engine (SDE) with a spatial layer displaying water rights data administered under the *Water Sustainability Act*, and it includes data for both surface water and groundwater Points of Diversions (PODs). To focus the search on the entire Okanagan watershed (rather than use search words linked to individual streams and drainages), a shape layer for the Okanagan watershed boundary was created and used to identify only those licenses within the watershed. A total of 5837 water licences were downloaded from a total of 84,996 licences province-wide. These Okanagan licences serve as the raw data set for the subsequent analysis, and the complete list can be found in the first worksheet ("All Licences_Download") of the accompanying Excel spreadsheet (Okanagan Water Licences and Storage Analysis_2021.xlsx).

2. Licence assessment and elimination of redundancies

Water licences are classified according to authorised (beneficial) use categories or purposes (e.g., waterworks, domestic, conservation, irrigation, etc.). Most water licences are for extractions at specified Points of Diversion (PODs) and do not have storage allocations associated with them. So it was necessary to isolate those licences that did have storage allocations by focusing specifically on the “Stream Storage: Non-Power” use category, which includes all upland storage reservoirs.

From the complete set of "Stream Storage: Non-Power" water licences, all the inactive, cancelled, and abandoned licences were removed from the database, leaving only currently active licences. In scanning these licences, it was discovered that there were a series of redundant entries, which needed to be eliminated. Duplicate entries with identical information (e.g., same licence #, same priority date, same owner, same volume allocation) were eliminated. In addition, multiple licence entries with the same “Maximum Licenced Demand for Purpose with Multiple PODs” (noted as ‘M’ in the QTTY_FLG column) were considered redundant and removed. This ensured that there was only one licence per ‘M’ listing remaining in the database, which accurately reflects the fact that the maximum allowable volume to be extracted is counted only once regardless of how many PODs were listed. For example, a municipality might have a water licence to extract 100 ML of water for storage in total, but there might be three points of diversion, each of which could conceivably provide up to 100 ML of water and each of which would appear as a listing under the same licence number (although the combined extraction should never exceed the licensed volume of 100 ML regardless of source). The resulting worksheet is the second tab labelled “Stream Storage_Non-Power” in the Excel spreadsheet.

Upon removing all ‘M’ redundancies, additional redundancies were identified with respect to “Total Demand for Purpose, one POD” water licences. These have been highlighted in yellow in the second worksheet. Ultimately, a total of 189 redundant entries were removed from the database and the resulting list of storage licences can be found in the third worksheet labelled “Final without redundancy”.

3. Total Volume of Licenced Storage in Perspective

As a result of the quality controls described above, the total volume of water that is licensed for storage (for non-power uses) in the Okanagan Basin is estimated to be 161,574,593 m^3/year. For purposes of comparison, the total annual inflow into Okanagan Lake is estimated at about 0.6 cubic kilometres or 6 x 10^9 m^3/year (Summit Environmental Consultants Inc., 2010). In other words, about 3% of the annual inflow (outflow) moving through Okanagan Lake is allocated to temporary storage in reservoirs across the entire Okanagan watershed. In contrast, the total volume of Wood Lake (south of Oyama) is estimated to be about 200 x 10^3 ML, so the total volume of licensed storage in the upland reservoirs of the Okanagan watershed is about 80% of the volume of Wood Lake.

4. Caveats

The licensed storage values reported above are the best estimates currently available. Nevertheless, there is uncertainty around these estimates, in part because the provincial water licensing database is large and complex. It is known, for example, that a number of small dams (some of which are not regulated) are not identified in water licences even though they may be known to the Dam Safety Program. In other cases, the water licence identifies a dam as part of the infrastructure associated with the licence, but the dam may not have been constructed or was constructed to larger (or smaller) capacity than stipulated in the licence. And the licences themselves are coded in complex ways, in many cases based on paper records from more than a century ago. Thus, the values in this report should be considered rough estimates at best.

APPENDIX E: Beneficial Use Clause of the Water Sustainability Act

Human use of the landscape is a complex manifestation of the interaction of economic, social, political, and geographical considerations that govern whether and how the natural environment around is modified to suit societal needs. Because our attitudes, norms, and circumstances shift over time, so does our footprint on the land. But the general need for water is pervasive. Thus, the primary purpose of a water licensing system such as the BC Water Sustainability Act is to control and regulate the use of water for *beneficial purposes* as defined through democratic processes. According to Royal BC Museum records in the Thompson-Okanagan, the principle of beneficial use has been part of BC water law since 1859, and it was enshrined in the BC Water Act of 1909. The BC Water Sustainability Act (2016) defines beneficial use:

(a) in relation to the use of water under an authorization, means using the water

> (i) as efficiently as practicable,
>
> (ii) in accordance with any applicable regulations, and
>
> (iii) for the water use purposes, in the manner and in the period or at the times, authorized by the authorization, and

(b) in relation to the use of water other than under an authorization, means using the water for a water use purpose

> (i) as efficiently as practicable,
>
> (ii) in accordance with any applicable regulations, and
>
> (iii) in accordance with the provisions of this Act or the regulations that apply in relation to the use of water without an authorization;

Failure to make beneficial use of water, as defined in the licence, may lead to the licence or approval being suspended or cancelled. Water licences may be cancelled if the licence holder has not made beneficial use of the water for more than 3 consecutive years. Beneficial use is thought to be fundamental from an equity perspective because it prevents stockpiling of water access by a licensee and frees up water for other parties to use, if approved.

The threat to existing licence holders with early priority dates is that temporary stoppage of use for longer than 3 years may lead to the licence being revoked. For some purpose uses there may be periods when consecutive use may be halted for more than three years (e.g., replanting of an orchard), and in other circumstances backup water supplies may be essential but not used “beneficially” on a continuous basis. If a beneficial use audit results in the cancellation of a water licence appurtenant to agricultural land, it could lead to a situation where otherwise arable land has no access to water for irrigation. In many watersheds, the streams are already over-allocated so the prospects of re-applying for a licence and received approval are essential nil. This takes the land out of agricultural production in perpetuity. Concerning storage licences for dams, the outcome of a licence cancellation may mean that there will be dams left on the landscape without a responsible party. In general, however, the licensee retains responsibility for the works associated with the licence and may be required to decommission the works if they are no longer used. Changes in property ownership are particularly challenging in this regard because new owners may not be aware of their legal obligations.

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