DAM REMOVAL & SAFETY IN CANADA:

Creating Opportunities through Gaps in Policy & Process

Student: Janna Peterson **Supervisor**: Felipe Montoya

Date of submission: _____, 2015

A Major Paper submitted to the Faculty of Environmental Studies in partial fulfillment of the requirements for the degree of Master in Environmental Studies, York University Ontario, Canada.

X

Dr. Felipe Montoya
Professor: York University

X

Janna Peterson
MES candidate. York University

Table of Contents

Foreword

The culmination of many profound events in my life have been the inspiration that has led to the writing of this major paper. I have been influenced by the people and world around me. My passion for the environment along with the how's and why's of our human interaction with it, fascinate and intrigue me. The process of earning a Master's degree in Environmental Studies at York has guided me towards that which I am truly passionate about: Water & People! More precisely; how the socio-hydrology nexus forms our current reality. So, when I stumbled upon the process of dam removal, I knew I wanted to delve deeper into this new and evolving challenge. I am interested in how the process affects communities, forms political policy and environmental legislation and the ways in which stakeholder involvement, adaptive management schemes and education can play a pivotal role in bringing communities together to create a consensus for dam removal. I am hopeful that the process of dam removal and the recommendation in this paper lead to improved positive ecological, social and economic outcomes and that this process has the potential to improve global ecological resilience and human well-being.

Source: https://en.wikipedia.org/wiki/Socio-hydrology

Abstract

The effects of age and climate change are taking their toll on Canada's dams. These mighty structures were once the powerhouses that drove Canada's economic boom during the mid-20th century. Many industries developed after WWII required electricity and vast resources, much of which were supplied through the harnessing of water by dams. This development was preceded by the territorial evolution of Canada which played an important role in the development of provincial territories and subsequent Acts, including the navigable waters protection Act which governed waterways and the development of dams.

We have now reached a time in our history where a perceptional shift in our ideas about these structures is fundamental to our safety and well-being. These once monolithic symbols of power and prosperity are now becoming an immense burden on provincial infrastructure expenses as well as safety hazards to people and the environment. Dam safety is evolving as a central focus for many provincial Ministries as they grapple with how to budget for the repairs and maintenance of these often decaying structures. Canada urgently needs an updated and cohesive nationalized system to deal with these dam safety issues. Dam removal needs to be an integral part of this new system as it offers an often less expensive and ecologically beneficial alternative. The objective of this paper is to provide recommendations to proponents of dam safety on ways to include dam removal in Canada's dam safety management framework. The recommendations I propose include an increase in funding for both dam removal projects and the provincial ministries in charge of regulating them, the creation of a more comprehensive and nationalized dam inventory and classification system, the implementation of a stream-lined dam removal program, tools for more integrated and efficient approach to prioritizing dams for removal and an accessible framework with which to track and monitor dam removal projects as well as catalogue dam incidents. Recommendations for improvement of this process will be addressed using information from the current Canadian Dam Safety (CDA) guidelines, as well as examining the current provincial Acts and legislation addressing dam safety and dam removal in Canada.

I have drawn inspiration and information from dam safety programs and dam removal case studies in the United States as well as correspondence with a variety of professionals in the dam industry such as, engineers, policy makers and biologists. Some of the contents of our correspondence is included, in whole, into this document as information on dam removal in Canada is scarce. Dam removal is a complex undertaking, with each project having a unique set of circumstances. Each case is sui generis, and requires a holistic and interdisciplinary approach in order to ensure successful outcomes. The safe removal of dams across Canada is possible and has the potential to revitalize communities, economies and environments.

Introduction

The golden era of dam construction has slowed in North America, and an increase in overtopping structural failure, and recently dam removal, are following on the heels of its demise.[1] Dams in Canada and across the globe are becoming a problem for a variety of reasons. It is now widely recognized that dams create more problems than they solve, and that their cumulative negative impact on river ecology and the environment is becoming more pronounced (WCD, 2000). Many of the dams in the industrialized world are aging and have either outlived any usefulness or are in the need of major maintenance and repair. Extreme weather conditions brought about by climate change are also stressing dams and their infrastructure. In this modern age, dams have also become a security risk and are potential targets, vulnerable to both physical and cyber-attack.

[1] The term dam decommissioning refers to the full removal of the dam and
Its associated structures as well as partial removal or lowering the height of the dam (OMNR: http://www.creditvalleyca.ca/wp-content/uploads/2011/02/stdprod_069407.pdf) .

The increase in dam failures translates into an increase risk to human safety, infrastructure and the environment. Dams continue to have negative impacts on fish populations, beach erosion and water quality. And though dams were originally constructed to provide energy, drinking water, irrigation, flood control, recreation, milling, tailing storage, navigation, logging and transportation, many have become obsolete, less efficient and hazardous. Furthermore, the original benefits provided by dams can most often be satisfied through alternative more modern techniques. Two options for resolving many of these issues are either to maintain and repair existing dams or to remove them. The financial and environmental cost of maintaining and repairing dams is often very expensive and does not alleviate all the negative issues associated with dams. Dam removal on the other hand, can be a less costly alternative and provides further benefits through the restoration or revitalization of the environment.

Unlike our neighbors to the south in the U.S., dam removal remains almost unheard of in Canada. And, with dam failure incidents on the rise, I felt compelled to look into why dam removal had not been embraced in Canada. What I discovered was a gaping hole on information and awareness about the process and benefits of dam removal, little to no funding for dam removal projects or dam safety programs and staffing as well as a lack of legislative process. Unlike the U.S., dam removal has not been well integrated into dam safety policy and regulations in Canada's provincial Acts. Therefore, dam removal regulation, policy and programs in the U.S. were used to guide my research in Canada.

Information on dam removal in Canada is scarce and often vague. Dams are regulated provincially hence, legislation varies from province to province. The U.S., on the other hand, has created an extensive framework which promotes the process of dam removal. However, in Canada I had to rely heavily on information gathered through email and telephone conversations with the Ministry of Natural Resources in Ontario, the Canadian Dam Association, Parks Canada, Engineers, biologists, the Ministry of Forest, Lands & Natural Resource Operations in B.C. as well as dam safety officers (DSO). Through this research, I discovered gaps that if addressed, could promote dam removal and thereby improve dam safety as well revitalize ecosystems, communities and livelihoods in Canada.

In order to achieve these results, I propose the following recommendations: create a better inventory of small dams, provide tools for prioritizing dam removal, develop a more robust dam classification systems, catalogue dam incidents, expand funding for dam removal and dam safety programs, build community capacity and awareness through conservation and local dam removal projects and implement a stream-lined national program for dam removal projects.

The State Of Dams in North America

Age and climate change are taking a toll on our nations dams. Dams are coming down, often without warning, or increasingly, through a process called dam removal and/or dam decommissioning. Figure 1 below depicts all the dams removed in the U.S. since 1936.

Figure 1.

US Dams removed since 1936. www.AmericanRivers.org/DamRemovalMap

Beginning in the 1950's through to the 1990's, Canada and the U.S. experienced unprecedented levels of development projects undertaken along their waterways. The average life expectancy of a dam is 50 years, and the National Inventory of Dams (NID) estimates that 85% of the 87,000 dams inventoried in the U.S. (only dams over 6'), will reach this age by 2020 (Quinn, 1999). Furthermore, the Association of Dam Safety Officials (ADSO) in the U.S. released a report in 2009, which estimates that the cost of rehabilitating these dams is in excess of $51 billion ("ASDSO", 2015). This amount is calculated for inventoried dams only and doesn't include the total number of small dams in the US, that is estimated to be over 2 million (Poff, 2002). In this modern age terrorism is also a factor in dam safety. In February 2015, the FERC published a draft revision of a Security Program for Hydropower Projects. Security inspections are now performed on significant and high consequence dams in conjunction with dam safety inspection to evaluate the security measures in place for both physical and cyber-attack, as well as to monitor their effectiveness against current threat conditions. With this in place, implementation of periodic inspection schedules and resulting reports facilitate dam safety enforcement as well as the implementation of emergency preparedness plans (EPP) [2]and reduce the potential for a dam incident or failure.

As mentioned, dams were and are built for a variety of purposes however, over time, some dams have become obsolete or no longer functional. Many have become safety hazards with the cost of maintenance and/or rehabilitation outweighing the cost of removal. As dams age they are more likely to fail and hence, become a safety hazard to people and infrastructure downstream.

Dams built in the post-war era, to drive industry and the economy in the U.S., are now deteriorating and are experiencing an increase in the number of failures and incidents (ASDSO, 2015).

[2] Document which contains procedures for dealing with various emergencies, as well as communication directories and may contain inundation maps showing upstream and downstream water levels and times of arrival of floods which would result from the failure of the dam or its appurtenances.

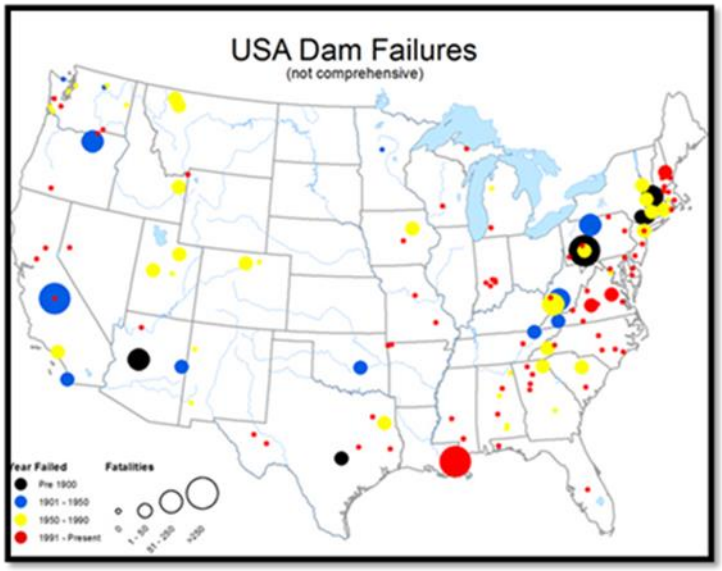


FIGURE 2.

A list of dam and levee failures compiled by USDSO.

An increase in dams and levees being breached due to extreme flooding events, is also on the rise and as a result, so are the incidents of significant infrastructure damage and loss of life (Dewan, 2013).

Globally, hundreds of thousands of people have lost their lives as a result of dam failures (Graham, 1999). Furthermore, as populations increase so do their migration and habitation of vulnerable areas along with the likelihood that these once remote occurrences, will pose an increased threat to human life. The Association of State Dam Safety Official explains on their website, “The current issue and debate is over the increasing number of these high-hazard structures--not because more high-hazard dams are being built, but that more development is occurring downstream (ASDSO, ‘n.d.).”

Dam safety regulators generally have no control over local zoning issues or developers' property rights. So this issue continues to worry regulators as the "hazard creep" trend persists (“ASDSO top issues”, 2015).

The United States has been removing dams for over 100 years, with the majority of these removals occurring in the last 20 years. They have removed more than 1150 dams in the past couple of decades; 72 of them in 2014, and collected scientific data on the process, as well as monitored outcomes of these removals ("American Rivers", 2015). The U.S. has established a national as well as state-wide databases that inventory over 87,000 dams in their National Dam Inventory (NID, 2013). Governments, conservation groups and NGO's have created funding opportunities for dam removal as well as made dam removal approval easier by streamlining the process in a variety of states. Prioritization tools along with environmental revitalization programs, have assisted in the recovery of degraded waterways and conservation of endangered fish populations. Countries such as Japan are following suit and just recently, began its largest dam removal project in history- the removal of the Arase hydropower Dam on the Kuma River (JFS, 2015). Sweden has also joined in and has been removing numerous small timber dams as illustrated in this montage of time-lapsed videos below.

Figure 3.

Dam Removal ReMiBar (removing migratory barriers in streams). Source: YouTube: https://youtu.be/bG5K8mzwTXM

The State of Dams in Canada

The Canadian Dam Association estimates that there are over 14,000 dams in Canada with approximately 1000 of them registered as large dams ("CDA", 2015). The CDA is a membership based, volunteer organization made up of engineers, dam owners, operators and regulators, which provides dam safety guidelines that can be used as a template for regulators to evaluate, classify, review and assess the safety of dams in Canada. We are ranked as one of the top ten dam builders in the world by the International Committee of Large Dams (ICOLD)[3], yet not until the recent past, have we begun in earnest to establish dam safety guidelines and revised and enhanced our provincial dam safety regulation and legislation policies. However, the topic of dam removal has not been adequately addressed in these changes. There is currently no national agency or federally regulated dam safety program to address the problem of monitoring, repair and maintenance of these ageing and potentially hazardous dams. Typically, dam safety is provincially or territorially regulated, with the exception of Parks Canada. And, some Canadian provinces have not yet implemented safety guidelines or regulations to address the issues of dam safety.

Canada's vast freshwater resources have, for decades, been harnessed through the construction of dams to supply energy for economic and industrial development, and to supply communities with a continuous supply of fresh drinking water, irrigation and flood control. Dams are often used to help reduce the seasonal fluctuation in water availability by impounding and storing water behind large walls of concrete, and then releasing it when needed. The price of this water security is the destruction of river ecosystems and their services and can often be achieved through alternatives such as improved efficiency, re-use, groundwater recharge, re-operation of existing dams and water markets.[4]

[3] ICOLD leads the profession in setting standards and guidelines to ensure that dams are built and operated safely, efficiently, economically, and are environmentally sustainable and socially equitable (ICOLD website).
[4] http://www.americanrivers.org/initiatives/water-supply/dam-alternatives/

Furthermore, many of Canada's dams are reaching the end of their physical and functional lives and often, do not meet current dam safety guidelines. These dams can potentially, pose a threat to downstream communities as well as to the environment and surrounding infrastructure. Owners of these dams are often unaware of the latent danger an unmaintained dam possesses, while some dam owners simply cannot afford the cost to repair and/or maintain them. Dam safety programs in Canada are evolving more rapidly than ever, and exposing the weaknesses of certain dam management programs, policy and procedures. The gaps that currently exist in Canada's regulation and management of dams and dam safety programs, are an opportunity for learning and improvement as well as a gateway for the implementation and acceptance of the dam removal process.[5]

Dams and Climate Change

In addition to the issues noted above, climate change is affecting us globally, through an increase in the magnitude and frequency of flooding incidents, drought, thawing of permafrost, rising sea levels and earthquakes, thus putting further strain on an era of aging and deteriorating dams and making them more susceptible to dam bursts, overtopping, breaching and ultimately collapse. The timely removal of unsafe dams and the return of natural flow regimes can help mitigate some of the environmental and ecosystem stressors caused by climate change.

[5] The Canadian Dam Association will be hosting its annual conference and exhibition October 4-8, 2015 in Mississauga Ontario. A part of the technical program will include managing small dams. To learn more, you can download their brochure at CDA Conference & Exhibition 2015.

Below, figure 4 outlines the impacts to infrastructure based on climate change hazards and also highlights the vulnerability of Canada's dams to drought, permafrost, rising sea levels and flooding. Adapting future dam safety management programs that address the effects of climate change is an important and necessary step to ensuring human safety and access to drinking water.

CLIMATE HAZARD AND/OR WEATHERING PROCESS LIKELY AFFECTED BY A CHANGING CLIMATE	INFRASTRUCTURE IMPACTS
Drought	• Increased water demands and pressure on infrastructure • Water apportion issues • Loss of potable water • Increased water quality problems • Increased risk of flooding • Dam failures
Permafrost degradation	• Rupture of drinking water lines • Rupture of water storage tanks • Increased turbidity and sediment loads in drinking water
Rising sea level	• Saltwater intrusion in groundwater aquifers
Flooding	• Water-borne health effects from increased flooding • Volatilization of toxic chemicals • Summer taste/odour problems in municipal water supply

FIGURE 4.

Climate change and infrastructure impacts: Water infrastructure. Figure from, IISD report November 2013.

In the U.S., the Pennsylvania Climate Adaptation Planning Report is addressing warmer temperatures, increased precipitation, more frequent and intense storm events, flooding and drought by creating an action plan that will minimize hazards to existing structures (PDEP, 2009). The CDA has also addressed some of the impacts of climate change and the emerging techniques and technologies for mitigation and adaptation in their 2015 Climate Change Technology Conference.

The unavoidable need for such climate adaptation planning reports was reinforced for me when, on a recent trip to Australia in February 2015, cyclone "Marcia" hit Queensland, causing a breach of the Callide dam, resulting in a flood to downstream communities.

Sunwater, the operator of this dam suggested that the breach was due to heavy rainfall that was a 1-in-10,000 year event, though more recent news reports say that they were unable to predict when the dam would reach capacity. The uncertainty over extreme weather events caused by climate change, along with the number of dams being breached and/or failing continues to rise while the uncertainty of these events seems to be diminishing. This makes the need for effective dam safety regulations and in particular, the inclusion of a more streamlined dam removal processes, more urgent than ever. The process of removing dams revives and restores ecosystems and communities thereby allowing them to become more resilient and able to adapt to the effects of drought and flooding. The effects of climate change can be mitigated through the benefits of dam removal. These benefits include the return of wetlands, floodplains and riparian vegetation- all offering improved flood control. Healthy floodplains and wetlands increase infiltration of rain water and aquafer recharge thereby increasing the opportunity for increased carbon fixation through a more abundant and diverse plant and animal biomass (Palmer et al., 2009). As the effects of climate change increase, the need for dam removal, as a way to help mitigate and even reverse anthropogenic environmental degradation, restore ecological systems, revitalize communities, increase sustainable economic opportunities and create new water management schemes, becomes more urgent.

A Brief History of Canada's Water Legislation

Understanding the historical evolution of water management and licensing in Canada, can help shed light on how dams are currently managed and how dam removal can become a more integral part of the process. The late 1800's and early 1900's saw the development of Western Canada and the creation of the provinces. The formation of Canada's provinces, invoked the transfer of water resource management from federal jurisdiction under the 'Natural Resources Act', to provincial jurisdiction.

According to the CDA, "the transfer of water rights from a federal to provincial jurisdiction is a significant event. From this Act, and the connection of dams with water resources, dams and dam safety also become a provincial responsibility (CDA, 2010:p.2)." As such, each province is responsible for the implementation of dam safety regulations. Historically, the provinces regulated dams in order to manage the demands of water availability for domestic, agricultural and industrial uses. A regulatory evolution is underway now focused on policy concerned with safety and the environment.

The economic expansion of the post-war era saw a boom in dam construction and the implementation of a variety of water license and allocation management regimes (CDA, 2010). For instance, dam safety in Alberta was legislated in 1978 and in 1999, Alberta enacted the Water Act which today, legislates and hence, regulates dam safety (CDA, 2010). In Ontario, dam safety, modification, construction and removal must be approved by the Ministry of Natural Resources (MNR) and in some cases Fisheries & Oceans, Transport Canada, Ontario Ministry of the Environment, Ontario Ministry of Culture as well as the municipality in which the dam is situated. This is regulated under the Ontario Lakes & Rivers Improvement Act. Quebec has the most comprehensive dam safety Act which was enacted in 2000 in response to extensive flooding in 1996 of the Saguenay River. [6] In British Columbia, water supply dams are regulated by the Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) Dam Safety Program and require a license under the Water Act.

[6] The Saguenay Flood (French: Déluge du Saguenay) was a series of flash floods that hit the Saguenay-Lac-Saint-Jean region of Quebec, Canada, on July 19 and 20, 1996. It was the biggest overland flood in 20th century Canadian history. Over 8 feet (2.4 m) of water ran through parts of Chicoutimi and La Baie, completely levelling an entire neighborhood. Over 16,000 people were evacuated. The official death tolls were seven deaths, but other sources (notably Canadian Geographic.
http://www.canadiangeographic.ca/magazine/ma97/feature_saguenay_floods.asp). Estimates reach CAD $1.5 billion in damages, a cost made greater by the disaster's occurrence at the height of the tourist season. Post-flood enquiries discovered that the network of dikes and dams protecting the city was poorly maintained. In the end, 488 homes were destroyed, 1,230 damaged and 16,000 people evacuated from the entire area, with ten deaths in the mudslides produced by the incredible rain.[2]: http://www.collectionscanada.gc.ca/sos/002028-1300-e.html?PHPSESSID=mqubhdap68k4igpbi63bd726j0)

Tailing storage dams are regulated separately under the Mines Act. Needless to say, the variation in Canadian dam safety legislation has evolved alongside Canada's historical need for water to drive its economic engine, and hence, has created a confusing and disorganized system for the regulation of dams in Canada.

Dam Safety Regulations and Removal in Canada

Dam safety and removal are interdependent. The regulation of dam safety in Canada is as important to the process of dam removal, as the removal of dams is to dam safety. "Numerous dams have been removed in Canada. However, these removals have generally been implemented without a structured assessment process, often following a dam failure event. For this reason, most of the projects are not documented and any benefits (or detrimental effects) are not known (Donnelly, 2005:1)." There is currently no cohesive national policy or federal regulatory agency that provides a framework for the regulation of dam safety and management in Canada. Canadian dams, with the exception of boundary waters, canals and national parks are regulated by each individual province or territory. And, according to the CDA, as of 2010 only 4[7] out of 13 Provinces and Territories had specific dam safety regulations.

On the next page, figure 5 offers a partial summary chart of dam regulation in Canada. It outlines the various *Acts* under which dams are regulated. However, keep in mind that this is separate from the enactment of dam safety inspections programs and in general, refers more to permit approvals for the construction and water licensing of dams.

[7]BC, Alberta Ontario & Quebec.

The column under 'guidelines' shows which provinces have enacted inspection and maintenance programs around dam safety, and which ones, have not. Not all provinces are listed below but can be found on the CDA website.

Province/ Territory	Ministry/ Agency	Contact	Legislation/ Regulation	Regulation	Guidelines (Other Than CDA)	~ Number Of Dams
British Columbia Water Supply Dams	Minstry of Forest, Lands & Natural Resource Operations Water Management Branch	Scott Morgan Head, Dam Safety Section 250-387-3265	Water Act	Dam Safety Regulation	Inspection & Maintenance of Dams Inspection Guidelines Plan Submissions	Regulated Dams ~ 1,650 Unregulated Dams ~ 460
British Columbia Mining Dams	Ministry of Energy & Mines	George Warnock Manager, Geotechnical Engineering (250) 565-4457	Mines Act	Health, Safety & Reclamation Code	Dam Safety Inspection Guidelines APEGBC Professional Practice Guidelines - Legislative Dam Safety Reviews in BC.	118
Alberta Water Supply & Tailings Dams	Alberta Environment and Sustainable Resources Development	Javid Iqbal, Manager Dam Safety (780) 644 7437	Water Act	Water Ministerial Regulation	Dam Safety Guidelines	1360 Water 40 Tailings
Saskatchewan Water Supply Dams	Water Security Agency	Ashley Gusikoski Dam Safety and Major Structures (306) 694-7738	Water Security Agency Act (1)	No	No	1300 (2)
Saskatchewan Tailings Dams	Environment	Tim Moulding Uranium and Northern Operations (306) 933-7063	Assessment Act	No	No	15
Manitoba	Water Stewardship Department	Steve Topping (204) 945 7488	Water Res Admin & Water Rights	No (Planned	No	570

Figure 5.

Regulation of Dams in Canada. CDA 2010. To view all of the Canadian provinces visit: www.cda.ca

Due to restrictions on the length of this paper, the following 2 sections will only cover some of the legislated guidelines and safety regulations from B.C. and Ontario's provincial *Acts* pertaining to dams and dam removal. This should highlight the complexity and perplexity inherent in Canada's current system of dam safety and regulation.

Dam Regulations & Safety in B.C.

There are approximately 2119 dams regulated under the Water Act in B.C. and these dams are covered by the dam safety program, 153 of these are breached or abandoned (MFLNRO, 2014)[8]. According to the MFLNRO website, "dams 9 metres or higher are the responsibility of Victoria based staff and dams less than 9 metres are generally a Regional responsibility. There are also a number of tailings dams, sewage retention ponds, dugouts and other structures that retain water that are not licensed under the Water Act and therefore are not covered by the BC Dam Safety Program (MFLNRO) ".

The status of dams regulated under the Water Act is determined through dam audits, carried out by Dam Safety Officers (DSOs) to ensure compliance. The frequency of these audits is correlated to the dam's failure consequence classification which are listed as either; significant, high, very high and extreme. According to the MFLNRO (2014), changes to BC dam safety regulations and compliance for both regulated and mining dams are currently underway. Regulated water dams are covered in the MFLNRO's Dam Safety Report, Strategy and Procedures for Compliance and Enforcement (2104). The report includes enforcement options for DSOs, as well as enforcement actions which can include the cancellation of a Water License as well as a DSO directive to remove the dam. Statutes and regulations pertaining to enforcement are listed in Appendix A. The report also acknowledges the need for enhancement to the compliance and enforcement procedures, improvements to the dam registry as well as ongoing monitoring and auditing of dams by dam owners and dam safety officers. Dam safety is important as an evaluative tool. The classification of a dam as a dangerous due to the need for repair, upgrade or maintenance may act as a catalyst for the implementation of a dam removal order.

[8] Of the regulated dams, 1,483 are operational dams ranging in size from some of the largest structures in Canada, such as the Mica Dam which generates hydroelectric power, to small earth-filled dams that create water storage for domestic use (http://www.env.gov.bc.ca/).

In 2000, the Ministry of Forests, Land and Natural Resource Operations (MFLNRO) in B.C., under the *Water Act*, enacted the *BC Dam Safety Regulation* (44/2000). It was then amended in 2011, following changes made to the CDA dam classification scheme, from a 4 to 5 tiered system (Appendix D). Dams regulated under the Water Act, are covered through the B.C. dam safety program. However, there are a number of tailings dams, sewage retention ponds, dugouts and other structures that retain water but are not licensed under the Water Act and therefore, not covered by the BC dam safety program. Under the *Act,* the dam owner is defined as the person who holds the water license to store or divert water. If there is no water license associated with the dam, then the dam owner is defined as the person who built the dam or who owns the land associated with the dam. The regulations outlines the requirements for the safe operation and maintenance of the dam. In order to remove the dam or make alterations, requires the dam owner to apply for and receive permission from a dam safety officer (DSO). The regulations also defines the parameters for dam classification based on the probability of failure and its consequences[9]. While the CDA guidelines are not mandated and have no legal status in BC, they, along with dam safety review guidelines produced by the Association of Professional Engineers and Geoscientists of BC (APEGBC)[10], aid dam owners in understanding their responsibility for ensuring the safe operation and maintenance of their dams.

[9]The BC Dam Safety Regulation - Schedule 1 "Downstream Consequence Classification Guide" outlines a classification guide for all dams in British Columbia. The consequence classification (very high, high, low, or very low) identifies the potential for damage and loss in the unlikely event of a dam failure. The consequence classification is not a reflection on how safe the dam is; thus age and condition of the dam are not reflected in the Consequence classification.

[10] The Association of Professional Engineers and Geoscientists of British Columbia is the licensing and regulatory body responsible for BC's professional engineers and geoscientists. The association is charged with protecting public safety in BC by setting and maintaining high standards of professional practice and ethical conduct for its members and licensees retrieved from: https://www.apeg.bc.ca/Home

APEGBC has created a dam safety review process chart which can be seen below in figure 6.

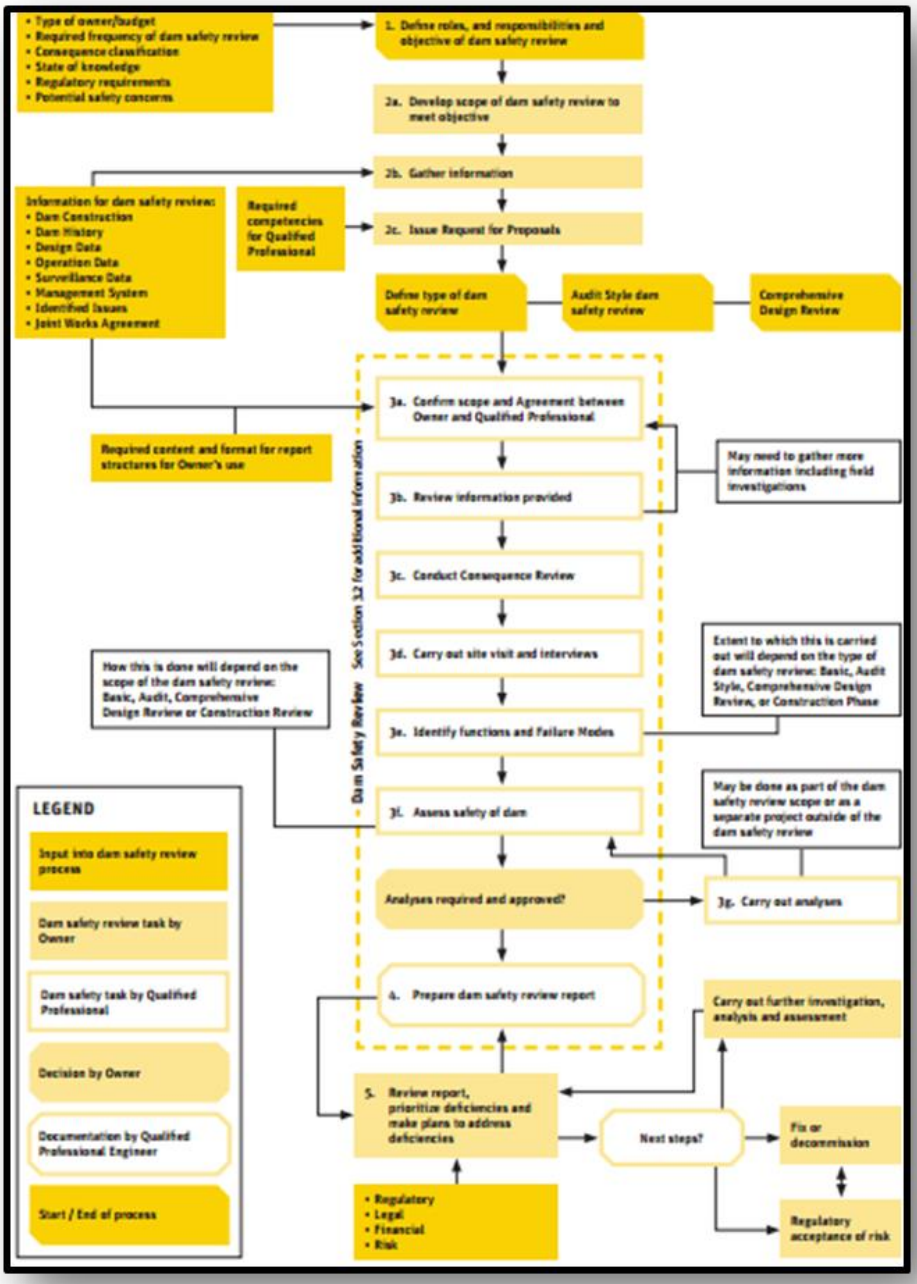


Figure 6.

Dam Safety Review Process in BC. *(APEGBC)*

Professional Engineers and Geoscientists of B.C. (APEGBC) also released a 2012 report titled, Legislated Dam Safety Reviews in BC, which states that, "the understanding of the natural hazards imposed on the dam is continuously evolving and technical methodologies for dam safety analyses are continuously developing as new knowledge is acquired in various aspects of dam safety (APEGBC, 2010)". Furthermore, BC Hydro released a new 2014 Seismic Study and Action Plan that addresses hazards to dams due to earthquakes. They also provide a Dam Safety Fact Sheet outlining their dam safety program governing all 79 of their dams.

In the past, compliance with dam safety regulations in B.C. has been voluntary. However, in November 2014, MFLNRO updated their Dam Safety Compliance & Enforcement Policy which outlines dam owner requirements, as well as details on the promotion, verification and enforcement of such compliance (MFLNRO, 2014).[11] And, while it is still voluntary, there are a larger number of dam owners initiating and submitting dam safety reviews. The goal of this document is to provide dam owners with a clearer understanding of dam safety requirements, the necessary steps for compliance with all regulatory requirements and to ensure the protection of public safety and to minimize impacts to the environment and the economy. More specifically, the MFLNRO states that, "the purpose of the *BC Dam Safety Program* is to reduce the risks to people, property, infrastructure, cultural values and the environment that are associated with the design, construction, operation, maintenance and/or decommissioning of a dam (MFLNRO, p1)."

Dam Safety Officers (DSO's) also have a list of escalating enforcement options for non-compliant dam owners which are found on page 12 of the Dam Safety Compliance & Enforcement Policy (2014) and include (*in Italics*): the following 10 compliance steps:

[11] A Dam Safety Compliance & Enforcement Policy was endorsed by Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) executive and approved by the Water Policy & Legislation Committee and the Director of the Compliance & Enforcement Branch of MFLNRO in November 2014. The Compliance & Enforcement Strategy and Procedures were prepared by the Dam Safety Section, Water Management Branch in consultation with regional Dam Safety Officers and the Compliance & Enforcement Branch. These two documents are identified in the Policy as related documents and referenced in Sections 7 and 8 of that policy.

1. *Letter – clear written communication with the dam owner describing what needs to be done and when it is to be completed.*
2. *Email reminder*
3. *Telephone reminder*
4. *Letter reminder*
5. *DSO visits site and may conduct a dam audit*
6. *DSO & NRO visit site together*
7. *NRO visits dam owner*
8. *NRO follow-up site visit*
9. *Write Water Act Order*
10. *Cancellation of the Water License*

Enforcement actions include the following, usually in this order. Specific actions appropriate for various types of non-compliance are identified in the options table.

1. *Ticket is issued to a dam owner by the NRO. The three types of tickets are: compliance notice, warning ticket and fine ticket.*
2. *Deliver Water Act Order3 to dam owner to: repair the dam, drain or lower the reservoir or to stop work.*
3. *Deliver Water Act Order4 or DSO directive to remove the dam.*
4. *Charges under the Act.*

The section of the Water Act, pertaining to dam removal can be found in B.C. Reg. 163/2011, Section 9 of the B.C. Dam Safety Regulation under the heading, "suspension of normal operation or removal of a dam." The regulation is as follows:

(1) A dam owner must give the controller or regional water manager at least 60 days written notice before undertaking any of the following activities:

(a) Removing all or a significant part of a dam;

(b) Decommissioning or abandoning a dam;

(c) Stopping the normal operation of a dam for a period of time longer than one year.

(2) The dam owner must prepare and submit to a dam safety officer for approval,

(a) A plan respecting an activity under subsection (1) (a) or (b), or

(b) If required by the dam safety officer, a plan respecting an activity under subsection (1) (c).

(3) The dam owner must, at least 14 days before the date on which the work is expected to commence, notify a dam safety officer before commencing any work under the approved plan.

(4) The dam owner must submit to a dam safety officer, on the completion of the work performed under the approved plan, a report on the work and the manner in which it was performed.

(5) The dam owner must undertake any further actions that the comptroller or regional water manager requires to alleviate any adverse consequences to any person, the infrastructure or works, other property or the environment that may be affected by any work performed on the dam.

(6) An approval under subsection (2) respecting the decommissioning of a dam is subject to the Environmental *Assessment Act and to approvals, if any, required under that Act.*

It is estimated that only 21 dams have been removed in B.C. since 2006 (Brennan Clarke, MFNR). They include the Heber River dam, Mavis Lake dam and the Jack Lake dam located on Vancouver Island, and on the Upper Greyback dam near Penticton (Int'l Water Power, 2013). The majority of these dams were removed as the cost of repairs and maintenance outweighed the cost of removal. Figure 7 provides a summary of dam removal activity in B.C., but that doesn't reflect the numbers above.

Areas	New Dams[1]		Rehabilitation		Removal	
	Project Review	Construction	Project Review	Construction	Project Review	Construction
Dam Safety Section (Major Dams >9m high)	3	1	7	1	9	1
West Coast	0	0	1	1	0	1
South Coast	10	0	3	2	1	1
Thompson	0	1	4	1	0	2
Okanagan	2	1	1	1	1	1
Kootenay	1	0	0	2	2	0
North	1	0	2	0	0	1
Cariboo	1	0	1	0	2	2
Total	**18**	**3**	**19**	**7**	**14**	**9**

Figure 7.

Summary of dam construction and removal projects in B.C. 2013/14**.** BC dam safety program annual report 2013/2014

In 2013, prompted by safety concerns due to its ageing structure, the Ministry owned Providence Dam in Greenwood was decommissioned. A list of the projects challenges and other information can be found on the project engineer's website at: Kerr Wood Leidel. More recently, the failure of the Testalinden dam in 2010 has prompted B.C. to review all its dams and identify those that didn't meet the dam safety standards as well as those that no longer served their original purpose (IWP, 2013). Also, the City of Nanaimo recently received a letter from the provincial Dam Safety Section ordering the city to make a decision on the Colliery Dams by May 1, 2015. These dams were built in 1911, serve no current purpose and deemed unstable. According to Bill Sims, the city's manager of water resources, the cost to remove the dam will be approximately $7 million, whereas the cost to rehabilitate or build new ones will be in the range of $20-$30 million. For more information visit the city of Nanaimo's website and search under the Collier Dam information page.

Finding information on policy, process and regulation involving the removal of dams in B.C., is difficult. In my quest for information, I contacted Monty Miedreich, a Senior Dam Safety Officer, in the Dam Safety Section of the Water Management Branch. I sent him an email asking him to list the steps a dam owner would follow, if they wanted to remove a dam in BC. He mentioned that, "*A key factor in dam removal/decommissioning is that every case has a unique set of circumstances so every project has its own unique set of requirements for its completion."* He also provided me with a list of steps involved based on current regulations under the *Water Act,* and indicated that the process is currently under review and new guidelines will be established by the end of 2015. The water Management Branch, under the Dam Safety Section of the MFLNRO has provided *(in italics*) the following information regarding the process of dams removed in B.C.,and regulated under the Water Act:

The holder of a Water Licence may advise the Dam safety section of their intention to remove the dam they own. The owner is requested to obtain all relevant authorizations that may be necessary from relevant government agencies that may be affected by the project. Section 9 of the Dam Safety Regulation states the dam owner must provide a plan, prepared by a qualified professional, describing the removal project, for review and approval. The complexity of the removal design will depend on the size of the dam and other factors.

The dam owner must then provide, at a minimum, the following information for our Section 9 approval review:

<u>Complete Dam Removal</u>:

The entire dam and associated works must be removed so that no trace of the structure remains and to ensure that the outlet channel is protected from erosion as necessary.

<u>Partial Dam Removal</u> (Partial Breach):

In some cases a complete removal is not feasible or practical.

A partial removal or partial breach may be acceptable if it conforms to the following minimum standards (similar to the minimum spillway design standards that are laid out for in our Plans Submission Guidelines):

Capable of passing the inflow design flood quantified for the appropriate consequence classification noted for that dam. Many small dam owners may not have the design information available to them. In those instances, the qualified professional should determine the design flood for the watershed and design a breach capable of passing that flow,

The Breached section must:

- *Be cut down to the natural stream bed, or undisturbed ground,*
- *Be a minimum 4 meters wide at the base (to reduce possibility of debris blockage and beaver activity),*
- *Have minimum side slopes of 3H: 1V*
- *Be protected against erosion as necessary,*
- *Be protected against debris build-up or damage.*

Other things that may also be required prior to issuing a Section 9 approval include:

- *A plan to reduce the water storage in the reservoir prior to the dam removal,*
- *A plan to safely pass remaining flows during the dam removal,*
- *An emergency response plan for potential high inflow management during dam removal, and*
- *A reservoir sediment control and removal plan (If there is the possibility of sediment mobilization after the dam is removed).*

Since the breach is only partial, the last dam owner, as per the Water Act, would still be liable for any damages caused by the remainder of their works. Also, a partial breach would require an engineered breach channel which would have to be constructed to pass the design flood for the new consequence classification.

The approval can be done in 3 ways:

- *Approval to De-Commission letter from DSO, e.g. Penticton #1 dam, September 2006*
- *Order under the Water Act, e.g. Coursier & Heber River Dams*
- *Water Licence or amendment with LCC clause; then a letter of LCC from the DSO*

In B.C., there are an additional 98 tailing storage facilities (TSF) and 160 mining dams that are not regulated by MFLNRO. Not only are the tailing dams not regulated under the *Water Act,* but the BC Dam Safety Annual Report for 2012, estimates that there are an additional 398 unregulated[12] water dams, many of which are small irrigation dams located close to human populations. These dams are regulated by the Ministry of Energy & Mines under the Mines Act and the Health, Safety and Reclamation Code for Mines in British Columbia. The safety of these tailing dams are guided, in part, by requirements listed in the CDA Dam Safety Guidelines, and include an annual submission of a dam safety inspection report (DSI) by a qualified geotechnical engineer to be submitted to the chief inspector of mines, plus regular inspections by the Ministry of Energy and Mines (NRS, 2015).

[12] Unregulated dams are those that do not meet height, storage capacity or dam failure consequence classification criteria specified in the Regulation (http://www.env.gov.bc.ca/).

Yet, in August 2014, the Mount Polley mine tailings pond collapsed and released selenium, arsenic and other metals into the Quesnel Lake and Cariboo River, causing the Cariboo Regional District to declare a local state of emergency and the Australasian Mine Safety Journal to declare it the, 'largest environmental disaster in modern Canadian history (Australasian Mine Safety Journal, 2014).' Annual Reports highlighting the Ministry's mine inspection activities and mining accidents can be found on the Ministry of Energy and Mines website. These incidents acts as a reminder that stricter dam safety regulations and measures to enforce compliance are needed.

Safety requirement for tailing ponds and mining dams are subsequently under a microscope. In a January 2015 Report, on the Mount Polley Tailings Storage Facility Breach, an independent panel of engineers, outlined the reasons for the Mount Polley dam failure, along with seven recommendations and three actions (MEM, 2015). In response, operating mines with tailing storage ponds must now establish independent tailings pond review boards. According to a 2014 article by Global News, new environmental rules, though interim, established by the ministries of environment and mining, say that mining firms must consider the possibility of a tailings disaster and evaluate the environmental, health, social and economic impacts of such an accident (March 20, 2014). These changes mean companies must now include, in their tailing management applications, the best-available technologies and options in order to enhance safety and reduce the risk of a dam failure (Smallbridge, 2015).

Dam safety reviews in B.C. can be costly and complicated. This may act as a deterrent, particularly for small dam owners considering removal. A costly dam safety analysis (DSA), in many cases, may not even be necessary in order for some dams to be removed. And as such, many dam owners could avoid the unnecessary financial burden.

Aaron Hahn, an engineer with Interior Dams in Kelowna, BC explained in an email to me, "*that a Dam Safety Review (DSR) can cost anywhere from $25,000 to $250,000. The more expensive ones typically are large hydro-electric/energy dams that are looking to have their automated gate systems modeled among other things. For example, BC Hydro operates 79 dams in BC that generate over 43,000 gigawatts of electricity per year. This provides them with the income required to upgrade and maintain these structures. Currently, they are investing more than 1.9 billion in a Seismic Upgrade Program that they hope will reduce the risk of damage to infrastructure and loss of life in the event of an earthquake* (BC Hydro, 2012). *However, more than 90% of dams in BC are small irrigation dams (earth berms) in very remote locations. These are typically used for domestic and irrigation use and are located wherever there are people.*

These dam owners do not always have the resources necessary to conduct a DSR. He also indicated that*, "DSR's take quite a while to conduct. Since dams are often located at higher altitude (>1500m), access is often difficult due to snow. Inspection times are usually within a smaller window from late June to September. They are also required every 10 years for* higher *consequence dams. Dam removal is always an option. Typically they are there for a reason (such as a water use license for domestic) so they don't often get removed. However, some get removed every year for a variety of reasons.*

Sometimes the owners are unable to properly maintain them and an order to remove is issued. This process is somewhat outside of the scope of a DSR but it may be a recommendation if there is negligence.

This process is also highly sensitive to the environment. Though this particular engineering firm has not conducted removals before we have bid on those services. We usually retain consultants such as Eco-scape Consultants Ltd of Kelowna, for the environmental components of these works.

Aaron also indicated, '*that a huge component of a dam safety reviews (DSR) is the geotechnical/structural (strength), hydro-technical (proper sizing of spillways/etc. for major storms) and the "dam system analysis" and that, in recent decades, there has been a major shift from statistical approaches for estimating storms (using data loggers and gumbel projections for 1:1000-1:10000 year events)*[13] *to probable maximum flood estimations (which is a meteorological exercise whereby the maximum probable storm cell that could occur is estimated). This has been a huge shift in the guidelines and will be the standard now with climate change etc. Major shifts in the "dam safety analysis" are just now taking place.* He mentioned that, "*in the past, dam safety reviews have always been like a checklist, where the major design components are checked to meet a factor of safety. This may include YES/NO questions such as; does the owner have adequate inspection frequencies? But the totality of all the checklists have not been analysed.*

He continued on to answer my question of why dams fail and stated that*, it has also been proven that most failures are due to a "systems failure" whereby not just one component's failure resulted in an incident. Rather, it is almost always a combination of errors, power outages, human error, etc. that lead to incidents. This is why there is a major shift in the regulations (and the CDA guidelines) right now towards systems analysis.*

He indicated that*, "a popular method proposed recently has been to use Monte Carlo simulation using packages like* GoldSimPro[14] *to model vulnerabilities with simple systems* (A. Hahn. Personal communication, February 5, 2015)".

[13] In probability theory and statistics, the Gumbel distribution is used to model the distribution of the maximum (or the minimum) of a number of samples of various distributions. Such a distribution might be used to represent the distribution of the maximum level of a river in a particular year if there was a list of maximum values for the past ten years. It is useful in predicting the chance that an extreme earthquake, flood or other natural disaster will occur (Wikipedia: https://en.wikipedia.org/wiki/Gumbel_distribution).

[14] It is a powerful and flexible platform for visualizing and dynamically simulating complex systems in engineering, science and business. You build a model in an intuitive manner by literally drawing a picture (an influence diagram) of your system. In a sense, GoldSim is like a "visual spreadsheet" that allows you to graphically create and manipulate data and equations (Source: http://www.goldsim.com/Web/Products/GoldSimPro/). .

Dam Regulation in Ontario

There are approximately 2600-3000 dams listed in Ontario (CDA, 2014). The Ontario Ministry of Natural Resources is the largest single dam owner, with about 400 dams (ODI, 2014). Ontario Power Generation owns just under 10% of the total dams, putting them in second place. The core objectives of the MNR with respect to their dams are, the protection of life and property from floods and erosion; ecosystem health, including fishery management and preservation of fish and wildlife habitat; and wetlands (Judge, 2012). According to Kevin Brown, a senior project engineer with the Ministry of Natural Resources (MNR), many of the MNR owned dams were built in the 40's & 50's and became the property of the MNR, as they were either abandoned or a burden to their owners due to the high repair and maintenance costs. As a result, the MNR ends up taking responsibility for these often deteriorating dams (K. Brown. Personal communication March, 23. 2015).

The Haines Dam in Clarksburg is in very poor shape and may have to be removed.

Dam construction, repair, alteration, removal and use of dams in Ontario is administered by the Ministry of Natural Resources under Section 14, 16 and 17.2 of *The Lakes and Rivers Improvement Act* (LRIA). The purposes of the *Act* are to provide for:

a) The management, protection, preservation and use of the waters of the lakes and rivers of Ontario and the land under them;
b) The protection and equitable exercise of public rights in or over the waters of the lakes and rivers of Ontario;
c) The protection of the interests of riparian owners;
d) The management, perpetuation and use of the fish, wildlife and other natural resources dependent on the lakes and rivers;
e) The protection of the natural amenities of the lakes and rivers and their shores and banks; and
f) The protection of persons and of property by ensuring that dams are suitably located, constructed, operated and maintained and are of an appropriate nature with regard to the purposes of clauses (a) to (e). 1998, c.18, Sched.I, s.23.

The process of Dam removal or decommissioning requires approval under section 16 which states:

16. (1) No person shall alter, improve or repair any part of a dam in the circumstances prescribed by the regulations unless the plans and specifications for whatever is to be done have been approved by the Minister. 1998, c. 18, Sched. I, s. 31.

In August of 2011, the MNR published a Lakes and Rivers Improvement Act Administrative Guide, a Lakes & Rivers Improvement Act Technical Guidelines (2004), along with a series of technical bulletins (MNRF, 2011) and best management practices in order to provide a guide for the application of the LRIA when seeking approval from the MNR under section 16, to construct, alter, repair or improve water control infrastructure. In the administrative guide, there are 2 tables (Appendix C) that list which dams require LRIA approval and which dams do not, as well as a step-by-step process required for approval under sections 14, 16 and 17.2. There is also an LRIA Dam Decommissioning and Removal Technical Bulletin as well as a draft section (volume five – dam removal and Decommissioning) of the technical guidelines, which provides information on dam decommissioning in Ontario. It includes relevant issues associated with decommissioning, and information about the decision making process pertanant to dam decommissioning (MNR, 2010).

The LRIA technical guidelines devotes a small section (5.3.10) on dam removal and decommissioning and indicates that, “prior to decommissioning, the owner should be required to prepare a detailed plan for withdrawal of the dam from service, indicating measures necessary for site safety, especially with regard to public safety and flood discharge capability of spill structures (p. 29). The Government of Ontario’s website also provides a basic two page document titled, A Landowner's Guide to Removing Small Dams in Canada (OMNR, 2014). This guide suggests reasons to remove a dam and include public safety, prevention of property damage, decreased maintenance costs, future liability, and improvement to water quality and fish habitat as well as recreational and aesthetic improvements. Permission from the MNR is required, often along with permission from one or more of the following government agencies: Fisheries and Oceans Canada, Transport Canada, Your local Conservation Authority, Ontario Ministry of the Environment, Ontario Ministry of Culture and your Municipality. The guide suggests that small dam owners hire a consultant to guide them through the removal process.

Below is Ontario's Dam decommissioning decision-making flow chart which outlines the 5 stages recommended for the decommissioning of a dam.

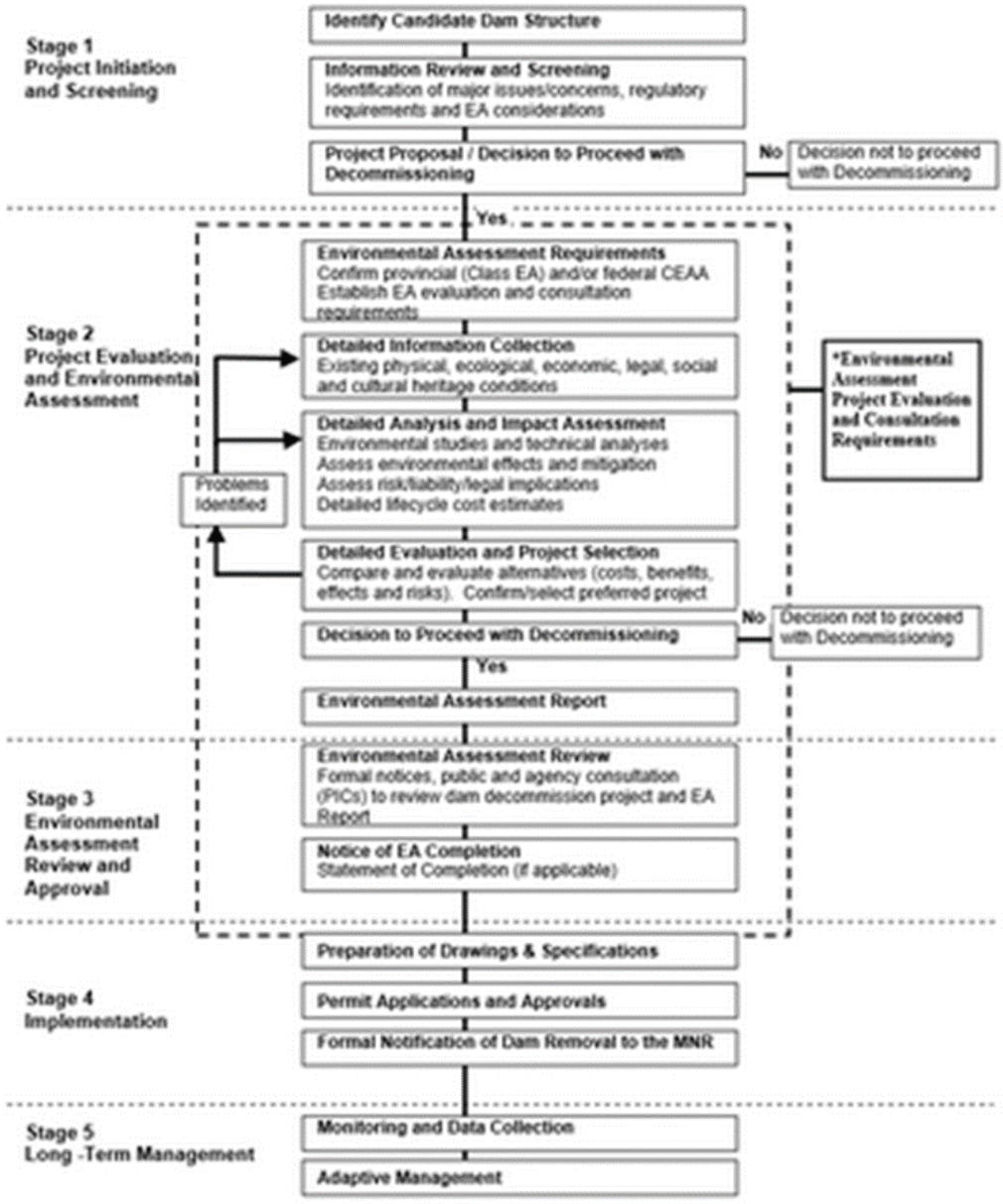


Figure 8.

Ontario's Dam decommissioning decision-making flow chart. MNRF technical bulletin August 2011.

While the MNR is responsible for administering approvals for the safe construction or removal of dams, there is not enough funding to support the staffing levels required to oversee the safe operation, maintenance or removal of dams in Ontario. As such, many dams have been built and removed in Ontario without MNR approval. Compliance with LRIA dam safety guidelines is voluntary and the responsibility lies with the dam owner. According to Kevin Brown, there is no legislative 'hammer' in place that would punished an owner for building or decommissioning a dam without approval. Often, MNR is only called in after a problem occurs.

The number of dams removed in Ontario, using the LRIA Dam Decommissioning and Removal Technical Bulletin, are few. The first documented case in Canada is the Finlayson Dam on the Big East River in Ontario (Donnelly et al, 2001). This dam, once used by the logging industry, no longer served its original purpose and furthermore, blocked the passage of Brook trout and other fish species. The physical removal of the dam took place from July -September, 2000. What made this removal unique, was that it was the first time that Ontario's draft set of dam decommissioning guidelines had been put to the test (figure 9). The project followed the process laid out in the guidelines by obtaining a baseline from which the alternatives to either retrofit, remove, rehabilitate, or do nothing, could be evaluated. An Environmental Assessment (EA) was completed, as was consultation with stakeholders and then a decision was rendered. Ultimately, the Finlayson dam was removed and deemed a success, after the results of a 2 year post removal monitoring study confirmed the presence of Brook trout.

www.google.ca

Table 1: A comparison of the Ontario and ASCE decommissioning guidelines*Ontario Ministry of Natural Resources

	1999 OMNR* draft guidelines	1997 ASCE guidelines
Step 1: Preliminary	Identify potential candidates and stakeholders, commence consultation with other agencies	Phases 1 and 2: Initial retirement study, public consultation
Step 2: Assessment	Design studies, assessment of risks and costs, environmental issues, legal issues	Phases 3 and 4: Data collection and analysis, evaluation of alternatives
Step 3: Draft proposal	Review risks/costs, other potential alternatives, selected preferred alternative	Phase 4
Step 4: Review/Approval	EA Process, public consultation	Phase 2: Consultation
Step 5: Implementation	Tender, decommission dam, perform long term monitoring as required	Phase 5 and 6: Implementation, long term management

Figure 9.

Finlayson dam removal. A comparison of the Ontario and ASCE decommissioning guidelines*Ontario Ministry of Natural Resources.

Kevin Brown also mentioned that in Ontario's Northwest Region, there are approximately 100 MNR dams, and that he was involved in the removal of The Onion Lake Dam. He confirmed that there had been a partial removal and rehabilitation of the Mill Dam in Kenora, as well. He emphasized that one of the challenges with removals in Canada, is there is insufficient data to help support the removal option as well as any specific framework to address the requirements of a post monitoring to determine that what was done was beneficial. This is due in part, because of the limited data addressing Canadian dam removals as well as a lack of funding.

Increasingly, there are more and more documented cases of the impacts of dam removal being documented in the US (American Rivers *et al.,* 1999). Yet, Canada lags behind in this regard. Further information on the emerging science of dam removal, can be found in reports from a 2002 Heinz Centre Dam Removal document as well as an Aspen Institute: Dam Removal-A New Potion for a New Century(2002). Josh Annett, a Program Officer working in the policy division of the Ministry of Natural Resources (MNR) was also helpful in shedding some light onto Ontario's current dam management practices and policy.

In a personal email exchange on March 24, 2015, Josh answered some questions for me, regarding dam removal and policy in Ontario. His responses are in *italics* below:

Q: Are the Ontario dam safety guidelines (2010) still in draft form? If so, when do you anticipate they might become part of the LRIA legislation/regulation?

A: *In 2010, the Ministry, through on-going consultation with dam owners and government stakeholders, proposed to update provincial dam safety requirements for the approval of new dams and major alterations, and new regulatory requirements for the management of existing dams. These draft Technical Guidelines were posted to the Environmental Registry for public comment.*

Following the review of feedback received, the ministry revised some of the proposed updates and released the LRIA Administrative Guide and a series of supporting Technical Bulletins and Best Management Practices in 2011.

The LRIA Administrative guide provides greater clarity around the application of the LRIA and the review and approval process.

The Technical Bulletins outline the specific technical guidelines and standards to be considered when seeking LRIA approvals. A specific Technical Bulletin was released regarding Dam Decommissioning and Removal.

These documents are government policy and guidance that provide support for the administration of the Act and it's supporting Regulation – they are not regulations.

Q: What triggers the dam removal process? For instance, are there regulations that may force the removal of a dam if it is deemed to be a safety hazard, impacts the environment in a negative way (reduces water quality or restricts fish passage etc.)? How would removal be funded?

***A**: The dam decommissioning/removal process is applicant driven. There are no MNRF regulations to force the removal of a dam; there is an order power under section 17(1) of the Lakes and Rivers Improvement Act to remove, open up, repair, improve or otherwise alter a dam.*

The Dam Decommissioning Technical Bulletin discusses issues relevant to dam decommissioning, which include public safety, environmental considerations, and socio-economic factors, and is a tool to inform the dam owner decision-making process.

Dams proposed to be decommissioned or removed are subject to LRIA approval under section 16 of the Lakes and Rivers Improvement Act. Other local, provincial and/or federal approvals may also apply.

The cost to decommission a dam is the responsibility of the dam owner.

Q: Dams are aging and hence, becoming a hazard to the public. Does Ontario (MNRF) have policies or programs in place that allow for the monitoring of their dams? How/When is a dam deemed to be unsafe? Who decides this? Is there any way to enforce dam owner compliance within the current guidelines/regulations if a dam is deemed to be unsafe?

A: *Dam owners are responsible for the safe management of their facilities and for ensuring their structures provide an appropriate level of safety. Dams are in compliance with the LRIA provided they are constructed or altered/improved/repaired in accordance with their LRIA approval and any associated conditions, and if they are operated in accordance with any applicable water management plan (if required for the dam in question).*

There is no requirement in the LRIA or supporting regulation that requires dam owners to report on the safety of their dams. Where a dam owner submits an LRIA application for the construction of a new dam, or the alteration, improvement or repair of their existing dam, the Ministry ensures that the proposed work, along with any related components of the dam, meet or exceed Ministry approved guidelines to provide for dam safety.

The Act provides for powers and duties of inspectors and engineers which include determining if: approvals, conditions of approvals, orders under the LRIA, or the regulation has been complied with. Inspectors or engineers appointed under the Act may enter and inspect any place, structure or land under the control of the owner; and, inspect any document, data or thing under the control of the owner.

The Canadian Dam Association has also published Dam Safety Guidelines (2007) *for Canada's dam industry which outline principles applicable to all dams, and processes and criteria for the management of dam safety in accordance with the principles. These guidelines are also supported by a series of companion technical bulletins on specific dam safety topics. These guidelines and technical bulletins are guidance and advice to dam owners and are not enforceable under any regulatory authority.*

Q: Why are some dams listed in the Ontario dam inventory, and others are not? How many dams (total) are there in Ontario? Does Ontario have a complete accounting of the numbers and details on all dams in Ontario?

A*:The Ministry estimates that there may be up to 3000 dams in the province that serve various purposes, from wetland creation and conservation, to mine tailings storage, to generate waterpower, and to regulate water levels and flows.*

The Ontario dam inventory includes only those dams that are considered 'medium' or 'large', including MNRF-owned dams.

Most dams in the province pre-date modern information management policies and practices, and there is no regulatory requirement for existing dams to 'register' with the Ministry.

Q: Do you have any recommendations for how Ontario could increase the number of dams removed? Funding? Education? Regulation? EA? Policy?

A*: The removal and decommissioning of dams is a dam owner decision.*

I have attached a fact sheet that was prepared to make dam owners aware of the option to remove a dam: "A Landowner's Guide to Removing Small Dams in Ontario. "The LRIA Dam Decommissioning and Removal Technical Bulletin outlines MNRF considerations and requirements as it relates to dam decommissioning, including the role of Environmental Assessment in the decommissioning process.

Currently, the MNR is working on implementing a dam management plan that entailss the development of a dam asset management plan (DAMP) and includes the application of a risk-based profiling system configured into a database called the Total Capital Planning Solution. These elements ensure that high risk dams are identified and deficiencies are resolved through the prioritized allocation of limited funds (Judge, 2012).

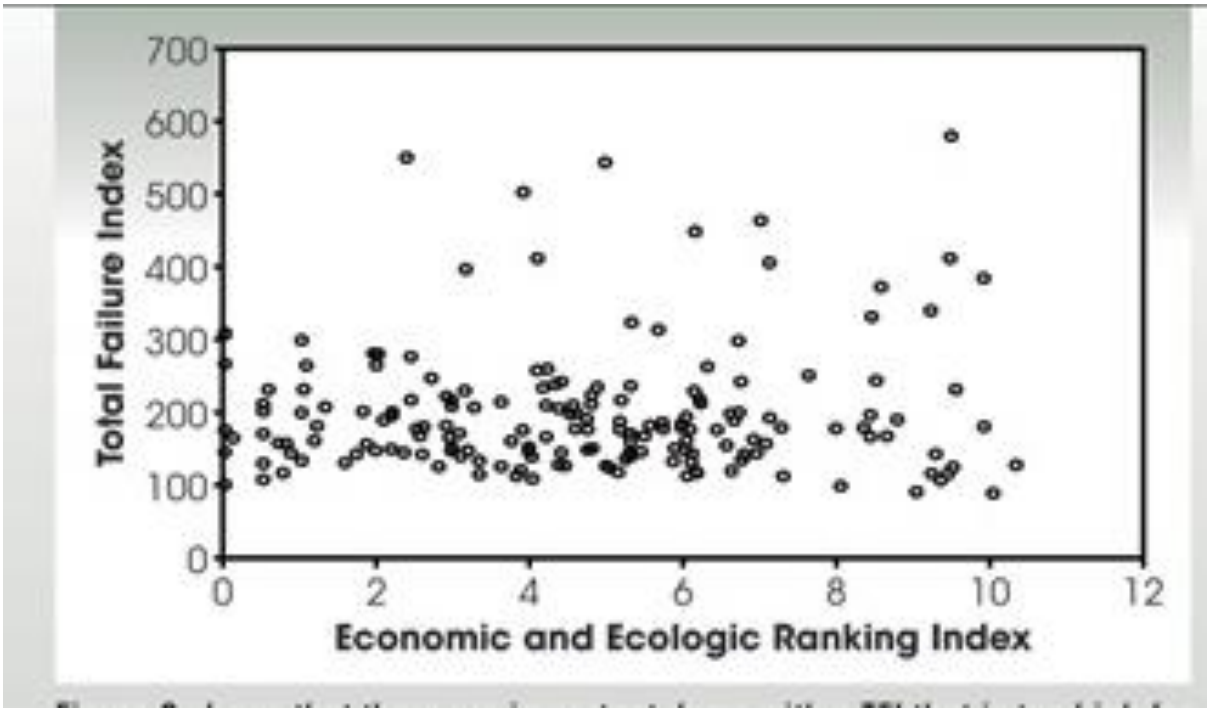


Figure 10.

MNR's DAMP Total Failure vs. Economic & Ecological Ranking. www.hydroworld.com

Recommendations

Create Awareness and Build Capacity

The provinces of B.C. and Ontario are examples of the complexity and jurisdictional challenges inherent in the process of dam removal and safety. Each case of removal is as complex, as it is unique (Babbitt, 2002). The process of decommissioning a dam becomes further impeded by time consuming permitting and regulatory hurdles, inconsistent procedures from province to province and costly engineering and environmental assessment reports. These obstacles, along with other limiting factors such as finite financial and human resources, and increasing future costs of dam maintenance may make implementing a more cohesive, nation-wide dam management and safety regulations more urgent and appealing. There are opportunities for regulators to adopt regulations that reduce project delays. Dam removal could be facilitated by fast-tracking some of the permitting requirements. Particularity, those dams being removed for the purpose of river revitalization only. I have adapted the following recommendations to improve the process of dam removal and stream restoration projects in Canada from an American Rivers 2015 report titled, *Review of New Jersey Regulations Pertaining to Dam Removal & Stream Restoration*:

- Establish a province-wide dam removal/river restoration task force that (a) develops and disseminates public education materials describing the benefits of dam removal and river/stream restoration, (b) develops clear guidance for dam removal projects that addresses important technical issues including sediment management, contaminant analysis, and construction methods, and (c) reaches out to researchers, practitioners, advocates and agencies globally and from neighbouring provinces for guidance of proactive measures and, (d) improve and clarify dam removal permitting process.

- Build Capacity: Create a program, called for example, "I Can Do That!" A community stewardship program of connectivity teams comprising small dam owners and members of the local community, which empowers them by providing the tools required to remove obsolete dams (SARP). Also, (b) Create a dam removal team that specializes in the inventorying, prioritizing and removing of small dams. Who would be responsible for (a) identifying and inventorying all small and unregistered dams, (b) tagging them for removal based on identified prioritization outcomes for each specific case and site (LSRCA, 2012), (c) establishing an information dissemination opportunities through the involvement of local groups, and thereby, (d) providing job and volunteer opportunities within the dam affected community.

- Establish a national team of project coordinator(s) for all dam removal projects in Canada who has the expertise and can (a) serve as a single point-of-contact, (b) fast-track the projects through the various jurisdictional divisions, (c) resolve internal deliberations, and, (d) expedite permit approvals, particularly when a dam poses risk to public safety or property (e) use new prioritization tools and techniques to identify new projects and (f) train new project managers.

- Establish a national goal or performance metric pertaining to dam removal and stream restoration projects such as (a) linear kilometres of rivers re-connected or restored, (b) acres of floodplains or wetlands restored or (c) number of fish species recovered and, (d) number of hazardous structures removed, (d) identify areas for improvement by creating a forum for sharing stories of success and failure.

- Implement an Owners Dam Safety Program (ODSP), such as the one developed by the Federal Energy Regulatory Commission (FERC) in the U.S.[15] According to the Association of State Dam Safety Officials (ASDSO), the ODSP program helps to protect property and

[15] Assuring the safety of licensed dams is a cooperative effort between owners, consultants and the FERC with the most important role being that of the owners. The owners are the ones who see the dam regularly and through surveillance and monitoring are monitoring and evaluating the health of the structure (www.ferc.gov).

> people from the disastrous effects of avoidable dam accidents and failures and in establishing emergency procedures for unforeseen occurrences (ASDSO, 2015).

Examples of U.S. Regulation & Enforcement Programs

The U.S. is a leader in dam safety regulation and enforcement and many of their programs can be used as a framework on which to create similar programs in Canada. The U.S. National Dam Safety Program (NDSP) led by the Federal Emergency Management Agency (FEMA), has been around for 30 years and is a partnership between federal agencies, states and stakeholders created in order to promote responsibility and awareness with regard to the issues of dam safety. Another important resource is FEMA, which provides dam safety training, grant assistance in support of state dam safety programs, as well as support for dam safety research. Recently, FEMA and its partners released a report titled, Strategic Plan for the National Dam Safety Program Fiscal Year 2012-2016'. It outlines their goals and objectives for a national agenda in dam safety and includes; reducing the likelihood of dam failures, reducing the potential consequences resulting from dam failures, the promotion of public awareness (benefits and risks related to dams), the promotion of research and training for state dam safety and other professionals and the alignment of relevant Federal programs to improve dam safety.

The U.S. Federal Energy Regulatory Commission (FERC) also plays a crucial role in the enforcement of dam safety guidelines through its hydropower relicensing responsibilities.[16] The FERC is authorized by U.S. congress to regulate approximately 2,300 non-federal hydroelectric dams. It does so through the issuance and relicensing of water licenses. When a dam owners licenses expires (often after 30-50 years) the dam owner must renew it. In order to qualify for relicensing under U.S. Code, title 16, sec. 797(e), the FERC has the authority to deny the

[16] The Federal Energy Regulatory Commission (FERC or the Commission) is an independent agency that regulates the transmission and wholesale sale of electricity and natural gas in interstate commerce, and regulates the transportation of oil by pipeline in interstate commerce. FERC also reviews proposals to build interstate natural gas pipelines, natural gas storage projects, and liquefied natural gas (LNG) terminals, and FERC licenses non-federal hydropower projects (www.ferc.gov).

relicense application if it is not in the best interest of the public. It then has the power to order the removal of the dam (Bowman, 2002).

Hydropower relicensing is just one of the regulatory avenues through which the FERC can order the removal of a dam. An article by Margaret Bowman titled, '*Legal Perspectives on Dam Removal*,' provides two additional regulatory avenues available to the FERC in making an order for dam removalT they include, dam safety inspections and the issuance of a license surrender order or the issuance of a non-power license. Bowman's article indicates that, "The FERC has the authority to inspect and ensure maintenance of dams under their jurisdiction (CFR, title 18, part 12). These inspections generally occur every 5 years (CFR, title 18, sec.12.38). As in state dam safety situations, if FERC identifies safety problems at a dam, it will order the dam owner to alleviate the problem (Bowman, 2002:p.740)." The mitigation of dam failures incidents can be achieved through improved and enforceable safety measures, and often, a cost-benefit analysis may entice a dam owner to remove the dam rather than make expensive repairs. Currently, there exists no Federal Canadian equivalency to FEMA or FERC with respect to hydropower or dam safety (re)licensing. The only information I could find on re-licensing in Canada, were submissions under Environment Canada's *International River Improvements Act (2014)* from BC Hydro and Saskatchewan Power Corporation (SaskPower).

Reducing Red Tape

An American Rivers report titled, Permitting Dam Removal: The State of (Several) States (2006), highlights examples of how several states are leading the way in modifying their policies to reflect the reality and complexity of the dam removal process. It explains how they have been proactive in achieving a more fluid, less complicated, less time consuming and less expensive procedural process. Below, are examples of how the permitting requirements in three states; Connecticut, New Hampshire and Pennsylvania, have been modified to streamline and therefore increase dam removal success.

Connecticut is just one of six states and has over 5000 dams and may have played a role in negatively affecting local commercial fisheries by blocking fish migration and destroying spawning habitat(FAO, 2001). The U.S. Fish and Wildlife Service estimates that 91% of the migratory fish habitat in northern New England is blocked by dams. Additionally, it is experiencing more severe and frequent storm events placing further pressure on ageing dam infrastructure. Currently, Connecticut's Department of Energy and Environmental Protection (DEEP) regulates over 3,043 registered dams and is the largest single owner with 265 dams. In 2014 changes were made to Connecticut's Dam Safety Program . The state requires that any dam which by breaking away or otherwise might endanger persons or property, be registered (Regulation: CGS 22a-401). Existing dam safety statutes also provide the authority for orders to be issued orders for the repair of unsafe dams along with dam registration and inspection programs (CGS 22a-401 through 22a-411). Recent changes to regulation 409-2, amended the statute to reflect the responsibility of each dam owner to hire and engineer to inspect their dams. The owner responsible inspection section has been revised and now requires dam owners to ensure that a regulatory inspection is conducted in accordance with a schedule based on the dams' hazard level (CGS 22a-409(c) (Revised). The Nature Conservancy also play a role in the removal of several state dams, as well as conservation measures such as mandating the installation of fish way construction on several of Connecticut's dams. Yet, in many parts of the Canada and the U.S., dam owners are not aware of their responsibility for dam safety and their liability. The requirement to register their dam, even if its hazard rating is low, has the potential to raise awareness with owners, increase inspections and maintenance, improve public safety, as well as create an awareness for the option of removal for unsafe dams.

The state of Pennsylvania is a leader in promoting dam safety and includes dam removal as a powerful mechanism in their toolbox of enforcement options. In 2014, for the 12th year in a row, Pennsylvania topped the list for river restoration through dam removal (Hopey, 2015). An American Rivers press release indicated that in 2014 Pennsylvania removed 17 dams and restored more than 1,200 kilometers of streams and rivers (AR, 2015).

There are Federal permitting requirements that need to be achieved in order for a dam to be removed, but at the state level, according to the Pennsylvania Department of Environment Protection (PADEP) Division of Dam Safety, it has instituted an expedited process referred to as a *restoration waiver*. [17] This helps ensure an easier process for the removal of qualified smaller dams which no longer serve a purpose. Pennsylvania's Fish and Boat Commission (PFBC) set up to, '*protect, conserve, and enhance the Commonwealth's aquatic resources and provide fishing and boating opportunities',* has also mandated and has the authority to enforce the removal of dams as an option to improve fish passage (PFBC, 2010). You can find more information on dams and dam removal at Pennsylvania's Department of Environmental Protection, division of dam safety as well as a dam safety fact sheet outlining the steps required for breaching a dam in Pennsylvania.

New Hampshire's dams and dam decommissioning are regulated under the Water Division of the Department of Environmental Services (NHDES) Dam Bureau. Their website states that, "selective dam removal can eliminate a public safety hazard, relieve a dam owner's financial and legal burdens and restore a river to a healthier, free-flowing condition. Consequently, some dam owners, government agencies and communities are taking a second look at dams." With this in mind, the NHDES also created a dam removal and river restoration program to assist dam owners with the process of removal and in 2000, the New Hampshire River Restoration Task Force was formed in order to identify dams, whose removal would help to restore rivers and/or eliminate a hazard to the public. The State of New Hampshire has approximately 4,800 dams. While very few are yet slated for removal, the Department of Environmental Services (NHDES), "has created a dam removal process that combines the dam safety program with the wetlands program to identify, evaluate, and (when warranted) remove unwanted or unneeded dams along New Hampshire's rivers and streams (NHDES, P.1) ."

[17] See 25 Pa. Code 105.12(a)(11) and (a)(16) for more details.

The NHDES provides several other services to facilitate the process of removal and restoration. They are listed on their website under Dam Removal and River Restoration Program, and include:

- Information about various components of the dam removal option.
- Technical assistance in obtaining the necessary permits
- Assistance in developing a funding package to offset the costs of removal.
- General assistance through the process.

This website also includes a three page dam removal application form with a 60 day processing time. The DES River Restoration Coordinator can be reached at 603-271-3406.

The dam industry in Canada recognizes that dams are deteriorating and that enforceable dam safety regulations and monitoring, as well as repair and maintenance are important to ensure public safety. Dam removal is a viable option and should be among one of the considerations when addressing an unsafe dam. However, given the recency surrounding the concept of dam removal and a lack of awareness and education, it is rarely offered as an alternative to costly maintenance and repairs or upgrades for large or small dams. For the small dam owner, the economics of dam removal may be a challenge as there exist many regulatory hurdles, as well as complicated permitting processes and expensive and time consuming application procedures and costly engineering reports. The greatest opportunity for a positive impact on future dam safety in Canada, may lie in the regulatory and procedural gap between small dam owners and current dam removal procedures. Setting up a simplified dam removal process through an integrated national program that offers assistance and funding alternatives may assist current small dam owners in achieving this goal.

Dam Ownership

Dam safety reviews are an important first step in the assessment of dams for removal. In order to ensure that *all* dams are safe, it is important to address the topic of dam ownership in Canada. The onus is on the dam owner to provide proof that their dam meets the standards of safety under the guidelines legislated by each province. However, mandated privacy of some owners by regulators limits access to this information. Figure 11 shows the percentage of small dams owned by private individuals. In B.C. the number is as high as 49%.

Province	Hydro	Industrial	Government	Municipalities ("Small")	Private ("Small")	NGO Wetland Conservation ("Small")	Total % Dams Owned by "Small" Owners
Newfoundland	58	1	18	22	N/A	N/A	22%
Nova Scotia	38	6	15	18	9	13	40%
Quebec	35	10	21	14	19	1	34%
Alberta	2	11	17	7	41	21	69%
British Columbia	5	3	12	13	49	16	78%

Figure 11.

Dam ownership in 5 Canadian provinces. http://www.mecoengineers.com/articles/6/Small-Dams-in-Canada

This further inhibits the ability of dam safety officers to contact these owners and creates inconsistencies in the documentation of small dams with possible high consequence structures. If DSO's had better access to this information they could better manage Canada's dams. This would ensure increased monitoring, appropriate assessments of hazard classification and thus, a reduction in the potential hazards produced by these dams.

Inventory Small Dams

Small, unregulated dams are prime candidates for removal. As mentioned by Josh Annett, with the MNR, and as indicated in the Ontario Dam Inventory (ODI) MNRF publication, 'The Ontario dam inventory includes only those dams that are considered 'medium' or 'large', along with all MNRF-owned dams'… but, ' does not contain small dams, small water control structures, beaver dams, water crossings, or culverts (ODI, 2014). However, many dams that are prime candidates for removal, are covered under their Provincial Environmental or Water Acts. Some do not fit the criteria for size or hazard level required under the provincial consequence classification system whereas others may not be classified as dams under the CDA guidelines. Small dams in Canada have the potential to pose an even larger risk to the public than larger dams. Of the 1,742 dams listed in the Ontario Dam Inventory list, more than 1,258 dams are missing (ODI, 2014). Based on their hazard potential classification of low to moderate and their small size, these dams are considered to pose no threat to the loss of human life. However, studies have shown that cumulatively, they may present more of a safety hazard than large dams (ICOLD, 1997).[18] The size of a dam is not necessarily the only indicator of the potential for catastrophic or fatal outcomes due to failure or breach. An article by Mitchel titled, *Small Dams in Canada*, suggests that more than 75% of registered (not necessarily regulated) dams in Canada are small dams, that a large percentage of small dams have High Consequence ratings, and that the largest population of dams owners in the provinces generally have limited resources available for maintenance, construction supervision or dam safety management programs (MECO, 2014).

[18] This bulletin is devoted to the 150 000 large or small dams 10 to 30m high; capacity of most of their reservoirs is in the range of 1 hm3 but several thousand reach dozens of hm3. Design criteria and typical designs are generally different from those of high dams. Construction methods, often focus upon economy, may increase risks and corresponding accidents have globally caused more victims than for high dams.

While gathering data for their article on small dams it was revealed that, "the combination of inconsistent consequence classification systems, inconsistent data fields and instances where various data fields were blank for some dams of the databases, confounded a complete detailed statistical review of the data (MECO, 2014:1)". They recommend that, in order to help these small dam owners meet the CDA dam safety guidelines, there is a need to provide owners of small dams a way to economically calculate probable maximum flood (PMF) and other important data in order to better assess the classification of their dams and meet safety standards set by the provincial dam safety programs. An ICOLD bulletin (143) titled, *Small Dams: Design, Surveillance and Rehabilitation,* estimates that worldwide, small dams make up almost 90% of the total global dam inventory (ICOLD, 2011). Environment Canada estimates that in B.C. alone, there are approximately 2500 small dams (Environment Canada, 2013). The CDA website estimates that 1650 small dams are regulated while approximately 460, are not. According to Environment Canada, Quebec has 5144 dams with heights ≥1 m in their database. The CDA website estimates that there are 5,806 in Quebec, 2400 in Ontario, 1360 in Alberta, 1300 in Saskatchewan and 570 in Manitoba 570 (CDA, 2015). This disparity in dam numbers, highlights the difficulty in sourcing accurate dam inventory numbers. As mentioned, a high number of small dam owners have High Consequence structures (MECO, 2008).[19] Additional reasons why small dams have the potential to be unsafe are that historically, many small dam owners had fewer resources to commit to the construction, repair and maintenance of their own dams, as well as the ongoing financial burden required to conduct a dam safety report or an emergency preparedness plan.

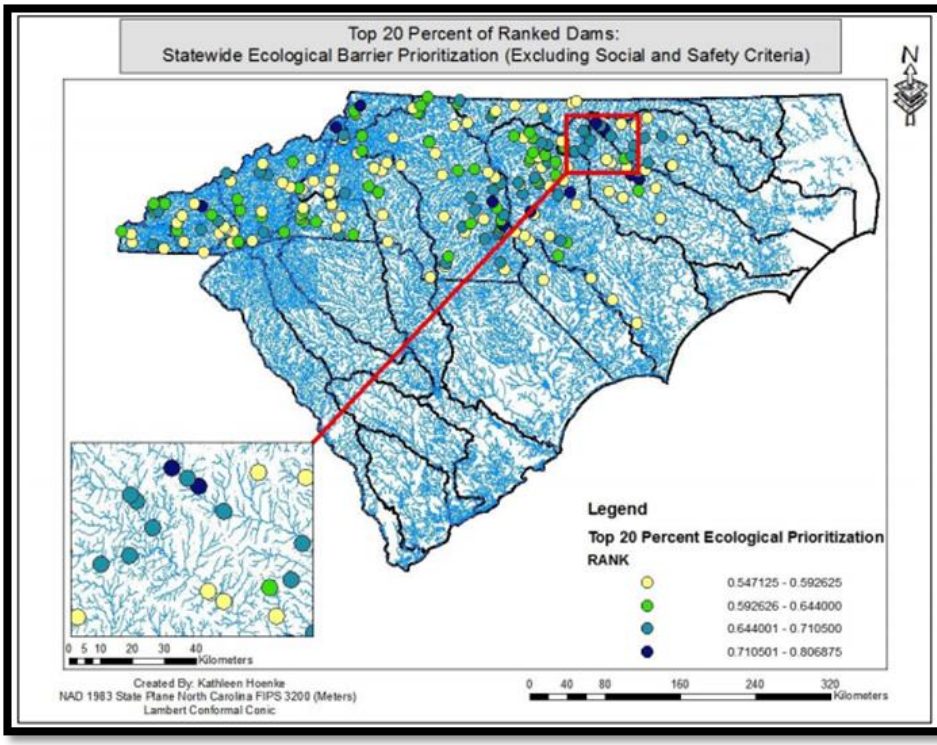
[19] In Ontario, dams are classified using the Hazard Potential Classification (HPC) system. The HPC system categorizes dams according to the potential hazards presented by the dam. The hazard potential is determined through an assessment of the greatest incremental losses that could result from an uncontrolled release of the reservoir due to the failure of a dam or its appurtenances. Potential incremental losses are to be assessed with respect to life, property, the environment and cultural - built heritage sites at the dam site, upstream, downstream, or at other areas influenced by the dam.
The dam's HPC is used to provide guidance on the expectations on dam owners and their designers in identifying additional requirements of the dam safety program for the structure (e.g. standards for dam design, construction, operation, maintenance, surveillance, inspection and emergency preparedness planning).

The removal of small and/or abandoned dams in Canada should be a crucial focal point for regulators and policy makers in the mitigation of future dam incidents. The re-classification and proper inventorying of these dams needs to be re-evaluated. The inclusion of all dams in Canada through a national dam safety program and legislation, would help ensure common safety standards and regulations, as well as a way for the central government to track and allocate funding across Canada for dam removals and infrastructure maintenance in areas of greatest need. This would help reduce the uneven burden placed on a single province that may have less financial resources. It would also introduce efficiencies and allow for higher standards of safety. Within this scheme, there is an opportunity for policy makers to address the concerns of small dam owners by creating legislation that directly addresses the issues of removal without the expense of costly engineering reports and environmental assessments. The long-term benefits of small dam removal and decommissioning are not only safety, but more improved and sustainable water resource management practices and hence, increase water quality for future generations.

Tools for Classification and Prioritization of Dams for Removal

Enforceable dam safety regulations that promote and facilitate the process of dam removal are an important component of a new Canadian dam policy framework. However, the financial and subsequent staffing constraints limit the potential and reduce the likelihood of dams being removed. Prioritizing dams for removal, therefore becomes a critical component of the dam removal framework, as funds can be targeted towards high priority projects. Recent new technologies in Geographical Information Systems (GIS) have helped to prioritize dams for removal. GIS is a layered mapping system that brings together a variety of geospatial data and integrates and stores it in a way that makes the prioritization of dams for removal a much simpler task. The beauty of this tools is that the identification of each dam removal project can be achieved, each through the application of a unique set of eco-hydrologic and social criterion.

An article by Hoenke titled, *A GIS based approach for prioritizing dams for potential removal* explains that, "the tool is applied for three commonly considered prioritization scenarios that rank dams based on their suitability for removal using both social and ecological criteria together (Hoenke *et al*., 2014:1)." This tool is ideal for dam removal projects as it can be tailored to be site and stakeholder requirement specific. In other words, the complexity and uniqueness of both the social and ecological conditions surrounding a specific dam site can act as data inputs in order to evaluate a dam for removal and ensure the desired and most effective outcomes. Interestingly, one of the weakness' inherent in the tool is that there is no data input for a 'willingness' ranking for owners of privately owned dams, to remove their dams (Hoenke *et al,* 2014).



Top 20 Ranked Dams: Ecological Prioritization		
KHID	Rank	Current Potential Project?
13	1	Yes
48	2	No
32	3	No
53	4	No
5167	5	Yes
46	6	No
5096	7	No
3068	8	No
5017	9	No
25	10	Yes
838	11	Yes
5116	12	No
4756	13	No
5168	14	Yes
4	15	No
3975	16	No
3638	17	Removed
34	18	No
3809	19	No
5138	20	No

FIGURE 12.

Dams ranked for removal based on an ecological prioritization scheme**.** (Hoenke, 2012)

The Hoenke *et al* article highlights the importance of the ecological indicator for '*connected river mile'*, as being a main indicator contributing to an increased priority ranking for removal. The reduction in river mile by dams has negative impacts on fish populations as well as water quality. Fish are often limited or completely cut off from prime spawning grounds as well as nutrient rich sediment that once nourished them and other aquatic life. Commercial fisheries, which were once an important part of the Canadian and U.S. economy, have been devastated over the years, due in large part from the obstruction of rivers by dams. The NOAA National Marine Fisheries Service (NMFS) website calculates the annual commercial fish landings by group as well as recreational fish statistics and the numbers show a dramatic decline. This is another useful tool for the calculation of fish numbers caught by species and weight in pounds. The data dates all the way back to 1950, and a quick calculation for the number of Alewives caught in all of the US in 1950, for example, reveals that over 47 million pounds were caught compared with only 1.6 million in 2012/13. This tool could be of use for local communities interested in removing dams and assessing the resultant economic and social benefits of fishing activities. The financial rewards generated from healthy fish populations are great, as revealed by a recent study conducted by The Department of Fisheries and Oceans Canada (DFO), which estimates that recreation anglers in Canada contributed $8.3 billion to the Canadian economy in 2010, with Ontario and BC being high on the list for foreign anglers (DFO, 2010)[20]. This further highlights the importance of the collection of barrier data information for all dams along a river system. The collection and mapping of this information is paramount for determining dam removal for fish project restoration projects and other conservation programs.

[20] The 2010 Survey of Recreational Fishing in Canada collected information about recreational fishing activities to assess the economic and social importance of recreational fisheries to Canada's provinces and territories. This nationally-coordinated study provides the most comprehensive information on recreational fisheries activities and harvests in all regions of the country. It is also the most up-to-date source of detailed statistics on the economic contribution made by anglers at both provincial/territorial and national levels (http://www.dfo-mpo.gc.ca/stats/rec/can/2010/RECFISH2010_ENG.pdf). .

Another group who support the conservation of aquatic resources in the southeastern U.S. is Southeast Aquatic Resources Partnership (SARP). Their program mission is to:

(a). Provide technical support and training for assessment tools to facilitate on the ground restoration from assessment results.

(b). Initiate connectivity teams in the 14 SARP states and bring these teams together to initiate and develop working relationships

(c). Collectively define the scientific basis of river restoration through connectivity improvement.

(d). Communicate among states to support and build on past experiences.

According to SARP, "the rivers and streams of the southeastern United States are extremely diverse, containing numerous threatened and endangered species. In fact, southeastern rivers contain the largest number of at-risk freshwater fish and invertebrates than any other region of the country. The presence of dams and other man-made barriers fragment the river network, contributing to habitat loss and therefore negatively impacting freshwater biodiversity. In addition, dams often impede the movement of resident and diadromous fish species. Resident imperiled species of darter and redhorse are unable to move freely in the system, and anadromous fish such as the American shad and striped bass are unable to reach their historical spawning grounds upstream. Due to the effects of dams and anthropogenic barriers on the ecosystem listed above, connectivity improvement is listed as a top priority under SARP's Southeast Aquatic Habitat Plan (SAHP) Objective Number 3. To address this objective, SARP has consistently funded barrier removal projects. In addition, the Southeast Aquatic Connectivity Assessment Project (SEACAP), a project funded by the South Atlantic Landscape Conservation Cooperative and led by SARP and TNC address river fragmentation by assessing dams based on their ecological benefit if removed or bypassed.

SEACAP is developing a comprehensive spatial database of dams, an analysis ranking f these dams, as well as a web based GIS tool allowing managers to prioritize dams for potential removal or passage by using a suite of ecological metrics.

As an extension to this project, SARP has created the SEACAP Program, to both promote the SEACAP project and promote the efforts already occurring in states to advance river restoration through fish passage projects. The Southeast Aquatic Connectivity Assessment Program has a partnership with American Rivers to develop a framework for states that create connectivity teams that advance efforts in river restoration through dam removal and fish passage projects. This approach will be phased in with a pilot project focusing in NC, TN, and SC, where currently functioning connectivity teams exist. Once a working model has been developed in these states, American Rivers will continue to regularly support the pilot states and SARP will expand the creation of Connectivity Teams to other states with workshop support from American Rivers SARP, 2015)."

The program's website gives the public access to invaluable connectivity tools for dam removal as well as a forum sharing important dam removal data and valuable scientific research on a variety of issues pertaining to the management of aquatic resources (Olsenius, 2014). The SARP website also contains several connectivity tools and barrier studies for water resource managers and communities interested in prioritizing dams for removal. Additional prioritization and assessment tools can be found at:

- The Nature Conservancy (TNC)/ Chesapeake Fish Passage Prioritization Tool
- North Carolina Barrier Prioritization Tool.[21]
- Southeast Aquatic Connectivity Assessment Project (SEACAP).
- Tennessee-Cumberland Connectivity Assessment Project.

The NC Barrier Prioritization Tool (NC BPT) is updated yearly and currently used to prioritize dams for removal and fish passage within NC on both the regional and local scale. Please contact Kat Hoenke at Kat@southeastaquatics.net for the link to download the tool.[21]

Below, figure 13 depicts the interface of the Barrier Prioritization Tool along with an example of output from a statewide social plus ecological prioritization map (Hoenke *et al*., 2014).

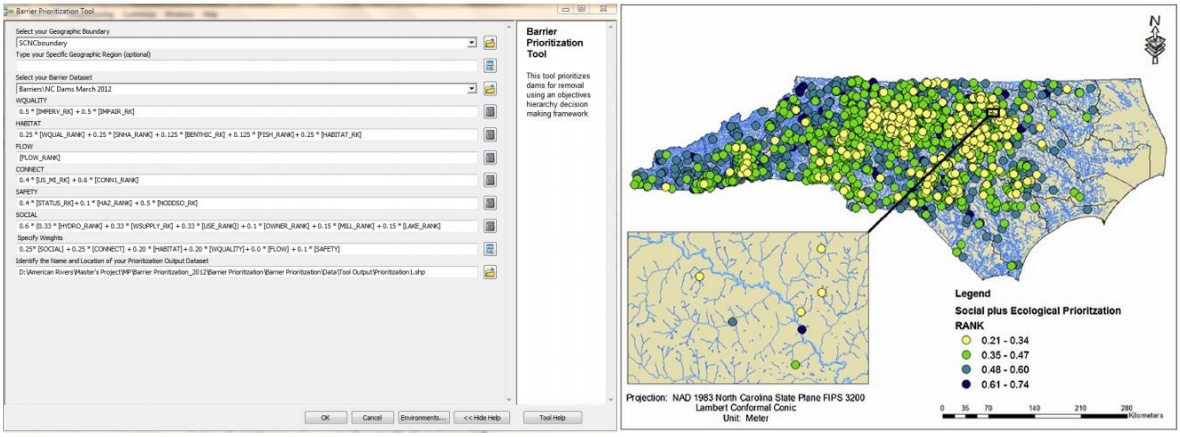


Figure 13.

Barrier Prioritization Tool Interface (left) and Output ranking for social and ecological criteria (right). (Hoenke, 2014).

A cost-benefit analysis is another way of prioritizing a dam for removal. Removal is often a cheaper alternative to repair (often 1/3 of the cost of repair and maintenance), though the real cost of whether or not to removal a dam is as complex as unique as the project itself (Whitelaw, 2002). Whitelaw provides 6 guiding primary and secondary analytical principles to consider when calculating the true economic consequences of dam removal. They include:

Primary analytical principles:

1) Benefits as well as costs

Removing or keeping a dam would generate economic benefits as well as economic costs. Consider them both to understand the full effect on the value of the goods and services derived from streams, forests, and other resources.

2) Positive as well as negative impacts on jobs

Dealing with a dam would have both positive and negative effects on job opportunities. Consider them both to understand the full effect on workers, their families, and their communities.

Secondary analytical principles

1) Distribution of consequences and fairness

Those who enjoy the benefits or jobs of a decision on a dam would not necessarily be the same as those who would bear the costs or job losses. Consider the full distribution of economic consequences to understand who wins, who loses, and the fairness of the distribution.

2) Rights and responsibilities

With any decision on a dam, property owners and resource users behave differently than they otherwise would. Consider whether these changes represent infringement of their rights or enforcement of their responsibilities.

3) Uncertainty and sustainability

Any decision on a dam would rely unavoidably on information insufficient to guarantee the outcome. Consider fully the potentially high costs from decisions yielding undesirable outcomes that are irreversible or extremely difficult to reverse.

4) More than just salmon conservation

Removing or keeping a dam would have a variety of ecological and economic effects, such as changes in the quality of stream water used for other purposes that may seem peripheral. But consider all the effects.

The rapid expansion of GIS technology is allowing for the improved monitoring of data on river ecosystems, fish populations and social metrics, thereby providing dam removal proponents with the tools necessary to pinpoint and prioritize dams for removal. As dams age, the price tag, complexity and urgency to repair or remove them increase, thus making these tools an essential part of an effective national policy for dam safety and removal. Ontario's Ministry of Natural Resources, in a quest to better manage their dam infrastructure has developed a dam asset management plan (DAMP). It was developed to ensure that the limited funds available were targeted to the maintenance of dam infrastructure prioritized and in line with their core objectives of protecting public safety, economic benefits, and environmental/ecological value. The input of these key performance indicators assist the MNR to rank and prioritize their dams in order to achieve their main objectives. Below is a table of Ontario's top-ranked dams by economic ranking.

Rank	Dam Name	District	Region	HPC	RI_{econ}
1	Bala (North) Dam	Parry Sound	Southern	Low	7.0
2	Mary Lake (Port Sydney) Dam	Parry Sound	Southern	High	6.8
3	Magnetawan Main Dam and Lock	Parry Sound	Southern	High	6.8
4	Crane Lake Dam	Parry Sound	Southern	Very Low	6.6
5	Bala (South) Dam	Parry Sound	Southern	Low	6.5
6	Galeairy Lake Dam	Bancroft	Southern	High	6.4
7	Magnetawan Centre Dam	Parry Sound	Southern	High	6.0
8	Cache Lake Dam	Algonquin	Southern	Very Low	5.8
9	Magnetawan East Dam	Parry Sound	Southern	High	5.8
10	Weslemkoon Lake Dam	Bancroft	Southern	Low	5.6
11	Port Carling Dam	Parry Sound	Southern	Low	5.5
12	Hollow Lake (Kawagama) Dam	Parry Sound	Southern	Low	5.3
13	Burditt Lake Dam	Fort Frances	Northwest	Low	5.3
14	Snowshoe Rapids Dam	Red Lake	Northwest	Significant	5.2
15	Tea Lake Dam	Algonquin	Southern	Low	5.1
16	Agimak Lake Dam	Dryden	Northwest	Significant	5.1
17	Johnnie Lake Dam	Sudbury	Northeast	Low	5.0
18	Forest Lake Dam	Dryden	Northwest	Low	4.7
19	Lyndhurst Dam	Kemptville	Southern	Low	4.7
20	Talon Lake Dam	North Bay	Northeast	Low	4.6
21	Clayton Lake Dam	Kemptville	Southern	Low	4.5
22	Harris Lake Dam (Spillway No. 3)	Parry Sound	Southern	Low	4.5
23	Harris Lake Dam (Earth Plug)	Parry Sound	Southern	Low	4.5
24	American Trail (Harris Lake) Dam	Parry Sound	Southern	Low	4.5
25	Harris Lake Dam (Spillway No. 2)	Parry Sound	Southern	Low	4.5

Figure 14.

Ontario's Top-Ranked Dams by Economic Ranking Index. (www.hydroworld.com)

Comprehensive and Standardized Dam Inventories

An accurate accounting of Canada's dam inventories is difficult to ascertain as Canada has no single, comprehensive national accounting system of dams. Furthermore, individual provincial accounting is inadequate and variation in legislation and regulations along with dam owner privacy issues, limit access, making estimates more difficult to ascertain. The Provinces of B.C., Quebec and Ontario have dam registries while other provinces and territories are still in the initial stages of developing their dam inventory data-bases, or have none (Figure 15).

Area	Internal Registry	External (Public) Registry
Newfoundland and Labrador	In Process	Not Available
Prince Edward Island	N/A[1]	N/A[1]
Nova Scotia	Environmental Registry[2]	Y[2A]
New Brunswick	N	N
Quebec	Detailed Inventory[3]	Detailed Inventory[3] (without personal identification)
Ontario	Detailed Inventory[4]	N
Manitoba	N	N
Saskatchewan	Detailed Inventory	N
Alberta	Detailed Inventory[5]	N
British Columbia	Detailed Inventory	Partial Inventory[6]
Yukon		N
Parks Canada Agency	Detailed Inventory	N
Canada Nuclear Safety Commission	N	N
IJC	N	N

N = Not Available
1 PEI has no dams
2 Registry of all approvals to construction and/or maintenance of dams. Dams being inventoried include ones smaller than CDA definition.
2A Subject to the Freedom of Information and Protection of Privacy Act of Nova Scotia.
3 All dams greater than 1.0 metre high and located on a water course.
4 Registry includes provincially-owned dams only. Access must be requested to view registry.
5 All dams including mining dams licensed under the Water Act, with detailed characteristics and reference material and reports.
6 Public Inventory contains limited characteristics. Mining dams available from the mining branch

Figure 15.

Dam registry in Canada as of 2010. (CDA 2010)

Part of an effective dam safety program is an updated and accurate inventory of *all* dams. The Canadian Dam Association's website indicates that there are over 10,000 dams in Canada, of which 933 are classified as large under the ICOLD definition for size (CDA, 2003). Then, in 2014, the CDA released a dam safety presentation that revised the old estimate from 10,000 to over 14,000 dams in Canada. The estimates vary from one source and province to another, making it very confusing and difficult to obtain accurate information about dams in Canada. Herein, lies another opportunity to learn from the current creation and evolution of Canada's various provincial dam inventories by gleaning from them the most useful and user friendly dam inventory and classification applications. In BC, for instance, the MFLNRO Annual Report 2013/2014, estimates that there are currently 1570 water supply dams that are regulated under the BC Water Act. A list of over 80% of these classified dams can be viewed on Google Earth and DataBC (Figure 16).

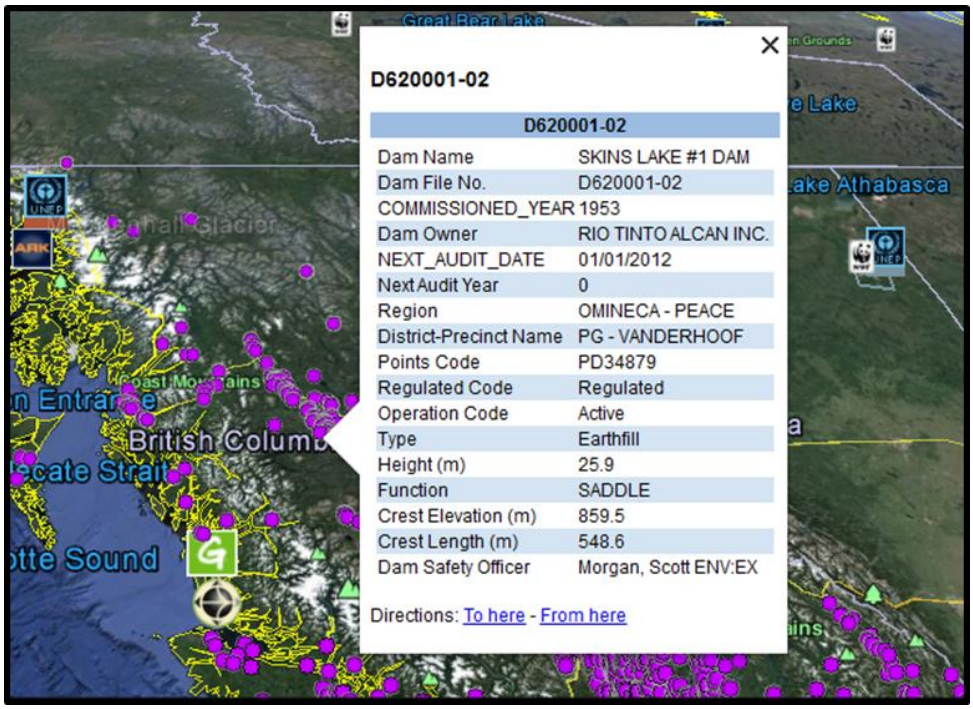


FIGURE 16.

Dam Inventory in BC. Google Earth. Each purple dot represents a dam in BC.

B.C.'s system of inventories is fairly comprehensive and user friendly. It provides the name of the dam, the owner's information, year commissioned, type, height, function as well as the safety officer's name along with several other pertinent pieces of information. B.C.'s database is accessible to the public which helps facilitate the job of dam safety officers (DSO) in monitoring dam owner compliance. Easy accessibility also facilitates the dam owner's ability to input information about their dams. And, according to a MFLNRO report, "The dam registry is being improved to allow more effective tracking of compliance by DSOs and NROs (MFLNRO, 2014)".

Furthermore, new improvements to the MFLNRO website include, "under the compliance tab in E-Licensing, the Compliance with Regulations options can now be manually set to take into account a broader range of issues. In addition, an *Enforcement* tracking tab has been added to record enforcement activities and to monitor the required timelines and deadlines (MFLNRO, 2014)". Unfortunately, this registry does not include the unregulated dams that failed to meet the requirements for dam height, water storage volume or failure consequences, and therefore, are not subject to B.C. dam safety reviews. Many of these unregistered dams may be prime candidates for removal but because of their unregulated status, they do not require a dam safety review and hence, may not be prioritized for removal or inspected for safety.

Dam safety reviews (DSR) are an important step in the process of identifying safety and maintenance issues, and also as a trigger for dam for removal. Having updated inventories allows dam safety officers to register a dam as unfit for structural or environmental reasons thus providing the catalyst for its decommissioning. An example of how this process can set in motion the removal of a dam, we can refer the Edwards Dam on the Kennebec River, Maine. In 1999, the Federal Energy Regulatory Commission (FERC) refused to renew the dam licence due to negative environmental impacts and the dam was ordered to be removed(Doyle, 2003). Though the Edwards Dam was regulated, many smaller, unregulated dams have grave environmental impacts, as well as the potential to be a safety hazard to communities living downstream. This gap of non-inventoried and hence, unregulated dams could be reduced through a broader classification system of dams coupled with a more updated and national accounting of all dams throughout Canada.

In the Province of Ontario, the database of inventoried dams is called the Ontario Dam Inventory (ODI). It lists over 1700 dams but does not contain small dams, small water control structures, beaver dams, water crossings, or culverts (ODI, 2014).This ODI information is processed through the Ministry of Natural Resources and Forestry, Spatial Data Infrastructure Mapping and Information Resources Branch, Corporate Management and Information Division. The document, *Ontario Dam Inventory* (ODI, 2014), through a series of FAQ's provide the current status of dam inventories. There are three questions followed by answers that describe Ontario's dam inventories. The first is Q: "*Where can I find the Dam & Barrier data model'?* This dam & barrier data model was developed prior to 2009 and the dataset is no longer being maintained and will be retired from the LIO Editor and Warehouse (ODI, 2014). The second Q: *Where can I find the Provincial Dam Inventory?* Between 2003 and 2009 the Lands & Waters Branch of the MNRF worked in association with Conservation Ontario and MNRF districts to produce the Provincial Dam Inventory (PDI). The PDI is in a Microsoft access database format and the data quality control process has not been completed. The Lands & Waters Branch no longer exists in the MNRF and the PDI is not currently being maintained. The third Q: *Where can I find information about dams in the Ontario Hydro Network (OHN)?* Refer to the OHN User Guide and Data Capture Specification for Hydrographic Features for more information on dams in the OHN (MNRF, 2014)". Ontario's database is limited and various bits of information were missing from some of the entries. I was able to access the list from a shape file but I had some difficulty converting it to a more readable format. The model diagram can be seen in figure 17 and the list can be accessed by contacting Land Information Ontario and using their Metadata Management Tool.

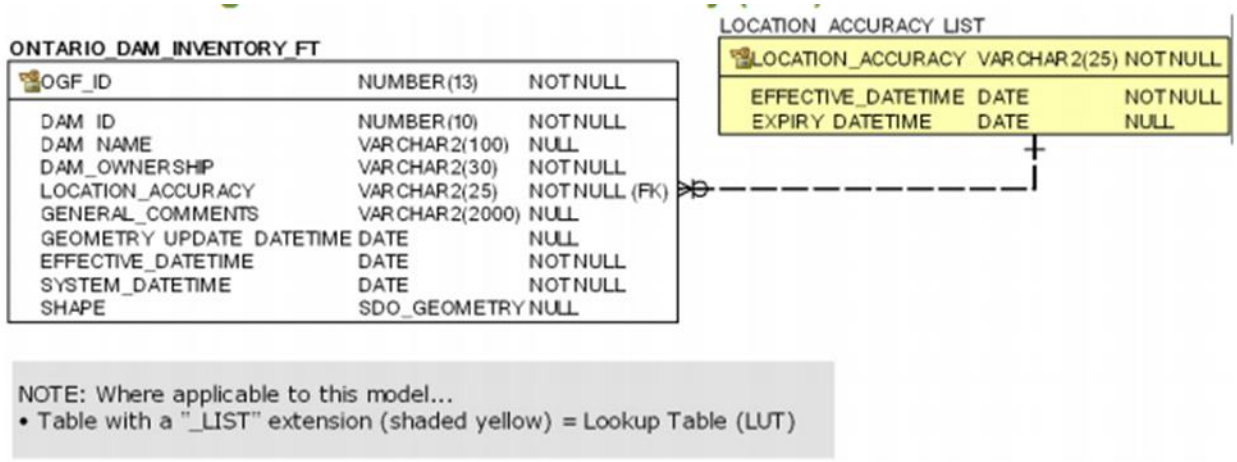


Figure 17.

Model diagram of the Ontario Dam Inventory (ODI). (2014)

Dam Inventories in the U.S are much more comprehensive and easily accessible. The National Inventory of Dams (NID) is managed by the U.S. Army Corps of Engineers. Its central database lists 84, 100 regulated dams, of which, 1,595 are listed as significant hazard dams and are within 1 mile of a downstream community (NID, 2013). The NID collects its dam data from 68 different sources including the federal and state government dam construction and regulation offices. The website lists dam inventories by individual state as well as nationally and provides graphical information on dams by hazard potential, dams that have emergency action plan (EAP), height, ownership information, type, purpose and year built. There is also a comprehensive interactive map and reporting system with tutorial that can be accessed on the web by clicking on 'instructions on using NID Interactive Reporting*.' According to the NID website, dams listed meet at least one of the following criteria (NID, 2013):

1) High hazard classification - loss of one human life is likely if the dam fails,
2) Significant hazard classification - possible loss of human life and likely significant property or environmental destruction,
3) Equal or exceed 25 feet in height and exceed 15 acre-feet in storage,
4) Equal or exceed 50 acre-feet storage and exceed 6 feet in height.

Most of the dams listed are regulated by federal or state authorities and the inventories have been updated as of 2013. Also, Stanford University, through its National Performance of Dam Program (NPDP), has established a very interactive and comprehensive database of dams. According to the website, they are developing their database to include:

- All dams in the U.S. regulated by state regulatory agencies.
- Dams in the U.S. that state dam safety programs maintain a record of (whether regulated or not).
- All dams in the current U.S. National Inventory of Dams (NID).
- Dams the NPDP has information on that pre-date the National Inventory of Dams or state dam safety programs (i.e., Teton Dam failed in 1976 and pre-dates the NID).

Unlike the NID which maintains data on dams currently in operation, the NPDP Dams Directory retains all dams—historic, currently operating, and recently removed or retired.

Features of the NPDP dams directory are:

- All dams remain in the database, including those that have been removed, failed and not re-built or repaired, etc.
- The capability to maintain a history of changes to a dam (e.g., changes to the spillway capacity, raising of the dam crest, removal of dam gates, etc.)
- Data on structures, systems and components at a dam can be included in the database (as such information becomes available).
- Dams no longer in service are retained.
- The Dams Directory is linked to the NPDP dam incident database, consequence and database.

Stanford's NPDP program is a good reference and template for agencies wanting to enhance or improve their dam inventory databases. It also offers a variety of other services and interactive activities related to dams such as, dam trivia, chronology of major events in U.S. dam safety, dam types and functions, a digital library, photographs, dam and penstock incidents data, dam incident consequence query, a page to report a dam incident, as well as a dams dictionary of terms.

Internationally, The Global Reservoir and Dam Database (GRanD) as well as the International Commission on Large Dams (ICOLD) lists global counts of large dam inventories and reservoirs. GRanD under the Global Water System Project (GWSP) has undertaken the chore of establishing a single database of dam and reservoirs[22], whereas ICOLD's database covers large dams no less than 15 meters.[23] See figure 18 for a preview of their website and list of member countries.

Figure 18. ICOLD list of member countries. www.icold-cigb.org

[22] The Global Reservoir and Dam (GRanD) Database provides the location and main specifications of large global reservoirs and dams with a storage capacity of more than 0.1km³ both in point and polygon format. The current version 1.1 of GRanD contains 6,862 records of reservoirs with a cumulative storage capacity of 6,197km³ and their attribute data. The development of GRanD primarily aimed at compiling the available reservoir and dam information, correcting it through extensive cross-validation, error checking and identification of duplicate records, attribute conflicts or mismatches; and completing missing information from new sources or statistical approaches. The dams were geospatially referenced and assigned to polygons depicting reservoirs outlines at high spatial resolution.

[23] The present edition of the Register take into account 58266 dams with a basic requirement of a structural dam height above foundation not less than 15 metres.

However, not all dam inventory projects need to be on this scale in order to be effective. Grassroots, community based conservation groups and NGO's collect and distribute invaluable information and data on smaller dams. Some local communities have started up conservation efforts which in turn help to establish a more complete inventory of dams, and at the same time contribute to improved water quality and fish habitats. Examples in Canada include Trout Unlimited and Ontario Rivers Alliance among others such as The Watershed Center, which in 2014, began traveling throughout the watershed conducting an Inventory of Small Dams on both public and private property (TWC, 2014). A complete inventory list of small and large dams as well as an expanded list of barriers to water is not only essential for a dam safety program to be effective, but it can also contribute to better outcomes for aquatic restoration efforts, water resource management and dam removal project prioritization.

An article in Frontiers in Ecology and the Environment titled, *Restoring Aquatic Ecosystem Connectivity Requires Expanding Inventories of both Dams and Road Crossings*, highlights the importance of systematic inventories of all barriers in restoring waterways (Januchowski-Hartley, 2013). The authors assert that, "…spatial database documents 38 times as many road crossings as dams in the Great Lakes basin, and case studies indicate that, on average, only 36% of road crossings in the area are fully passable to fish. It is therefore essential that decision makers account for both road crossings and dams when attempting to restore aquatic ecosystem connectivity. In addition to knowing the locations of dams and road crossings, decision makers also need information on how passable engineered structures are for species of interest. Understanding the ecological impacts of these structures on aquatic connectivity is essential when prioritizing efforts to maximize returns on limited funding (Januchowski-Hartley, 2013:1)". From an environmental, conservation and watershed management perspective, these databases are invaluable and may support a dual purpose not only by saving money for both federal and provincial projects both also by improving dam safety and environmental protection and restoration efforts.

Dam Classification

Dams are classified based on a tiered consequence classification system. The CDA provides guidelines for a dam classification system within Canada and several provinces employ the CDA's dam failure consequence classification guidelines within their dam safety programs to determine whether a dam is classified as extreme, very high, high, significant or low. Generally, this is determined by several factors relating to the exposure to risk, with a large emphasis on loss of life for a population (PAR), along with other loses such as economic, environmental, and cultural losses. The CDA dam classification criteria is outlined in the Dam Safety Guidelines (2007/2013 Revisions) manual and listed in Appendix B: "Downstream Dam Failure Consequences Classification." It not only provides a guide for regulators in Canada but, owners and operators of new and existing dams, dam safety officers, engineers and other managers who must classify dams not only for the purpose of determining dam safety requirements, but also assessing risk and creating emergency response procedures. Dam safety management includes the reduction of risk associated with dam failure or breach[24]. The reduction of the negative consequences associated with such a failure, is one of the objectives of the dam classification framework. The CDA's dam safety guidelines indicate that in some cases, the consequence classification based on population at risk (PAR) alone, is enough to determine the risk imposed by a dam. The PAR is generally a 5 tiered system that is based on the following: extreme (more than 100 deaths), very high (100 or fewer), high (10 or fewer), significant (unspecified) and low (0). In 2013, the CDA expanded this classification system of consequences of failure to include of a broader risk assessment approach. The 2013 revisions were to section 6.1, 6.2 and 6.3 of the Dam Safety Guidelines and can be found on the CDA website.

[24] Breach: The uncontrolled release of the contents of a reservoir through collapse of the dam or appurtenant structures.

There are several other factors that increasingly influence the current classification of regulated and unregulated dams. These factors tend to evolve over time and include downstream development. As populations increase, they often move into areas that were once uninhabited. So, while at one time a dam did not pose a threat to non-existent downstream populations and may not have been regulated, it may now pose a potential hazard under new conditions created through development. In this instance, it is important to maintain an up-to-date inventory of dams so that as new areas become populated, the classification of upstream dams can be modified.

Dam safety programs cover dams that are regulated under the various provincial Acts. However, there are thousands of unregulated dams throughout Canada as either they do not fit into the consequence classification failure rating system or they do not have a water license.[25] In B.C., for instance, dams that do not meet the criteria specified in the regulations for failure consequence, such as height or volume of water stored in their reservoirs, are not regulated. Neither are impoundment structures or tailing ponds, as they are regulated under the *Mines Act (MFLNRO, 2014).* Recent dam failures involving tailing dams, such as the Mount Polley disaster in 2014, have been on the front pages of many Canadian newspapers. This particular incident prompted the B.C. government to take steps towards the creation of a web-based reporting system where dam safety inspection reports can be posted publically (MEM, 2015). A $305,000 contract has been awarded to Hatch engineering to create this system, but it has not yet been implemented.

Mount Polley is just one of many tailing dam failures that have occurred worldwide (Rico, 2008). These disasters are not just random occurrences, rather they are a harbinger of things to come.[26]

[25] In BC, a dam's classification (also referred to as a dam consequence classification) is based on potential impacts of failure (i.e. consequences) on the safety of the population, the environment, cultural values, property and infrastructure (http://mssi.nrs.gov.bc.ca/1_LandingPage/FAQ_TailingsDam_Jan_30_2015_Final.pdf).

[26] The Obed mine site in 2013 was not registered as a dam even though it met the requirements. According to the auditor general, Merwan Saher, most of the mines used by the coal industry have not been inspected since the 1980s or 1990s and there are no safety reviews on file for 22 of the structures.

For example, the construction of the first tailings dam in the Alberta Oil Sands began in earnest in the 1960's, and now cover a surface area of about 140 square kilometers with a storage volume of 750 billion litres of toxic sludge (CDA, 2014).[27] In March 2015, The Huffpost in Alberta reported that there are 65 dams used by the oil sands, with, "a list of oil sands industry dams that pose either "extreme" or "very high" consequences if they were to fail indicating… [That]… there is no annual performance report or safety review for Syncrude's Mildred Lake dam (Huffpost, 2015)". I personally counted 27 extreme consequence dams listed on the Alberta Energy Regulator's report. The release of the auditor general of Alberta's March 2015 report[28] on systems to regulate dam safety was the impetus needed for the Alberta Energy Regulator (AER), which regulates the majority of Alberta's 1,500 dams, to launch an inspection program in May 2015. The results of which are expected in October 2015. Looking forward, the industry needs to heed these warning and ensure better dam education and safety measures that include dam breach analysis for tailings dams, emergency preparedness and cleanup plans as well as hefty fines for owners of dams that fail. These precautions will help mitigate future failures and environmental disasters. To find more information on mining dams in B.C., visit the government's interactive map of Permitted Mines in BC. [29]

In B.C., they have adopted the CDA guidelines, with minor modification under BC Reg. 44/2000, to the following categories: Loss of Life, Environmental and Cultural Values and Infrastructure & Economics (Appendix E). Although, according to MFLNRO's website, (under the Dam Safety Program), B.C. has not yet adopted the new CDA 2013 revisions to the Dam Safety Guidelines under sections 6.1, 6.2 and 6.3, which pertain to a risk-informed approach for classification and is characterized by the measurement of the probability and consequences of an undesired event such as floods and earthquakes (MFLNRO, 2014).

[27] Environment Canada has said the spill contained damaging compounds such as arsenic, mercury, cadmium, lead and manganese.
[28] http://www.oag.ab.ca/
[29] This mapping application identifies the locations of Mines in British Columbia and contains links to important, publicly available documentation regarding these mines. Documents available for public consumption include Inspection Safety Report, Emergency Response Plan, Incident Report, Site Visit and others. These mines are monitored through the Ministry of Energy and Mines. Use this application to locate mines, identify the owner of each, the mined ore as well as for accessing the various documents relevant to each mine (apps.gov.bc.ca).

These new changes take into consideration risk tolerance, based on the economic efficiency and social equity of such risk (CDA Revised, 2013).

The owner of a dam in B.C. with a classification of high, very high and extreme are required to complete an annual Dam Safety Regulation compliance form (see Appendix F). Currently, there exist 1570 water supply dams in B.C. that are regulated and which fall under these 3 classifications (MFLNRO 2013/2014). Dams classified as 'low' or 'significant' hazard potential dams are not required to complete this form. Herein lies another opportunity to reduce dam incidents by including all class of dams in the database so they can be monitored and inspected thus allowing future adjustments to dam classification to be made based on a variety of emerging factors (population and development changes, aging, climate, etc.). A study in the *Canadian Geotechnical Journal,* further emphasises the need to improve the classification system as, 'the frequency of failures for embankment dams[30] constructed prior to 1950 is about seven times higher than that for dams constructed after 1950 (Foster, 2000).' In the U.S., these dams represent the majority of dam failures.[31] This is important as embankment dams represent many of the dams built in Canada today. A more robust dam hazard classification may thereby precipitate a dam classification change from unregulated to regulated status dams, which, in turn may assist in prioritizing a dam for removal.

These are but a few of the reasons why broadening the ways in which dams are classified, and the introduction of a single, national data-base of dam inventories, can help reduce the gaps of missing dam data while at the same time, assist in providing data for the prioritization of dams for removal. There is no room for complacency in the upcoming era of deteriorating and unsafe dams.

---

[30] Any dam constructed of natural excavated materials placed without addition of binding materials other than those inherent in the natural material. The materials are usually obtained at or near the dam site. Embankment dams are usually referred to by type such as earth-fill or rock-fill. The term Embankment Dam is used to indicate a zoned fill dam involving selected areas of rock, gravel and impervious zones or a homogeneous earth-fill dam which is not necessarily zoned.

[31] Internal erosion is one of the leading causes of dam failures in the United States, and yet it remains one of the most difficult potential failure mechanisms to understand and predict (FERC Engineering Guidelines Risk-Informed Decision Making: Chapter R10. Internal Erosion and Piping).

A more accurate and complete inventory of dams along with a broader classification can help mitigate incidents of failure. The implementation of a broader dam classification system and a more comprehensive and accessible inventory system have the potential of enhancing current dam safety regulations and legislation by providing dam safety officers and owners with access to information. This, in turn will enable dam safety officers to apply more vigorous surveillance and maintenance enforcement initiatives.

Catalogue Dam Incidents

It is not enough to classify a dam based solely on the consequences of its failure. Rather, it is important to better understand the reasons why a dam might fail. The development of a dam incident and failure database is essential for the implementation of an effective dam safety program. Since 2008, the FERC dam safety program in the U.S. has been conducting Potential Failure Mode Analyses (PFMAs) for qualifying high and significant downstream hazard potential dams. It has also extended this process, on a voluntary basis, to owners of 'significant' and 'low' hazard consequence dams (FERC). Dam owners have access to a manual which provides guidance on how to self-implement the PFMA. This provides dam owners with an opportunity to learn more about their dams as well as any previously unknown potential for failure. It also allows for any risk reduction measures to be pursued by the owner as well as overseen preventative maintenance measures. The FERC's provides guidelines for the evaluation of hydropower projects as well as information on Monitoring the Performance of Dams.

As mentioned above, a high-hazard classification dam is generally considered as such due to its downstream consequences for potential loss of life during a natural flood event or failure.[32] It does not necessarily consider the age, structural integrity, foundation geology or other dam characteristics that may be indicative of whether or not a dam is more susceptible to failure. As a dam ages and incidents of failure increase these considerations should be an integral part in

[32] The classification of a dam based on the consequences of its failure and not the condition of the dam.

the classification of a dams. There are a number of resources available in the U.S. that provide case studies of dam failure incidents that can inform Canadian dam safety programs as well as owners about the potential risks of failure inherent in regulated and non-regulated dams. They include: Dartmouth University Database of Flood Related Incidents Including Dam Failures (Regan, 2009), Federal Energy Regulatory Commission (FERC) – Database of Safety Incidents, Kurt Douglas et al CONGDATA-Database of Concrete and Masonry Dam Failures and Incidents (Spannagle & Fell, 1998), ICOLD 1995 Dam Failures-Statistical Analysis, ICOLD 1999 Lessons from Dam Incidents, ICOLD 2000 Rehabilitation of Dams and Appurtenant Structures-State of the Art and Case Histories, ICOLD 2003 Dams and Floods-Guidelines and Case Histories, Mark Foster et al ERDATA1-Database of Embankment Dam Failures and Incidents, and the National Performance of Dams Program (NPDP) – Database of U.S. incidents, as well as the U.S. Bureau of Reclamation -Dam Safety Office Publications and USCOLD/ASCE Dam Incidents.

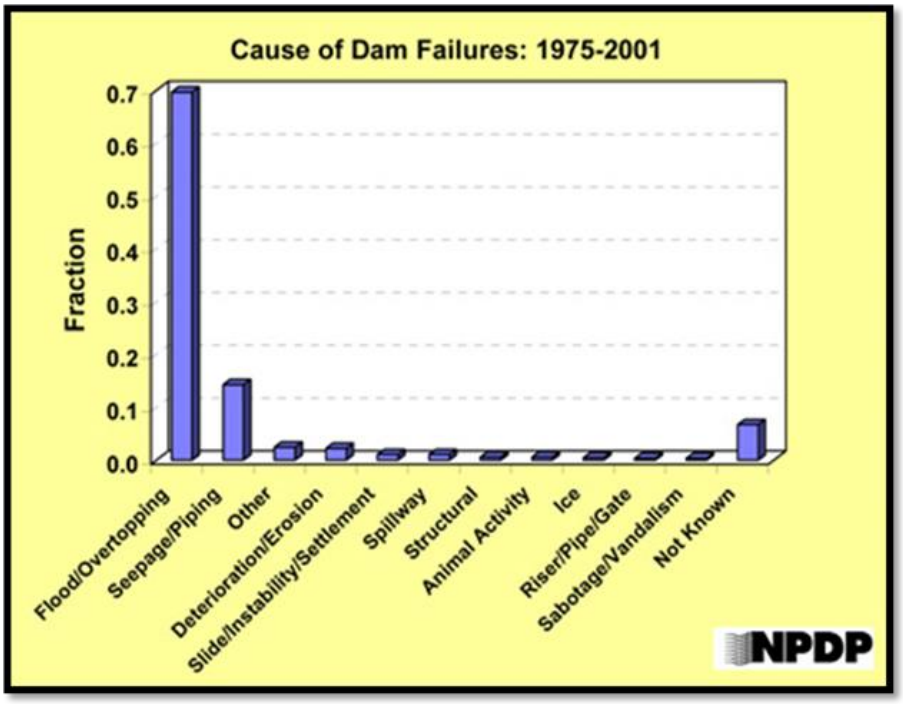


FIGURE 19.

Cause of Dam Failure according to National Performance of Dams Program (NPDP).

Track Outcomes of Dam Removal

Successful removal of a dam requires decision makers to evaluate other numerous dam characteristics. Thus, a central database outlining these characteristics would be beneficial in ensuring positive future outcomes of dam removal projects. According to an article titled, *How Dams Vary and why it Matters for the Emerging Science of Dam Removal,* "an ecological classification of dams is needed to characterize how the tremendous variation in the size, operational mode, age and number of dams in a river basin influences the potential for restoring regulated rivers via dam removal (Poff, 2002)." In doing so, it will allow for more accurate predictions in the outcomes of removal and provide and create an opportunity to develop a more robust and hence, more effective and efficient framework for dam removal. Unfortunately, dams slated for removal in Canada are still minimal. However, an increase in the science and documentation of the impacts of dam removal in the U.S. is on the rise and this will help decision makers to better assess if, how and when a dam should be removed.

Funding Needed for Dam Removal & Repair

The implementation of all these dam safety measures requires funding, and as dams age, funding for infrastructure maintenance, upgrades and dam removal becomes critical. The government of Ontario estimates that 70% of these dams listed are expected to require major repair or alterations by 2025 (Miller, 2003). The cost to repair these dams is often estimated to be 3X greater than the cost to remove them, and will no doubt put a strain on dam owners and government agencies (Whitelaw, 2002). Many large dams were built without factoring in the future costs of repair and have become un (der) funded liabilities. In 2009, the U.S. estimated the future cost of dam repair to be over 50 billion (ADSO, 2009). Currently the responsibility for dam repair and maintenance lies with the dam owner. This looming and unknown unfunded liability coupled with the probability that most dam owners haven't budgeted for these repairs, makes a thorough accounting of *all* Canadian dams crucial for the purpose of calculating and

budgeting for future costs of repairs and maintenance. This should be a consideration for all government agencies concerned with dam safety regulations, as well as federal and provincial policy makers. Otherwise, they may be faced with a huge budgetary shortfalls during a time of increasing dam failures. For example, New Brunswick recently announced that the cost of replacing its Hydro generating station at the Mactaquac dam in 2030 will be approximately $5 billion (CBC News, October 1, 2014). This is a hefty bill for a province with a declining population of only 755,000 and the worst economy in Canada. Also, on March 17, 2015 the town of Grand Bank, Newfoundland approved funding for repairs to a dam in their reservoir, and while the tiny towns share was only 10% of the cost, it was still over $400,000 for a population of only 2,580 citizens. These stories are only the tip of the iceberg and will become more frequent as dams age. In 2013, the American Society of Civil Engineers (ASCE) released an updated Infrastructure Report Card. In this report, dam safety was given a 'D' - partially due to the lack of funding available to support the repair and upgrade needs of the nation's dams (ASCE, 2013). Previously, in 2009, the Association of State Dam Safety Officials (ASDSO) task group concluded that it would take approximately $34 billion to rehabilitate the nation's non-federal dams, and $16 billion to rehabilitate the nation's most critical (high-hazard potential) dams that are in need of rehabilitation. Roughly $8.7 billion is needed to repair the publicly-owned high-hazard potential dams with the remaining $7.3 billion needed for the privately-owned high-hazard dams. In December 2012, a task group revised the estimates. Current figures place the total cost estimated for non-federal dams at $53.69 billion with high-hazard potential dams alone, estimated at approximately $18.2 billion (ASDSO, 2013).

The first Canadian Infrastructure Report Card (CIRC) was created in 2012 by the Canadian Society for Civil Engineering (CSCE). The most recent Canadian Infrastructure Report Card (CIRC)[33] was released in 2014, and provides a snapshot of the health of Canada's roads, bridges,

[33] The inaugural Canadian Infrastructure Report Card was released September 11, 2012 by the Canadian Society for Civil Engineering (CSCE), the Canadian Public Works Association (CPWA), the Canadian Construction Association (CCA) and the Federation of Canadian Municipalities (FCM). The Report Card provides information on a number of factors, including
the physical condition of the infrastructure, the available capacity, the value of the infrastructure systems, and the type of management systems that are used to collect information and make

transit and other infrastructure though, it does not provide recommendations on how to implement policy or action for repair. It estimates that, "the total value of infrastructure in a fair or worse state equates to approximately $13,000 per Canadian household (CIRC, 2014)".[34]

The Canada Strategic Infrastructure Fund Act was created in 2002 in order to provide funds to carry out strategic infrastructure projects, and recently, Canada's Economic Action Plan funded a $25.7 million infrastructure investment that included the rehabilitation and maintenance of the Latchford Dam in Ontario. It also contributed $2.4 billion through the Infrastructure Stimulus Fund 2007-2012. Also, Parks Canada just announced that it will be providing $58 million, over 2 years, for the repair of dams and bridges on the Rideau Canal and Trent-Severn waterway, and that there will also be dam reconstructions in five other locations including Hastings, Bolsover and Brighton (PC, 2015). These Government of Canada investment initiatives are often announced with great fanfare, yet it is difficult to ascertain the actual ongoing funding required for infrastructure repair and maintenance of dams in Canada. The CIRC lists 4 categories of infrastructure that include: drinking water, waste water, storm water and municipal roads. Under these categories, the infrastructure it referred to were reservoirs, pipes, pumping stations, management facilities and storage tanks, but not specifically to dams. I was unable to find a dam infrastructure report cards or an estimate cost for the repair and maintenance of these underfunded liabilities. Without funding for repair or removal, dam safety programs become ineffectual. In order to ensure compliance with dam safety regulations in Canada, owners of dams that require repair, maintenance or removal, may need to have access to funding. According to an article in Hydro Review, "in the early 2000s, the government of Ontario committed to invest C$8 million (US$8.15 million) annually in dam infrastructure management, but recently the funding level has been reduced by half because of other

---

infrastructure investment decisions. The Report does not include recommendations for changes to infrastructure policies or actions, but rather is designed to provide information that can be used by our municipal, provincial or federal governments to develop their own plans and policies (www.canadianinfrastructure.ca)

[34] 'Fair' rating definition: The infrastructure in the system or network is in fair condition; it shows general signs of deterioration and requires attention. Some elements exhibit significant deficiencies.

provincial requirements for funding. As a result, there is a significant backlog of deferred capital expenditures needed to upgrade the MNR aging dam infrastructure (Judge, 2012)".

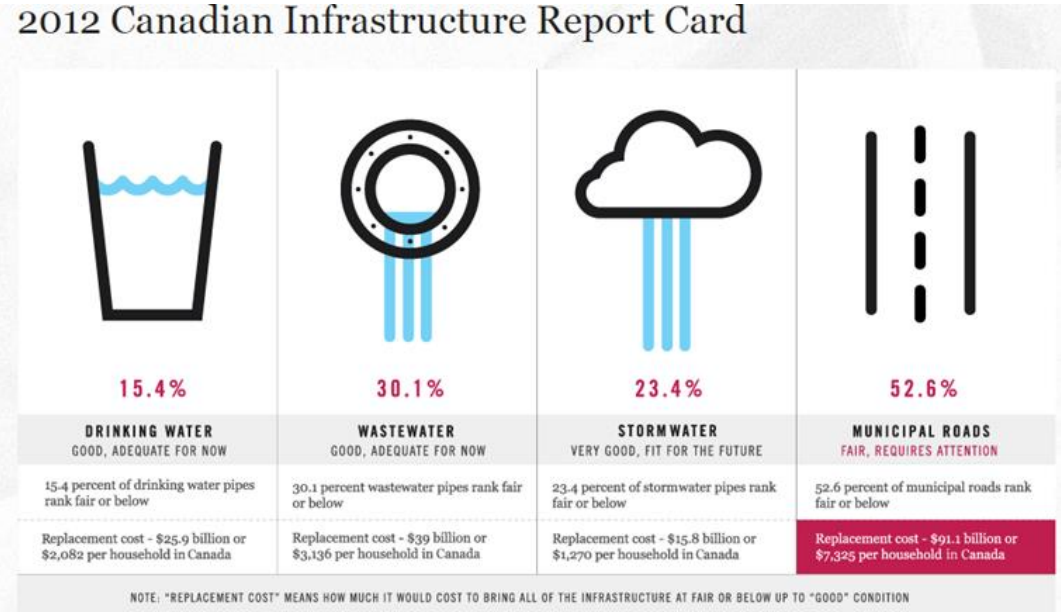


Figure 20.

The 2010 Canadian Infrastructure Report Card (CIRC).

In B.C., under certain circumstances, a Natural Resources Officer (NRO), may have access to funds from the Environmental Remediation Sub Account (ERSA) for costs related to contraventions under the *Water Act*. And if an owner is unwilling to remediate these issues, the DSO or NRO can authorize another person to do the repairs and then recover the expenses in court under Section 86. Also, programs offered through B.C. Hydro, such as the Fish and Wildlife Compensation Program, as well as programs funded through Trout Unlimited Canada, offer some funding for dam removal for the purposes of river and stream restoration albeit, on a small scale.

The U.S. is well ahead of Canada, and has several state and federal programs to help fund the removal of unsafe or environmentally detrimental dams. For instance, "The Pennsylvania Fish

and Boat Commission provides financial assistance statewide under their Consultation and Grant Program for Fish Passage and Habitat Restoration. Interested landowners with dams or other blockages are eligible to request assistance for their dam removal project (PFBC)". The Pennsylvania Department of Environmental Protection (PADEP) has also dedicated funding specifically for dam removal projects through a major bond initiative, disbursed via the Growing Greener competitive grant program. This program awarded American Rivers with $767,000 over three years (2003-2006) for allocation throughout the states. This award has enabled American Rivers to assist in funding 53 dam removal or fish passage projects statewide. It has leveraged over $3.4 million in matching funds from other state agencies, private foundations and additional funding sources. An article in an International Rivers brochure states that, "funding decommissioning financing remains an afterthought for most dam owners. One reason is the lack of formalized institutional arrangements ensuring regular, periodic monitoring of dams. The World Bank-sponsored World Commission on dams calls for stringent dam performance evaluations every 3-5 years and recommends setting aside funds for future decommissioning. Decommissioning funds established before or during project operation, such as those mandated for nuclear power plants, will help offsets future decommissioning costs, especially for large dams. Those who build, finance, and operate dams should be held responsible for the costs of decommissioning them (IR, n.d)."

Numerous funding programs have come out of a variety of environmental restoration policy initiatives in the U.S. As Canadians, we share a common aquatic borders with the U.S.- the Great Lakes. Together, both countries have worked together to assess the ecological health of the Lakes as well as steps to restore them though programs like the Great Lakes Restoration Initiative. Projects like this provides further opportunities to work together to improve policy around clean water management policy and legislation that could include as part of its mandate, dam safety and removal.

Conclusion

Dam removal is an integral part of dam safety. Improvement to current dam safety legislation and regulation to allow the streamlining of the dam removal process as well as increased government funding would further enhance dam safety and would, as a result, improve riverine ecosystems, fish populations, water purity, and reduce coastal erosion. Dam removal has the potential to be a powerful tool for ecological, social and economic revitalization as well as to provide a more sustainable and new opportunity in water management planning schemes (Hart, 2002). The process will asuage public safety concerns over the hazards of dam failure and reduce the potential for loss of life as well as infrastructure and environmental damage. Dam removal can play a key role in mitigating the trend in deteriorating water quality (Environment Canada, 2011) as it creates and rehabilitates wetlands that provide essential environmental services such as flood protection, carbon sinks, climate mitigation, habitat creation for plants and animals and water filtration and purification services. Dam removal also protects shorelines by restoring nearshore habitats through the release of sediment and nutrients that would normally remain trapped behind a dam.

Though the process of dam removal is a somewhat nascent phenomenon in Canada, it has great potential to positively impact our environment, economy and policy. It wasn't that long ago that the first U.S. government mandated dam removal request occurred on the Kennebec River in Maine (1997). Since then, the U.S has made great strides in developing dam safety and removal projects with impressive results. Documentaries, such as DamNation and Return of the River have had large impacts by creating public awareness and educating people about the benefits of dam removal, yet it is not commonplace in Canada. Implementing efficient and effective frameworks for the dam removal process by stream-lining the process, and funding a standardized national dam safety program, could lead to the increased application of dam removal, not only across Canada, but also on a global level. Furthermore, the process of dam removal can work to enhance awareness surrounding the social injustices associated with dam development projects. This, in turn, can act as a fulcrum and direct Canada's energy policy in a

more sustainable direction. Now, more than ever, we need to return our streams and rivers back to healthy ecosystems capable of restoring environmental resilience, and providing protection from the increasing effects of climate change. The safety risks, future financial burden, along with the negative impacts of dams have on the environment are all compelling reasons to make dam removal a top consideration when addressing future changes to dam safety legislation and regulations in Canada.

References

American Rivers: Interactive Map of US Dam Removals 1936-2014. (2015) Retrieved 10.01.2015, from http://www.americanrivers.org/initiatives/dams/dam-removals-map/

American Rivers: *Permitting Dam Removal: The State of (Several) States*. (2006). Retrieved from: http://www.americanrivers.org/assets/pdfs/dam-removal-docs/Permitting_Dam_Removal-The_State_of__Several__States8107.pdf?5e1a37

American Rivers: *72 Dams Removed In 2014. American Rivers Reports on Last Year's Successes, Sets Goal of 75 Dam Removals In 2015*. (2015). Retrieved from: http://www.americanrivers.org/newsroom/press-releases/72-dams-removed-in-2014/

American Rivers, and Trout Unlimited. (2002). *Exploring Dam Removal – A Decision Making Guide.* American Rivers and Trout Unlimited, Wisconsin.

American Rivers: *Review of New Jersey Regulations Pertaining to Dam Removal & Stream Restoration* (2015). Retrieved from: http://www.americanrivers.org/newsroom/resources/dam-removal-in-new-jersey-background-regulatory-guidance-and-practical-aspects/

American Rivers, Friends of the Earth, & Trout Unlimited. (1999). *Dam Removal Success Stories: Restoring Rivers through Selective Removal of Dams That Don't Make Sense*. Washington, D.C. Retrieved from: http://www.americanrivers.org/assets/pdfs/reports-and-publications/SuccessStoriesReport6f14.pdf

American Rivers: A history of Edward's Dam removal efforts: The FERC relicensing process. (2002) Retrieved from: www.amrivers.org/tableofcontents/history.htm

American Rivers. Comprehensive List of Dams Removed 1998-2014. http://www.americanrivers.org/wp-content/uploads/2015/01/DamsRemoved_1998-2014.pdf?65c5e7 (accessed 10.02.2015)

APEGBC Professional Practice Guidelines. *Legislated Dam Safety Reviews in BC*. (2013). Retrieved from: https://www.apeg.bc.ca/getmedia/a373a764-1869-41b5-b07d-81d36a0698c3/APEGBC-Legislative-Dam-Safety-Reviews.pdf.aspx

American Society of Civil Engineering (ASCE). (2013): Infrastructure Report Card. Retrieved from: http://www.infrastructurereportcard.org/

Association of State Dam Safety Officials (ASDSO). Retrieved 10.01.2015 from: www.damsafety.org

BC Dam Safety Website: http://www.env.gov.bc.ca/wsd/public_safety/dam_safety/index.html

BC Hydro Dam Safety: *Seismic Upgrade Program*: *Probabilistic Seismic Hazard Analysis Study* Retrieved from: http://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/safety/probabilistic-seismic-hazard-analysis-volume%201%20.pdf

Babbitt, B. (2002). What Goes Up, May Come Down. *Bioscience*, 52(8), 656-658

Bowman, M. (2002). Legal Perspectives on Dam Removal. *BioScience,* 52(8), 739-747.

Boyle, J. Cunningham, M. Dekens, J. (2013). Climate Change Adaptation and Canadian Infrastructure Retrieved from: http://www.iisd.org/pdf/2013/adaptation_can_infrastructure.pdf

Canadian Dam Association (CDA). (2015). Retrieved on 02.02. 2015 from: http://www.imis100ca1.ca/cda

Canadian Dam Association. (2010). CDA 2010 Annual Conference. Retrieved on 01.05.2015 from: http://www.roctest.com/en/NewsItems/Canadian-Dam-Association-2010-Annual-Conference

Department of Fisheries and Oceans Canada (DFO). (2010). Survey of Recreational Fishing in Canada. Fisheries and Oceans Canada Ottawa, Ontario K1A 0E6. Retrieved from: http://www.dfo-mpo.gc.ca/stats/rec/can/2010/RECFISH2010_ENG.pdf

Dewan, Ashraf M. (2013). *Floods In A Megacity: Geospatial Techniques In Assessing Hazards, Risk And Vulnerability*. Dordrecht; New York: Springer

Donnelly, C.R., King, L., Phillips, M. (2005). Once removed - decommissioning Finlayson dam. Water Power and Dam Construction. May 16, 2005. Retrieved from: http://www.waterpowermagazine.com/features/featureonce-removed-decommissioning-finlayson-dam/

Donnelly, C.R., MacTavish, B.A., Paroschy, N., Phillips, M., Holmes, P., and L. King. (2001). *The Process of Decommissioning Dams in Ontario.* Ontario Ministry of Natural Resources and Acres & Associated Environmental Limited, Ontario.

Doyle, M. W., Harbor, J. M., & Stanley, E. H. (2003). Toward policies and decision-making for dam removal. *Environmental Management*, 31(4), 0453-65.

Environment Canada. (2013) Threats to Water Availability in Canada. Jolley, W. (Senior Dam Safety Officer, Land and Water British Columbia Inc., Victoria, Canada). Personal communication, 15 July 2002.

Food and Agricultural Organization of the United Nations (FAO). *Dams, fish and fisheries Opportunities, challenges and conflict resolution.* (2001). Retrieved from: ftp://ftp.fao.org/docrep/fao/004/Y2785E/y2785e.pdf

Federal Energy Regulatory Committee (FERC). Extension of Potential Failure Modes Analyses to Significant and Low Downstream Hazard Potential Dams. Retrieved from: http://www.ferc.gov/industries/hydropower/safety/initiatives/extension-pfm.asp

Friends of the River. 1999. Rivers Reborn: Removing Dams and Restoring Rivers in California. Sacramento (CA): FOTR. (13 July 2002; www.friendsoftheriver.org/pub/RiversReborn.pdf).

Government of Ontario. Lakes and Rivers Improvement Act (LRIA). 2012. http://www.elaws.gov.on.ca/html/statutes/english/elaws_statutes_90l03_e.htm

Government of Ontario. MNR. (2011). Lakes and Rivers Improvement Act, Technical Bulletin For Dam Decommissioning And Removal. http://www.voccompliance.com/elis/print.asp?doc_id=ont_o11

Government of Ontario. MNR (2002) Water Management Planning Guidelines for Waterpower: Water Management Planning Guidelines for Water Power. Retrieved from: http://apps.mnr.gov.on.ca/public/files/er/251983.pdf

Graham, W. (1999). *A Procedure for Estimating Loss of Life Caused by Dam Failure*. U.S. Department of Interior Bureau of Reclamation Dam Safety Office Denver, Colorado. Retrieved from: http://www.usbr.gov/ssle/damsafety/Risk/Estimating%20life%20loss.pdf

Gregory, S., Li, H., and Li, J. (2002). *The Conceptual Basis for Ecological Responses to Dam Removal. BioScience* 52 (8), 713-723.

Halliday, R. (2004). Perspectives on dam safety in Canada. Proceedings of the Canadian Dam Association 2004 annual conference: guidance to good practice CD-ROM ed, (p. 500). Canada: Canadian Dam Association.

Hart et al. (2002). Dam Removal: Challenges and Opportunities for Ecological Research and River Restoration. *BioScience* 52(8):669-682.

Hopey, D. Pittsburgh Post-Gazette: *Dam Removal in Pennsylvania Tops for 12th Year In A Row.* (2015) Retrieved from: http://www.post-gazette.com/news/state/2015/02/01/Dam-removal-in-Pennsylvania-tops-for-12th-year-in-a-row/stories/201501300014

Heinz. J. III Center for Science, Economics, and the Environment. (2002). *Dam Removal – Science and Decision Making. Panel on Economic, Environmental, and Social Outcomes of Dam Removal.* The Heinz Center 1001 Pennsylvania Avenue, N.W., Suite 735 South, Washington, D.C. 20004. Retrieved from: http://water.epa.gov/polwaste/nps/upload/Dam_removal_full_report.pdf

Hoenke, K. M., Kumar, M., & Batt, L. (2014). A GIS based approach for prioritizing dams for potential removal. Ecological Engineering, 64(Complete), 27-36.

International Commission on Large Dams (ICOLD). World Register of Dams (WRD). Retrieved from: http://www.icold-cigb.org/GB/World_register/world_register.asp

International Commission on Large Dams (ICOLD). (2011). Small Dams: Design, Surveillance and Rehabilitation. ICOLD, Paris, France, *Bulletin 143.*

International Commission on Large Dams (ICOLD), (1997). Small Dams: Design, Surveillance and Rehabilitation. ICOLD, Paris, France, *Bulletin 109*.

International Rivers. Problems with Big Dams. Retrieved from: http://www.internationalrivers.org/problems-with-big-dams

International Rivers: The Global View of Dam Removal. (ND). Retrieved from: http://www.internationalrivers.org/files/attached-files/damremovalbrochure.pdf

International Water Power & Dam Construction: To Remove or not to Remove? February 5, 2013. Retrieved from: http://www.waterpowermagazine.com/features/featureto-remove-or-not-to-remove/

Januchowski-Hartley, S*. et al.* (2013). Restoring aquatic ecosystem connectivity requires expanding inventories of both dams and road crossings. *Frontiers in Ecology and the Environment* 11(4): 211–217.

Japan for Sustainability (JFS). (2015). *Arase Dam: Japan's First Dam Removal Project Underway.* Retrieved 18.06.2015 from, http://www.japanfs.org/en/news/archives/news_id035105.html

Judge, D., Hugh, J.C., Chow, A. Hydro Review. (2012). Dam Safety: Ontario Ministry Develops Dam Management Plan. Vol 31(8)

Lake Simcoe Region Conservation Authority (LSRCA): *Beaver River Subwatershed Plan*. (2012) Retrieved from: http://www.lsrca.on.ca/pdf/reports/beaver_river_subwatershed_plan_2012.pdf

Mitchelmore Engineering Company Ltd (MECO). (2008) Small Dams in Canada. Retrieved from: http://www.mecoengineers.com/about-meco/articles/small-dams-in-canada/

Michigan River Partnership (MRP). 2007. The Growing Crisis of Aging Dams: Policy Considerations and Recommendations for Michigan Policy Makers.

Miller, C. (2003). Atlas of US and Canadian Environmental History. Routledge. 29 West 35th Street. New York, New York 10001.

Ministry of Energy and Mines: *Report on Mount Polley Tailings Storage Facility Breach*. (2015). retrieved from: https://www.mountpolleyreviewpanel.ca/final-report

Ministry of Forests, Lands and Natural Resource Operations. (2014). Strategy and Procedures for Compliance and Enforcement: Dam Safety Program. Retrieved from: http://www.env.gov.bc.ca/wsd/water_rights/policies/cabinet/dam_safety_ce_strategy_procedures_final-2014.pdf

Ministry of Forests, Lands and Natural Resources Operations (MFLNRO). (2011/2012). BC Dam Safety Program Annual Report.

http://www.env.gov.bc.ca/wsd/public_safety/dam_safety/cabinet/bc_dam_safety_annual_report19June2012.pdf

Ministry of Forests, Lands and Natural Resources Operations (MFLNRO). (2013/2014). BC Dam Safety Program Annual Report. Retrieved from: http://www.env.gov.bc.ca/wsd/public_safety/dam_safety/cabinet/dam-safety-annual-report-sept-2014.pdf

Ministry of Natural Resources and Forestry (MNRF). (2014). Ontario Dam Inventory (ODI). Spatial Data Infrastructure. Mapping and Information Resources Branch. Corporate Management and Information Division. Retrieved from: https://www.sse.gov.on.ca/sites/MNR-PublicDocs/EN/CMID/Ontario%20Dam%20Inventory%20User%20Guide.pdf

Ministry of Natural Resources. (2010). Technical Guidelines and Requirements for Approval under the Lakes & Rivers Improvement Act. Volume Five – Dam Removal and Decommissioning. (Draft).

Ministry of Natural Resources and Forestry. (2011). LRIA Dam Decommissioning and Removal Technical Bulletin. http://www.voccompliance.com/elis/print.asp?doc_id=ont_o11

Mitchelmore Engineering (MECO): *Small Dams in Canada*. (2014). Retrieved from: http://www.mecoengineers.com/about-meco/articles/small-dams-in-canada/

Natural Resources Sector (NRS) of BC. (2015). Tailings Dam Terms and FAQ. http://mssi.nrs.gov.bc.ca/1_LandingPage/FAQ_TailingsDam_Jan_30_2015_Final.pdf

National Inventory of Dams (NID). U.S. Army Corps of Engineers. (2013) Retrieved from: http://geo.usace.army.mil/pgis/f?p=397:12

National Oceanic and Atmospheric Administration (NOAA). Retrieved from: http://www.noaa.gov/

National Performance of Dams Program (NPDP). http://npdp.stanford.edu/. Stanford University.

Olsenius, C., (2014). Conserving Fish Habitat from Rivers to the Sea: The Story of the Southeast Aquatic Resources Partnership (SARP).

Ontario Ministry of Forests, Lands and Natural Resources Operations (MFLNRO). (2014). Strategy and Procedures for Compliance and Enforcement. Dam Safety Program. Retrieved from: http://www.env.gov.bc.ca/wsd/water_rights/policies/cabinet/dam_safety_ce_strategy_procedures_final-2014.pdf

Ontario Ministry of Natural Resources. (2004). Lakes & Rivers Improvement Act Technical Guidelines. Retrieved from: http://www.renaud.ca/public/Environmental-Regulations/2004-06%20LRIA%20Technical%20Guide.pdf

Ontario Ministry of Natural Resources. (2011). Lakes and Rivers Improvement Act Administrative Guide. Retrieved from: Ontario.ca/dams

Ontario Ministry of Natural Resources (OMNR). (2014). A Landowner's Guide to Removing Small Dams in Ontario. Retrieved from: https://www.ontario.ca/document/small-dam-removal.

Ontario Ministry of Natural Resources. (1998). Guidelines for Decommissioning and Devolvement of MNR Owned Dams (Draft). Prepared for the Ontario Ministry Of Natural Resources by Lands and Natural Heritage Branch.

Ontario Rivers Alliance (ORA). http://www.ontarioriversalliance.ca

Palmer, M. A., Lettenmaier, D. P., Poff, N. L., Postel, S. L., Richter, B., & Warner, R. (2009). Climate change and river ecosystems: Protection and adaptation options. *Environmental Management, 44*(6), 1053-68.

Parks Canada. (2015). Trent-Severn Waterway National Historic Site of Canada. Retrieved from: http://www.pc.gc.ca/eng/lhn-nhs/on/trentsevern/ne/neA1/neA1i.aspx

Pennsylvania Department of Environmental Protection (PDEP). (2009) Pennsylvania Climate Adaptation Planning Report: Risks and Practical Recommendations. Retrieved from: http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-103584/2700-RE-DEP4303%20Combined.pdf

Pennsylvania Fish & Boat Commission (PFBC). (2012). *Biologist Report Schuylkill River Chester and Montgomery Counties 2012 American Shad Survey*. Retrieved from: http://fishandboat.com/images/reports/2012bio/6x07_09schu.pdf

Poff, L. & Hart, D. (2002) How Dams Vary and why it Matters for the Emerging Science of Dam Removal. Bioscience 52(8): 659-668.

Professional Engineers and Geoscientists of BC. *Legislated Dam Safety Reviews in BC*. (2013) APEGBC Professional Practice Guidelines. Retrieved from: https://www.apeg.bc.ca/Home

Quinn, E.M. (1999). Dam removal: a tool for restoring riverine ecosystems. Retrieved from: http://horticulture.cfans.umn.edu/vd/h5015/rrr.htm

Rico, M. *et al.* (2008). Reported tailings dam failures: A review of the European incidents in the worldwide context. *Journal of Hazardous Material,* 152(2), 846-852

Sectoral Applications Research Program (SARP). National Oceanic and Atmospheric Administration (NOAA). Retrieved from: http://cpo.noaa.gov/ClimatePrograms/ClimateandSocietalInteractions/SARPProgram/AboutSARP.aspx

Saskatchewan Dam Inventory. Retrieved from: https://www.wsask.ca/Lakes-and-Rivers/Dams-and-Reservoirs/

Smallbridge, J. (March 2015). Canadian Press. *New Environmental Rules for Tailings Ponds*. Retrieved from: http://globalnews.ca/news/1892607/new-environmental-rules-for-tailings-ponds/

Southeast Aquatic Research Partnership (SARP). Retrieved from: http://www.southeastaquatics.net/sarps-programs/southeast-aquatic-connectivity-assessment-program-seacap/connectivity-resources

Tanabe, N. Japan for Sustainability (JFS). Newsletter No. 147, November 2014. http://www.japanfs.org/en/news/archives/news_id035105.html

The Aspen Institute. (2002). *Dam Removal: A New Option for a New Century. Program on Energy, the Environment, and the Economy*. The Aspen Institute Publication Office. Retrieved from: http://www.aspeninstitute.org/sites/default/files/content/docs/ee/damremovaloption.pdf

The Watershed Centre. Grand Traverse Bay. Retrieved from: http://www.gtbay.org/our-programs/small-dams-inventory/ (accessed 02.07.2015)

Toronto and Region Conservation Authority (TRCA). http://trca.on.ca/

U.S. Army Corps of Engineers National Inventory of Dams (USACE). (2014). Retrieved from http://geo.usace.army.mil/pgis/f?p=397:1:0::NO

Whitelaw, E. and Macmullan, E. (2002). A Framework for Estimating the Costs and Benefits of Dam Removal. *BioScience* 52(8), 724-730.

Wikipedia: List of Major Dam Failures. http://en.wikipedia.org/wiki/Dam_failure (accessed 11.02.2015)

World Commission on Dams. (2000). Dams and development: A new framework for decision-making: the report of the World Commission on Dams. London

APPENDIX A

Statutes and Regulations pertaining to Enforcement (www.env.gov.bc.ca)

Natural Resource Compliance Act:
http://www.bclaws.ca/civix/document/id/complete/statreg/11021_01

Offence Act:
http://www.bclaws.ca/civix/document/id/complete/statreg/96338_01

Offence Act:
Violation Ticket Administration and Fines Regulation: Schedule 1, see *Water Act* under Items 1B, 9B and 28B
http://www.bclaws.ca/civix/document/id/complete/statreg/89_97_02

Offence Act:
Violation Ticket Administration and Fines Regulation: Schedule 2, see *Water Act* under Column 1, pages 43 to 47.
http://www.bclaws.ca/civix/document/id/complete/statreg/89_97_03

Offence Act: under Section 81 (2) of the *Offence Act*
Investigation and Prosecution Costs Regulation, see *Water Act* under Column 1, p. 2
http://www.bclaws.ca/civix/document/id/complete/statreg/227_90

Water Act: Offences under Section 93 and 94
http://www.bclaws.ca/civix/document/id/complete/statreg/96483_01

APPENDIX B

Downstream Dam Failure Consequences Classification Table

Dam failure consequences classification	Population at risk	Consequences of failure		
		Loss of life	Environment and cultural values	Infrastructure and economics
Low	None[2]	There is 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, or (c) unique landscapes or sites of cultural significance.	Minimal economic losses mostly limited to the dam owner's property, with virtually no pre-existing potential for development within the dam inundation zone.
Significant	Temporary only[3]	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, or (c) unique landscapes or sites of cultural significance, and restoration or compensation in kind is highly possible.	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 irregularly for temporary purposes.
High	Permanent[4]	10 or fewer	Significant loss or deterioration of (a) important fisheries habitat or important wildlife habitat, (b) rare or endangered species, or (c) unique landscapes or sites of cultural significance, 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.
Very high	Permanent[4]	100 or fewer	Significant loss or deterioration of (a) critical fisheries habitat or critical wildlife habitat, (b) rare or endangered species, or (c) unique landscapes or sites of cultural significance, and restoration or compensation in kind is possible but impractical.	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.
Extreme	Permanent[4]	More than 100	Major loss or deterioration of (a) critical fisheries habitat or critical wildlife habitat, (b) rare or endangered species, or (c) unique landscapes or sites of cultural significance, 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] This table is a copy of Schedule 1 of the Dam Safety Regulation 163/2011. In case of discrepancy between this table and the approved Regulation, the Regulation takes precedence.
[2] There is no identifiable population at risk.
[3] 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.
[4] The population at risk is ordinarily or regularly located in the dam-breach inundation zone, whether to live, work or recreate.

APPENDIX C

Dams: Types of Works Requiring LRIA Approval

(Lakes and Rivers Improvement Act Administrative Guide 2011)

Type of Dam	Types of Works	Special Considerations	Applicable Types of Watercourses
Permanent Dams	1. Construction of a Dam 2. Alteration, Improvement or Repair to a dam which may affect the dam's safety or structural integrity, the waters or natural resources 3. Change in a dam operation plan from that contemplated in approved plans and specifications 4. Decommission of a dam	Includes locks or weirs	In Permanent Flowing Watercourses 1. all heights of dams In Intermittent Flowing Watercourses where: 1. the dam is 3 meters or more above the original stream bed; or 2. the dam is 2 meters or more above the original stream bed with 2 hectares of reservoir surface area; or 3. the watershed area above the proposed site is 1.5 sq. kilometres or more; or 4. fisheries or other natural resources dependent on the river will be adversely affected; or 5. failure of the dam could release into the lake or river any pollutant (likely to impair the quality of the water)
Seasonal Dams		Where a dam is maintained during a portion of the year only (usually the summer season)	
Mine Tailings Dams		Approval may include one or more phases of construction of a mine tailings dam over a number of years	
Temporary Dams	Construction of, or removal of the dam	Including coffer dams	
Emergency Dams	Construction of a dam immediately necessary to prevent injury to persons, loss of life, or loss of property.	Immediately give notice to the MNR District Office of emergency works and comply with any directions.	

Dams: Types of Works Not Requiring LRIA Approval

Type of Dam	Types of Works	Special Considerations
All Types of Dams	Dam Construction - not located on or connected to a lake or river.	No approval required where a dam is creating an off-stream dug-out or run-off pond supplied by exposure to the groundwater table, or fed by intermittent surface run-off, with no connection to a stream by a pipe or channel.
	Works that may not affect the dam's structural integrity or safety or may not affect the waters or natural resources	See Directive WR.4.03.05.05 for interpretation.
Conservation Authority Dams	Works that have been approved under Section 24 of the Conservation Authorities Act	MNR Section 24 approval under the Conservation Authorities Act must be based on the review of detailed engineering design documents.
Community Fisheries and Wildlife Involvement Program (CFWIP)	Dams	Works carried out under the Community Fisheries and Wildlife Involvement Program (CFWIP) are considered to be Crown projects and are therefore not required to obtain LRIA approval. It is MNR policy however, that MNR field offices will ensure the design for these projects adhere to LRIA policies and standards through consultation with the Ministry Engineer prior to construction.

APPENDIX D

BC Dam Failure Consequences Classification Conversion Table (March 27, 2012)[1]

Consequence Classification NEW BC Dam Safety Regulation 163/2011	Population at Risk	Loss of Life		Environment and Cultural Values[2]		Infrastructure & Economics[2]		Consequence Classification OLD BC Dam Safety Regulation 44/2000
	BC Reg. 163/2011 Only	BC Reg. 163/2011	BC Reg. 44/2000[3]	BC Reg. 163/2011	BC Reg. 44/2000	BC Reg 163/2011	BC Reg. 44/2000	
Low	None	No possibility of loss of life	Minimal	Minimal short-term and no long-term loss or deterioration	No significant loss of habitat or sites	Minimal economic losses mostly limited to dam owner's property	< $100K Minimal	**Very Low**
Significant	Temporary Only	Low potential for multiple loss of life[6]	Some Possible	No significant loss or deterioration incl. Important habitat Restoration or compensation possible	Loss or deterioration of regionally important habitat & sites – High chance for restoration or compensation	Low economic losses to buildings, services, public transportation, infrastructure, etc.	< $1M Limited Infrastructure, Public, Commercial	**Low**
High	Permanent Residents	< 10	< 10[4]	Significant loss or deterioration incl. Important habitat Restoration or compensation possible	Same as below	High economic losses to buildings, services, public transportation, commerce, infrastructure, etc.	< $10M[4] Same as below	**High (Low[4])**
Very High	Permanent Residents	< 100	< 100	Significant loss or deterioration incl. critical habitat Restoration or compensation impractical	Loss or deterioration of Nationally & Provincially important habitat & sites – High chance for restoration or compensation	Very high economic losses to **important** buildings, services, transportation, infrastructure, commerce etc. **Or** severe damage to residential areas	< $100M Substantial Infrastructure, Public, Commercial	**High (High[4])**
Extreme	Permanent Residents	>100	>100	Major loss or deterioration incl. critical habitat Restoration or compensation impossible	Loss or deterioration of Nationally & Provincially important habitat & sites – Low chance for restoration or compensation	Extremely high economic losses to **critical** buildings, services, transportation, infrastructure, commerce etc. **Or** destruction or severe damage to residential areas	>$100M Very High Infrastructure, Public, Commercial, Residential	**Very High**

[1] This table contains abridged descriptions of the dam failure consequences. Attachment 1 contains the full descriptions from BC Regulation 163/2011. In all cases the Regulation takes precedence over information contained in this table.
[2] Names for these categories in BC Reg. 44/2000 are "Environmental and Cultural Losses" and "Economic and Social Losses" respectively.
[3] Conservative estimate of loss of life amongst population affected by the flood waters (may equal Population at Risk).
[4] Sub-classifications of "High (Low)" and "High (High)" and associated thresholds were established by policy in 1998 for use in the BC Dam Safety Program risk-based assessment.
[5] A temporary population (e.g. in recreational areas) could be quite large and a "sunny-day" failure could result in multiple fatalities.

MFLNRO: BC Dam Failure Consequences Classification Conversion Table (March 27, 2012)

APPENDIX E

Downstream Dam Failure Consequences Classification Table

Dam failure consequences classification	Population at risk	Consequences of failure		
		Loss of life	Environment and cultural values	Infrastructure and economics
Low	None[2]	There is 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, or (c) unique landscapes or sites of cultural significance.	Minimal economic losses mostly limited to the dam owner's property, with virtually no pre-existing potential for development within the dam inundation zone.
Significant	Temporary only[3]	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, or (c) unique landscapes or sites of cultural significance, and restoration or compensation in kind is highly possible.	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 irregularly for temporary purposes.
High	Permanent[4]	10 or fewer	Significant loss or deterioration of (a) important fisheries habitat or important wildlife habitat, (b) rare or endangered species, or (c) unique landscapes or sites of cultural significance, 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.
Very high	Permanent[4]	100 or fewer	Significant loss or deterioration of (a) critical fisheries habitat or critical wildlife habitat, (b) rare or endangered species, or (c) unique landscapes or sites of cultural significance, and restoration or compensation in kind is possible but impractical.	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.
Extreme	Permanent[4]	More than 100	Major loss or deterioration of (a) critical fisheries habitat or critical wildlife habitat, (b) rare or endangered species, or (c) unique landscapes or sites of cultural significance, 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] This table is a copy of Schedule 1 of the Dam Safety Regulation 163/2011. In case of discrepancy between this table and the approved Regulation, the Regulation takes precedence.
[2] There is no identifiable population at risk.
[3] 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.
[4] The population at risk is ordinarily or regularly located in the dam-breach inundation zone, whether to live, work or recreate.

MFLNRO: Dam Safety Regulation (163/2011), November 30. 2011

This is a slightly expanded version than that found in the 2007 CDA Dam Safety Guidelines: Table 2-1: Dam Classification.

APPENDIX F

2014 DAM STATUS REPORT FORM
FOR OWNERS OF HIGH, VERY HIGH & EXTREME CONSEQUENCE DAMS

OFFICE USE ONLY:
File Number: D
Dam Safety Officer:
Region: HQ, VI, SR, KM, PN, NL, WL, PG
Consequence: AG, DA

BY JANUARY 31, 2015, COMPLETED FORM MUST BE SUBMITTED TO:

By Mail: Dam Safety Section, Water Management Branch
Ministry of Forests, Lands and Natural Resource Operations, Victoria BC.
Please mail to the address located at the bottom of this page.
By Fax: 250-356-0605
By email: dam.safety@gov.bc.ca

Please fill in Dam Name, Failure Consequence Class, and contact information: name, address, phone # & e-mail below:

Dam Name: **Failure Consequence Class:**

Your Name:

Your Address:

Phone number:

E-mail address:

Please read the information overleaf (page 2) before completing this form. For more information, see the Compliance and Enforcement section of our website: http://www.env.gov.bc.ca/wsd/public_safety/dam_safety/index.html.

1. Has your Formal Inspection for 2014 been completed? Yes ☐ No ☐
   Inspected By: Owner ☐ Other ☐ Who?
   Comments:
2. Did you undertake *regular* (see page 2) Site Surveillance? Yes ☐ No ☐
   Comments:
3. Have any new dam safety concerns been identified this year (2014)? Yes ☐ No ☐
   If yes, please elaborate:
4. ***If yes to #3:*** Has a plan been prepared to address the safety concern(s)? Yes ☐ No ☐ N/A ☐
   Comments:
5. Has a Professional Engineer completed your Dam Safety Review? Yes ☐ Year? _____ No ☐
6. In what year was your *Operation, Maintenance & Surveillance Manual* last updated?
7. Has the emergency contact information in your *Emergency Preparedness Plan* been updated and a copy submitted to the Dam Safety Officer this year? Yes ☐ No ☐ If Yes, which month?
8. Has there been any land use development downstream of your dam in the last year that might affect the failure consequence classification? Yes ☐ No ☐ If Yes, please elaborate:

Additional comments or suggestions:

Submitted by: **Date:**

Position: **Phone:**

Water Management Branch
3RD Floor, 395 Waterfront Crescent, Victoria BC Tel (250) 952 6700 Fax (250) 356 0605
Mailing Address: PO Box 9340 STN PROV GOVT Victoria BC V8W 9M1
Website: http://www.env.gov.bc.ca/wsd/public_safety/dam_safety/

APPENDIX G

Funding Opportunities for dam removal through Pennsylvania's Department of Energy and Environmental Protection Grant & Loan Program.

Grantee	Project	Municipality	County	Grant Amount	Grant Type
Somerset County Conservation District	Oven Run Systems Rehab	Shade	Somerset	$704,846	AMD Set-Aside
Cambria County Conservation District	Lesle Run Water Quality Monitoring Project	West Carroll Township	Cambria	$2,620	AMD Set-Aside
Paint Creek Regional Watershed Association	Upper Red Eyes Feasibility Study	Ogle Township	Somerset	$25,000	AMD Set-Aside
Western Pennsylvania Conservancy	Cherry Run Restoration Project - K Discharges	Jay Township	Elk	$734,737	AMD Set-Aside
Susquehanna River Basin Commission	Rausch Creek Mine Pool Evaluation and Discharge Transport	Hegins and Porter Townships	Schuylkill	$440,559	AMD Set-Aside
Evergreen Conservancy	Tanoma AMD Treatment System	Rayne Township	Indiana	$123,896	AMD Set-Aside
Mifflin County Conservation District	Continued Agricultural BMP Implementation in the Upper Kishacoquillas Creek Watershed	Menno Township	Mifflin	$394,216	EPA 319
Franklin County Conservation District	West Branch Antietam Stream Restoration	Washington Township	Franklin	$43,989	EPA 319
Izaak Walton League of America, York No. Chapter 67 Inc.	South Branch Codorus Creek - Ness to Centerville Creek	Codorus/Springfield Townships	York	$79,881	EPA 319
Pennsylvania Association of Conservation Districts, Inc.	Nonpoint Source Pollution (NPS) Education Office		Multiple	$541,700	EPA 319
Broad Top Township	Sandy Run SA0-D11 AMD Remediation	Broad Top Township	Bedford	$529,563	EPA 319
Donegal Chapter of Trout Unlimited	Conowingo Creek - Lapp, Lloyd and Stoltzfus Construction	Fulton & East Drumore Township	Lancaster	$376,896	EPA 319
Lancaster County Conservation District	Mill Creek Stream Restoration - Phase VI	Leacock & Upper Leacock Townships	Lancaster	$10,000	EPA 319
Etna Borough	Etna Borough Green Streeets Phase 2 - Construction	Etna Borough	Allegheny	$554,936	EPA 319
Bucks County Conservation District	Design/Permitting of a BMP within the Lake Luxembourg/Core Creek Watershed	Middletown Twp	Bucks	$153,145	EPA 319
Schuylkill Conservation District	Lorberry Treatment System Rehabilitation	Tremont Township	Schuylkill	$310,428	EPA 319
Luzerne County Conservation District	Implementation of Restoration Activities at Frances Slocum Lake	Franklin, Dallas & Kingston Townships	Luzerne	$269,964	EPA 319
Jacobs Creek Watershed Association	Southmoreland High School Section 319 Stormwater Improvements	East Hungtingdon	Westmoreland	$166,000	EPA 319
Lebanon Valley Conservancy Inc.	Quittie Creek Nature Park Stream Restoration	Annville	Lebanon	$422,462	Growing Greener
Centre County Conservation District	Gray, Brown & Brown Agricultural BMP Implementation Project	Halfmoon Township, Ferguson Township	Centre	$500,732	Growing Greener
Crawford County Conservation District	Initiation of a Watershed Implementation Plan for Conneaut Lake	Summit/Summer Hill/Conneaut Lake	Crawford	$104,167	Growing Greener
Environment Erie	Scott Run Watershed Protection and Restoration	Erie	Erie	$110,188	Growing Greener
Columbia County Conservation District	Columbia County Soil Health Project	Multiple	Multiple	$208,402	Growing Greener
Cambria County Conservation District	Northern Cambria Borough Flood Control Restoration Project	Northern Cambria Borough	Cambria	$69,648	Growing Greener
Snyder County Conservation District	Ulrich ACA & Pasture Improvements	Jackson Township	Snyder	$80,082	Growing Greener
Cambria County Conservation District	Cherry Tree Flood Control Restoration Project	Cherry Tree Borough	Indiana	$124,320	Growing Greener
Northcentral Pennsylvania Conservancy	Restoration of CBWI Priority Watersheds		Multiple	$273,972	Growing Greener

Acknowledgements

I wish to extend a special thanks to Don Butcher, executive director of the Canadian Dam Association for his generosity in furnishing me with a copy of the *Dam Safety Guidelines.* Thank you to Bill Chalmers, construction manager at B.C. Hydro for his patience in answering all my questions and his encouragement. As well, Monty Miedreich, Senior Dam Safety Officer with the Ministry of Forests, Land and Natural Resources Operations in BC, Kevin Brown, a senior project engineer and Josh Annett a policy advisor both with the Ministry of Natural Resources (MNR), for answering all my questions about dam removal. Much obliged to Steve Bobrowicz, Regional Fisheries Specialist (OMNR) as well as Ministry of Natural Resources Fish and Wildlife Specialist Jody Scheifley, for shedding light on the complexity of the relationship of fish populations and dams. Thanks to Aaron Hahn, an engineer with Interior Dams in Kelowna, BC for explaining the complexities of dam safety reviews and removal and to Albert van Dijk with Parks Canada for information on federal removals as well as Craig Mitchell, Supervisor - Flood Infrastructure and Hydrometrics, Ecology Division of the Toronto and Region Conservation Authority for directing me to a variety of useful resources. I am also grateful to my supervisor, Professor Felipe Montoya and advisor, Professor Ilan Kapoor for their never ending patience, wisdom and encouragement in finishing my Masters in Environmental Studies.

Minden generating station and Dam. Orillia Power Corporation.