Risky Business: Improving the Mine Reclamation Regime in British Columbia

by

Claudia Malinowski

B.A. (International Studies), Simon Fraser University, 2018

Project Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Public Policy

in the

School of Public Policy

Faculty of Arts and Social Sciences

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SIMON FRASER UNIVERSITY

Spring 2020

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Approval

Name:    Claudia Malinowski
Degree:  Master of Public Policy
Title:   Risky Business: Improving the Mine Reclamation Regime in British Columbia
Examining Committee:  Chair:  Maureen Maloney  
                        Professor, School of Public Policy, SFU
                        Dominique Gross  
                        Senior Supervisor  
                        Professor
                        Nancy Olewiler  
                        Internal Examiner  
                        Professor
Date Defended/Approved:  March 16, 2020
Abstract

Mine reclamation is considered an integral part of mine closure and is imperative to the conservation of land, watersheds, and natural habitats. British Columbia was one of the first jurisdictions in Canada to adopt mine reclamation legislation and has since expanded its reclamation regime. However, the province has experienced some of the largest environmental mining disasters in Canada and continues to have insufficient safeguards to ensure sustainable mine closure. Several studies have explored financial assurance as a solution to this issue, but few have evaluated the benefits of preventative efforts adopted during the mine planning process. This study attempts to fill this gap by evaluating pollution prevention policies in other mining jurisdictions and identifying options to enhance reclamation outcomes in BC’s mining industry. Three policy options are considered: prohibiting mines with perpetual water treatment, strengthening regulations on tailings storage facilities, and introducing a funding program aimed at mining innovation.

Keywords: Mine Reclamation; Environmental Policy; Pollution Prevention; Mine Planning; Tailings Facilities; Acid Rock Drainage
Acknowledgements

First, thank you to my parents for encouraging me to pursue my passions and offering compassion and wisdom during my times of need. Your hard work and courage inspire me every day.

Thank you to Dr. Dominique Gross for your supervision and advice on this study. You encouraged me to strive for excellence in all aspects of my work. Thank you to Dr. Nancy Olewiler for your patience, guidance, and mentorship during this journey. You have been a pivotal part of my learning and success in this program.

Thank you to my friends, colleagues, and cohort members who provided support and moments of release during hard times. You are like a family to me and I could not have done this without you. I want to especially thank Holly and Lewis for being my anchors. You took time to listen to my questions, provided thoughtful advice, and gave me reality checks when needed. I am grateful for your friendship and support.

Finally, a big thank you to Jordan, for being my rock and for always believing in me.
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<th>Description</th>
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<tbody>
<tr>
<td>ARD</td>
<td>Acid Rock Drainage</td>
</tr>
<tr>
<td>BADCT</td>
<td>Best Available Demonstrated Controlled Technology</td>
</tr>
<tr>
<td>BC</td>
<td>British Columbia</td>
</tr>
<tr>
<td>EA</td>
<td>Environmental Assessment</td>
</tr>
<tr>
<td>EAA</td>
<td><em>Environmental Assessment Act</em></td>
</tr>
<tr>
<td>ECCS</td>
<td>Ministry of Environment and Climate Change Strategy</td>
</tr>
<tr>
<td>EIA</td>
<td>Environmental Impact Assessment</td>
</tr>
<tr>
<td>EMA</td>
<td><em>Environmental Management Act</em></td>
</tr>
<tr>
<td>EMP</td>
<td>Environmental Management Plan</td>
</tr>
<tr>
<td>EMPR</td>
<td>Ministry of Energy, Mines and Petroleum Resources</td>
</tr>
<tr>
<td>MBI</td>
<td>Market-Based Instrument</td>
</tr>
<tr>
<td>NEPA</td>
<td><em>National Environmental Policy Act</em></td>
</tr>
<tr>
<td>RIAS</td>
<td>Regulatory Impact Analysis Statement</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
</tr>
<tr>
<td>SEA</td>
<td>Strategic Environmental Assessment</td>
</tr>
<tr>
<td>US</td>
<td>United States</td>
</tr>
</tbody>
</table>
Executive Summary

Mine reclamation is considered a cornerstone of responsible and sustainable mining. Until recently, mining companies in British Columbia (BC) were not required to reclaim lands disturbed by mining. As a result, many historical mine sites were abandoned in BC, leaving behind a legacy of contamination and ecological damage. Although the provincial government has taken steps to strengthen regulations, BC’s mining regime continues to lack early prevention measures to ensure effective reclamation. This poses a long-term threat to the environment that can last generations and lead to significant costs for surrounding communities and taxpayers.

This study examines BC’s reclamation policies and explores options to improve reclamation outcomes using a pollution prevention approach. The primary methodology is a multiple case study analysis that evaluates best practices in pollution prevention across three mining jurisdictions. The four dimensions examined are project planning, regulatory requirements, public participation, and market-based instruments. The results of the primary methodology are confirmed by evidence from empirical studies and academic literature. Overall, the case study analysis reveals that regulations and project planning have the strongest pollution prevention measures across the jurisdictions, followed by market-based instruments and public participation. The secondary analysis finds that regulations and market-based instruments are the most promising policy instruments to encourage greater pollution prevention in BC’s mining industry.

Three options are identified from the research findings and evaluated based on the following criteria: effectiveness, cost, administrative ease, and stakeholder acceptance. The first option is prohibiting mines that require perpetual water treatment, which targets mine sites with high potential for acid rock drainage and metal leaching. Although this option has the potential to improve reclamation outcomes, it poses some technical challenges and compliance issues that undermine its effectiveness. The second option is strengthening regulations on tailings storage facilities, and more specifically, phasing out the use of wet tailings. This option performs well on both reclamation outcomes and behavioural change and is relatively low cost to implement. The third option is introducing an innovation funding program aimed at pollution prevention in the mining industry. This option has moderate results for effectiveness but
boasts high support from the mining industry and is considered an important intervention for removing innovation barriers and addressing reclamation challenges.

Based on the evaluation, this study recommends that the Government of British Columbia implements the regulation on tailings facilities and the innovation funding program. Together, these options can provide a targeted approach that reduces long-term environmental risks at mine sites, promotes progressive reclamation, and spurs innovation in the mining industry. This two-pronged approach recognizes that mining requires both strong regulatory systems and innovation incentives to advance the industry toward a more sustainable future.
Chapter 1. Introduction

Mining has a long history in British Columbia (BC) and continues to play a strong role in the economy. Today, the province is considered a leading mine jurisdiction and the third largest mineral producer in Canada. In 2019, the value of total productions at BC mines was $9.7 billion, with a growth rate of 7.3% over the past year (Natural Resources Canada, 2019a). The industry also employs more than 30,000 people across the province and supports a host of other industries, including manufacturing, clean technology, and engineering (Natural Resources Canada, 2019b). At the global stage, BC is considered a world-leading centre of expertise and is home to the largest concentration of exploration companies (Government of British Columbia, 2019a).

While mining can yield a range of benefits to society, it is a complex and intensive process that poses significant risks to the environment and surrounding communities. Until recently, mining companies have faced lenient environmental laws and limited oversight from the provincial government. As a result, many historical mines were abandoned in BC, leaving behind a legacy of contamination and ecological damage. Contemporary cases like the Britannia Mine and Tulsequah Chief Mine shed light on the devastating impacts of mine abandonment, including polluted rivers and drinking water, loss of biodiversity, and long-term strains on communities.

Mine reclamation is an integral part of responsible mine closure that is well established in international practice and sustainable development principles. Mining organizations and governments now widely recognize that reclamation is a core environmental management practice that should be adopted throughout the mining lifecycle. International mining standards also emphasize the importance of integrated reclamation planning, financial surety, and post-closure monitoring (Initiative for Responsible Mining Assurance, 2018). In the Canadian context, federal and provincial governments have put forward commitments to ensure that areas affected by mining are returned to a safe and environmentally sound state.

This study evaluates BC’s reclamation policies to determine their effectiveness in protecting the environment and local communities. The first section of the study explores the current state of mine reclamation in the province, outlines environmental and other
impacts of premature mine closure, and identifies gaps in the policy framework. The second section uses a case study analysis to evaluate best practices in Australia, Chile, and the United States (US), and confirms the findings using a literature review. The final section conducts a policy analysis on three different options using an evaluation framework and provides a final recommendation for the Government of British Columbia.
Chapter 2. Mine Reclamation in British Columbia

Mine reclamation is considered a cornerstone of responsible and sustainable mining. This chapter defines mine reclamation and outlines its key elements. It also provides an overview of BC’s reclamation regime and the current challenges it faces.

2.1. Defining Mine Reclamation

Mining activities can have lasting impacts on the natural environment that continue long after operations cease. Today, most jurisdictions require that companies take appropriate steps to mitigate environmental impacts at all stages of mining, including the closure stage. Mine closure is the last phase of the mining cycle where the site is decommissioned, physical structures are removed, and rehabilitation work begins. Although the process is complex, mine closure is considered critical to the conservation of land, watersheds, and wildlife habitats. When mines are not properly closed at the end of their life or abandoned by mining companies, they pose a long-term threat to the environment and surrounding communities.

One of the key features of mine closure is reclamation. Reclamation is a process that restores and redevelops areas affected by mining to a safe and environmentally sound state, in order to support post-mining land use and healthy ecosystems. Contemporary reclamation generally involves planning, engineering, and management strategies that aim to protect natural resources and improve landscape quality (Dance, 2015). Mining companies can achieve this by removing buildings and equipment, treating polluted waterways, disposing hazardous material, removing leftover explosive stockpiles, and revegetating rock piles (Dance, 2015). This work can also include restoring habitats or preparing land for future use. While reclamation has many common elements, each reclamation project is unique and influenced by a variety of factors, including local regulations, environmental conditions, and community expectations (Roche & Judd, 2016).

Reclamation requires technical solutions to mitigate pollution and disturbances in mining areas, but it also involves environmental stewardship and policy planning that spans decades. Best practices in mining suggest that reclamation should be progressive and start early in mine development in order to maximize beneficial outcomes following
closure (Berchtold & Price, 2018). This requires a clear vision for post-closure land at the planning and approval stages and a comprehensive reclamation plan that mitigates environmental hazards and risks (Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development [IGF], 2019). It also requires sound management practices and an effective regulatory regime that provides clear lines of responsibility and accountability (Ghorbani & Kuan, 2017).

2.2. BC’s Mine Reclamation Regime

British Columbia was one of the first jurisdictions in Canada to introduce mine reclamation legislation and extend it to exploration sites. Up until 1969, mining companies were not required by law to reclaim all lands disturbed by mining and faced a legal framework that was favourable to companies and often inattentive to environmental concerns (Dance, 2015). Since then, BC has introduced a number of environmental protections and legislation targeted at mine reclamation.

Under BC’s existing legislation and policies, mining companies are fully responsible for environmental protection and reclamation at mine sites. Prior to the commencement of mining, companies are required to submit a program for environmental protection and a reclamation plan to demonstrate that their cleanup operations and monitoring programs will be effective (Government of British Columbia, 2019b). Major projects are also subject to an environmental assessment process and are required to obtain a number of permits and licenses. Once the project is accepted, mining companies provide reclamation security to the provincial government to ensure that reclamation obligations are kept. This security is returned to the company after reclamation is completed to a satisfactory level and there are no ongoing monitoring or maintenance requirements (Government of British Columbia, 2019b).

2.3. The Current State of Mine Reclamation in BC

While mine reclamation has become a well-established principle in BC, current practices have been insufficient to protect the environment and local communities. In recent decades, there have been many instances where mines have been improperly reclaimed or abandoned across the province, resulting in damage to habitats,
waterways, and heritage resources. This includes high-profile cases such as the Britannia Mine, the Mount Washington Mine, and the Tulsequah Chief Mine.

The Britannia Mine is considered one of the worst pollution cases in North America. The historic mine leached pollutants into the Howe Sound for decades after its closure and was largely responsible for the disappearance of fish and shellfish in the area (Coastal Ocean Research Institute, 2017). Remediation has been ongoing since 2001 and the provincial government has spent over $46 million in cleanup costs (Castrilli, 2007). Similarly, the Mount Washington Mine on Vancouver Island wiped out the salmon population in the Tsolum River, while the Tulsequah Chief Mine in the northwest contaminated a critical salmon watershed for nearly 50 years. Conservation efforts have increased the salmon count in the Tsolum River but attempts to clean up the Tulsequah Chief Mine have been largely unsuccessful (Allan, 2016). Since 2012, there has been no water treatment at the mine and acid drainage continues.

Aside from these cases, environmental contamination continues to be a principle concern at many other mines across the province. Today, there are over 1,100 historic mines in BC that have potential environmental concerns, including the risk of generating acid or leaching metals into the environment (Barazzuol & Stewart, 2003). The full breadth of environmental issues at these sites is not fully known, and BC’s landscape contains many historic mines that have not been properly documented or characterized (Barazzuol & Stewart, 2003). These historic mines represent a significant challenge for reclamation due to their remoteness and high cleanup costs. Reclaiming one mine site can cost upwards of $100 million, while BC’s liability for contaminated sites is estimated at $508 million (Ministry of Forests, Lands and Natural Resource Operations, 2016).

The scope of the issue goes beyond historic mines and affects modern mines as well. A major challenge with BC mines today is premature mine closure, or abandonment, which can occur for a variety of reasons such as environmental accidents, labour disputes, geotechnical issues, or changes in commodity prices. Another contributing factor is the high costs that mining companies incur at the reclamation phase, at a time when financial inflow is low (United Nations Development Programme [UNDP] & United Nations Environment Programme [UNEP], 2018). While premature mine closure is difficult to predict, it can undermine reclamation outcomes in the 22 major mines and 1,000+ aggregate mines across the province (Clarke et al.,
Even if mining companies are present during closure, there is still the potential for substandard reclamation, which can pose long-term threats to nearby waterways and constrain future land use (Tremblay et al., 2011). A recent example of premature closure is the Yellow Giant Mine, where operations were shut down for environmental and permit violations. The mining company filed for bankruptcy in 2016, leaving behind a mine with inadequate financial security to cover the full remediation costs (Hoekstra, 2016).

Moreover, mine reclamation activity has not been able to keep pace with new mining projects in the province. As shown in Figure 1, the total amount of land disturbed by mining has risen steadily over the past 50 years, while only 29% of land has been reclaimed (Office of the Chief Inspector of Mines, 2017). This represents a significant financial liability for the provincial government, which is currently estimated at $2.1 billion (Auditor General of British Columbia [AGBC], 2016). These numbers are expected to grow, with several new mines set to begin production in the near future. A recent survey revealed that exploration expenditures in BC increased by 66% over 2017 and have almost doubled 2016 levels (Ernst & Young, 2019). Much of the development is concentrated in the northwest corner of the province, which is known for its high acid rock drainage potential (AGBC, 2016). Given the continued growth of mining activity in the province, it is essential that the mining industry develops in an environmentally responsible and sustainable way.

![Figure 1. Total Areas Disturbed and Reclaimed by Mines in BC, 1969-2013](image)

Source: An Audit of Compliance and Enforcement of the Mining Sector, by the Auditor General of British Columbia, 2016.
Chapter 3. Environmental and Other Impacts

This chapter explores the environmental impacts of mining and risks associated with mine abandonment and inadequate reclamation. It also demonstrates the harmful effects on local communities across socio-economic and cultural factors.

3.1. How Mining Generates Pollution

Mining operations can generate pollution in many ways. The type of pollution depends on the mining method used, whether it is underground, open pit, or placer mining. In BC, open pit and underground mines are the most common.

The key sources of mine pollution are pit walls, waste rock, and tailings (Figure 2). Open pit mines create large quantities of waste rock that get stored at the mine site. Both waste rock and exposed pit walls contain acid and heavy metals that can become a source of pollution. Ore, which is mineralized rock containing valuable metals and minerals, is also processed at the mine site using various chemicals and separating metals to extract the final metal or mineral (AGBC, 2016). The by-products of this process are called tailings, which may contain toxic heavy metals and chemical agents such as cyanide or sulphuric acid (AGBC, 2016). Both waste rock and tailings can leach out contaminants into surface water and groundwater if they are improperly secured, leading to significant environmental damage (AGBC, 2016).

Figure 2. Potential Sources of Water Pollution at Open Pit Mines
Source: An Audit of Compliance and Enforcement of the Mining Sector, by the Auditor General of British Columbia, 2016.
Although pollution can occur at all stages of the mining cycle, the reclamation stage has the highest cumulative impacts and pollution control costs (Santos et al., 2016). This stage also has the lowest ability to influence environmental outcomes, compared to earlier planning stages. In effect, the most significant prevention steps can be taken during initial mine planning and design, where there are greater opportunities to mitigate negative impacts and improve operational performance (Santos et al., 2016).

### 3.2. Key Environmental Hazards

Mine abandonment and inadequate reclamation can create several environmental hazards at mine sites and in surrounding land and watersheds, as shown in Table 1. These hazards can occur either through natural processes, physical processes, or chemical processes. Many hazards are associated with heavy metals and chemical agents used in mining activities, along with degradation caused to the natural landscape. Together, these hazards contribute to varying levels of risk at mine sites, which are further determined by the terrain, commodities mined, and techniques used.

<table>
<thead>
<tr>
<th>Environmental Hazard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid Rock Drainage</td>
<td>Natural process that occurs when sulphides in rock are exposed to both air and water. Sulphuric acid is carried off the mine site by rainwater or surface drainage and deposited into nearby waterways.</td>
</tr>
<tr>
<td>Heavy Metal Contamination &amp; Leaching</td>
<td>Metals exposed by mining come into contact with water and are carried downstream as water washes over the rock surface. This process can be accelerated by acid rock drainage.</td>
</tr>
<tr>
<td>Erosion &amp; Sedimentation</td>
<td>Physical process where exposed soil carries sediment into waterways. Excessive sediment can clog riverbeds and erode watershed vegetation.</td>
</tr>
<tr>
<td>Tailings Dam Failure</td>
<td>Tailings dams contain toxic heavy metals and chemical agents such as arsenic, cyanide, or lead. When dams fail, significant quantities of tailings are discharged into the surrounding environment.</td>
</tr>
<tr>
<td>Fugitive Emissions</td>
<td>Air pollutants such as methane and carbon dioxide that are emitted from mine structures and waste piles.</td>
</tr>
<tr>
<td>Fugitive Dust</td>
<td>Particulate matter that becomes airborne and transports toxic material to soil. Dust can arise from unvegetated heaps, tailings, or restoration work.</td>
</tr>
<tr>
<td>Subsidence</td>
<td>Ground movement caused by a failure at the mine level. May cause flooding or drainage of soil, making the area unfit for reclamation.</td>
</tr>
</tbody>
</table>

Information adapted from Smith & Underwood, 2000 and Santos et al., 2016.
The greatest environmental hazard at the reclamation stage is water pollution resulting from acid rock drainage (ARD) and heavy metal and non-metal leaching (leaching). ARD can occur when mineral deposits are excavated and react with air and water to produce sulphuric acid (AGBC, 2016). While ARD is a natural process, it has the potential to severely degrade water quality and kill aquatic life (AGBC, 2016). On the other hand, leaching can occur when minerals containing heavy metals and non-metals come into contact with water and seep into the environment. The contaminants from ARD and leaching can be deposited into surrounding streams, rivers, lakes, and groundwaters, carrying significant risk to wildlife and humans (AGBC, 2016).

Planning and working to prevent ARD and leaching is an important part of mine reclamation. ARD has been identified as the largest environmental liability facing the Canadian mining industry and is estimated at $2 to $5 billion dollars (Tremblay & Hogan, 2000). In recent years, technological advances and improved mining practices have helped reduce the risks associated with ARD and leaching, but significant challenges remain (AGBC, 2016). A key challenge is the dynamic and complex nature of these chemical processes, which makes them difficult to predict (AGBC, 2016). Their occurrence and environmental impacts are also determined by a variety of factors, some of which are specific to the size, location, and characteristics of the mine (AGBC, 2016). Mining companies can mitigate the effects of ARD and leaching through effective planning and monitoring, but there is no short-term solution. A mine that is either generating, or has the potential to generate, contaminated water must be monitored indefinitely and may require perpetual water treatment (AGBC, 2016).

Mines that require water treatment carry high risk of contamination when mines are abandoned. While most mines do not require perpetual water treatment, the Auditor General of British Columbia (2016) estimates that approximately 10% of BC mines either have water treatment facilities or will require them in the future. If mining companies are unable to maintain these facilities or fulfill reclamation obligations, then the provincial government may have to assume responsibility and bear the costs. Some jurisdictions do not permit the opening and operation of mines that require long-term water treatment due to the increased environmental and financial risks they carry (AGBC, 2016). However, long-term water treatment remains a common practice in BC.
Water pollution can also occur in the event of a tailings facility failure. Tailings are a waste by-product that is contained in tailings dams or other storage facilities. These facilities are considered some of the world’s largest engineered structures and represent a disaster risk for local communities (Owen et al., 2020). If not managed properly, tailings can have long-lasting impacts on the environment and human health, along with substantial cleanup costs (International Council on Mining and Metals [ICMM], 2020). This harm is multiplied should a tailings facility fail and release high volumes of mine waste into surrounding waterways and drinking water sources (ICMM, 2020). Currently, there are 123 active tailings across the province (Independent Expert Engineering Investigation and Review Panel [IEEIRP], 2015). An expert panel of engineers have recently concluded that, based on the performance of past tailings, there will be two failures every 10 years and six every 30 years in BC (IEEIRP, 2015).

The Mount Polley Mine Disaster illustrates the environmental and financial consequences of tailings spills. In 2014, a tailings pond ruptured at the Mount Polley Mine, releasing 25 million cubic metres of tailings into nearby waterways (AGBC, 2016). The spill contained arsenic, selenium, and other heavy metals and had significant impacts on habitats, water quality, and resident fish populations (Canada’s Ecofiscal Commission, 2018). The company has undertaken remediation work following the spill and has spent over $60 million in cleanup costs (AGBC, 2016). However, the full extent of environmental damage remains unknown.

3.3. Ecological and Socio-Economic Consequences

As Table 2 illustrates below, the environmental hazards from mine abandonment or inadequate reclamation can have adverse impacts on the natural ecosystem, health and safety, the economy, community wellbeing, and cultural practices.

The direct consequences of mining projects are often ecological and affect a range of ecosystem services. Most notably, unremediated mines have the potential to contaminate critical watersheds, destroy habitats, and harm local biodiversity. This environmental damage can last decades and occur across landscapes and regions important to the provision of critical ecosystem services (Department of Environmental Affairs [DEA] et al., 2013). Of heightened concern is the damage to freshwater habitats and wetlands that support a rich biodiversity of aquatic life (Berchtold & Price, 2018). For
example, the loss of species such as salmon can have ripple effects that travel along the food chain (Metal and Diamond Mining Effluent Regulations, 2018).

Aside from ecological impacts, abandoned mines can create significant costs for surrounding communities and taxpayers. The nature of these costs includes health impacts or loss of life, financial liabilities, and economic impacts (Canada’s Ecofiscal Commissions, 2018). Health impacts from heavy metal pollution are of particular concern for local communities situated close to unremediated mines. Studies have found that exposure to toxic heavy metals such as mercury can lead to digestive disease, organ damage, cancer, and cognitive problems among children (World Health Organization, 2017). These health effects can have broader economic impacts on the healthcare system and labour productivity (World Health Organisation, 2010). Moreover, abandoned sites that pollute local waterways can lead to economic decline in commercial fishing, agriculture, and tourism industries.

Lastly, local communities in post-mining areas can experience a range of social and cultural impacts. Some examples include reduced food availability, restricted land use, and lowered visual aesthetic. Communities that rely on natural resources such as wildlife and plants for subsistence are especially vulnerable to environmental damage caused by unremediated mines. For example, damage to local flora and fauna can interfere with traditional fishing, hunting, and gathering activities of Indigenous peoples and affect the transmission of cultural knowledge that accompanies those activities (International Human Rights Clinic [IHRC], 2010). Indigenous members may also feel a spiritual connection to the land, and experience trauma when they see the environment injured by mining (IHRC, 2010). More broadly, these impacts speak to the non-material benefits that ecosystems deliver through spiritual enhancement, recreation, and aesthetic experience (Chan et al., 2012).

These findings illustrate that mine abandonment and inadequate reclamation can have far-reaching consequences in addition to environmental damage. Until mine sites are properly closed and reclaimed, their environmental and social legacies will continue to impact local communities, while financial liabilities will continue to grow.
<table>
<thead>
<tr>
<th>Category</th>
<th>Potential Impacts</th>
</tr>
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<tbody>
<tr>
<td>Ecological</td>
<td>Loss of biodiversity (wildlife, vegetation, plants)</td>
</tr>
<tr>
<td></td>
<td>Destruction and alteration of habitats</td>
</tr>
<tr>
<td></td>
<td>Decreased water, air, or soil quality</td>
</tr>
<tr>
<td></td>
<td>Increased greenhouse gas emissions</td>
</tr>
<tr>
<td>Human Health &amp; Safety</td>
<td>Illness or premature death from exposure to toxic chemicals in waterways, soil, and wildlife</td>
</tr>
<tr>
<td></td>
<td>Threatened food availability and drinking water supplies</td>
</tr>
<tr>
<td></td>
<td>Injury from unsecured sites</td>
</tr>
<tr>
<td>Economic</td>
<td>Government/taxpayer liability</td>
</tr>
<tr>
<td></td>
<td>Impacts on local economic activity (fishing, agriculture, tourism)</td>
</tr>
<tr>
<td>Social</td>
<td>Loss of future land use for productive, recreational, or other purposes</td>
</tr>
<tr>
<td></td>
<td>Impacts on aesthetic of landscape</td>
</tr>
<tr>
<td></td>
<td>Lower quality of life for local communities</td>
</tr>
<tr>
<td>Cultural</td>
<td>Loss of resources used for cultural activities, including traditional hunting and gathering</td>
</tr>
<tr>
<td></td>
<td>Cultural erosion or degradation</td>
</tr>
</tbody>
</table>
Chapter 4.  Policy and Regulatory Context

This chapter presents the policy and regulatory context for mine reclamation in BC. It includes an overview of relevant authorities and legislation in the province and highlights the pollution prevention gaps in the current reclamation regime.

4.1. Legal and Regulatory Framework

Mining activity is regulated by multiple levels of government in BC. At the federal level, the Canadian Council of Ministers of the Environment sets out guidelines for pollution prevention and contaminated sites, while the federal government contributes to the resolution of mine reclamation issues and administers the Fisheries Act, the Canadian Environmental Protection Act, and other federal legislation. Meanwhile, provincial and territorial governments are primarily responsible for mineral exploration, development, and conservation, as they own a majority of mineral rights.

British Columbia has its own mining legislation and designated ministries responsible for overseeing the mining industry. The Ministry of Energy, Mines & Petroleum Resources (EMPR) and the Ministry of Environment & Climate Change Strategy (ECCS) are the primary agencies responsible for mining operations in BC. Both ministries have environmental protection mandates and enforcement powers under provincial legislation (AGBC, 2016). The distinction is that EMPR’s responsibilities apply within the mine site, while ECCS’s responsibilities extend beyond the mine site. EMPR administers the Mines Act, issues mining and mineral exploration permits, and collects financial security deposits from mining companies. The ministry also conducts technical reviews of reclamation plans and leads enforcement and compliance activities. Meanwhile, ECCS administers the Environmental Management Act and regulates waste discharge from metal and coal mines.

Mining practices are regulated by a number of provincial statutes in BC. The Mines Act governs all mining activities from exploration to post-closure and sets out government authority in core areas such as permit issuance, monitoring, and enforcement. The Mines Act is supported by the Health, Safety and Reclamation Code for Mines in British Columbia (the Code), which sets out reclamation standards and includes provisions on environmental protection measures, water quality, and closure.
plans. The main purpose of the Code is to protect and reclaim the land and
watercourses affected by mining, and to ensure minimum environmental disturbance
from mineral and coal extraction. While these standards offer a starting point for mine
reclamation, they lack clarity to guide both industry and inspectors. Many provisions and
design standards are broadly defined in order to allow companies to develop their own
reclamation programs.

Other important provincial statutes are the *Environmental Management Act*
(EMA) and the *Environmental Assessment Act* (EAA). The EMA sets out general
environmental protection standards and regulates industrial discharge, pollution,
hazardous waste, and contaminated site remediation. It also enables the use of orders,
administrative penalties, and policy instruments to assist in achieving compliance. The
EAA provides a mechanism for reviewing major mine projects to assess their potential
effects. Major projects are evaluated for adverse environmental, economic, social, and
other impacts that may occur during the mining lifecycle.

**4.2. The Role of Pollution Prevention**

Since 2017, the Government of British Columbia has updated the Code and
introduced a broad range of regulatory reforms. These changes come in response to
recommendations provided by expert panels, the Auditor General of British Columbia,
and other third-party reports. The new reforms include a revitalized environmental
assessment process, regulations on tailings storage design, and structural changes
within EMPR. The provincial government is also developing a new financial assurance
policy, but there is no set date for its release. While the reforms improve the regulation
and oversight of the mining industry, some critical gaps remain. In particular, BC’s
reclamation regime continues to have a limited focus on pollution prevention strategies
that reduce long-term environmental risks and legacies at mine sites.

Pollution prevention is any practice that reduces, eliminates, or prevents pollution
at its source. This strategic management principle offers the opportunity to avoid or
minimize environmental damage from mining, while promoting economy and efficiency in
mine design and operation (*Environmental Law Institute [ELI], 2000*). Pollution
prevention can also contribute to better reclamation outcomes by reducing long-term
environmental risks, which in turn can lower remediation costs for mining companies and
increase the likelihood that reclamation activities will be undertaken (DEA et al., 2013). However, opportunities for pollution prevention are often not realized because government regulations tend to focus on treatment and disposal (United States Environmental Protection Agency [EPA], 2020). A number of mechanisms can promote greater pollution prevention, including mine planning, regulatory requirements, and market incentives.

The mitigation hierarchy also underlines the importance of pollution prevention. According to the mitigation hierarchy, the most effective way to protect from environmental impacts is to avoid them at the outset (Berchtold & Price, 2018). As shown in Figure 3, the hierarchy prioritizes avoiding and minimizing environmental harm first, then restoring affected areas, and finally offsetting residual impacts (Berchtold & Price, 2018). The underlying idea is that early prevention is more effective and cost-efficient than reclamation and offsets. Even with significant efforts and resources, reclamation is a limited process that can rarely replicate the diversity and complexity of the natural environment (DEA et al., 2013). It is therefore beneficial to place greater emphasis on early prevention measures, such as pollution controls, in order to achieve more sustainable reclamation outcomes. Prevention measures are often undertaken during the mine planning and design stage, and consider elements such as project location, scale, infrastructure, and technology (DEA et al., 2013).

Figure 3. The Mitigation Hierarchy
Definitions adapted from the Biodiversity Consultancy, 2015.
BC’s current policy framework has some provisions for pollution prevention, but they are limited in practice. Many provincial regulations provide general guidelines for industry, instead of mandating specific pollution prevention measures or incentivizing companies to adopt more sustainable options. For example, mining companies are required to consider best available technology for tailings facilities under the revised Code. Despite this, at least four large mining projects in BC have chosen to adopt the same tailings facility design used at Mount Polley (Berchtold & Price, 2018). In addition, the provincial government does not provide clear design standards for tailings dams and continues to permit mines in areas with high ARD and leaching potential (AGBC, 2016).

The lack of detailed technology or performance standards in BC are coupled with a lack of innovation incentives, which play a central role in integrating pollution prevention into mining practices. Recent reports have found that the Canadian mining industry has a low research and development (R&D) intensity and that it continues to underinvest in technology and innovation (Science, Technology and Innovation Council, 2014). At the same time, streamlined funding for mining innovation remains limited and is primarily targeted at energy efficiency. BC has recently introduced the Innovate Ignite Program that provides up to $300,000 to fund innovation projects in natural resources, applied sciences, and/or engineering (Innovate BC, 2018). However, the program has a broad focus and is not specifically tailored to mining activities.

Given the high environmental and socio-economic costs of inadequate mine reclamation, it is critical that BC explores stronger prevention strategies and safeguards. Effective mine planning and design can help prevent or minimize some of mining’s greatest environmental legacies, including ARD and tailings dam breaches. The following chapters will explore pollution prevention opportunities for the BC mining industry in more detail.
Chapter 5. Policy Problem and Stakeholders

My policy problem is British Columbia’s mining regime lacks early prevention measures to ensure sustainable and effective mine reclamation, leading to several cases where mines have been abandoned or inadequately reclaimed. This poses a long-term risk to the environment and surrounding communities, and can lead to adverse impacts on biodiversity, ecosystem services, and water quality. Unremediated mines also impose significant costs on communities and taxpayers, whether through financial liabilities or impacts on health and cultural wellbeing. Given these implications, there is a pressing need for stronger pollution prevention measures at the mine planning stage to help ensure the sustainability of current and future mining projects.

There are two key stakeholders to consider for this policy problem. The first is local communities situated close to mining operations, particularly remote and Indigenous communities. Proximity to mines makes these communities more likely to be directly impacted by environmental degradation and experience negative externalities such as health impacts, loss of productive land, and reductions in ecosystem benefits. Mining activities can also interfere with the traditional ways of life of Indigenous peoples and threaten the livelihood of communities that depend on healthy fisheries. The other stakeholder is the mining industry, which undertakes mineral exploration and extraction in the province and engages directly with local communities and several levels of government. This stakeholder group is subject to legal requirements and will likely experience financial or other impacts from government policies.
Chapter 6. Analytical Methodology

This study has two methodologies. The primary methodology is a multiple case study analysis, which includes an analysis of regulatory standards, policies, and programs in other jurisdictions. The research objective is to evaluate best practices in mine reclamation and identify potential policy options for BC’s mining industry. The analysis focuses primarily on pollution prevention practices adopted in mine planning and design that prevent or minimize long-term environmental risks from mining. This portion of the analysis is supported by academic literature, government sources, and grey literature. The secondary methodology uses evidence from the existing literature to augment and confirm the findings.

6.1. Case Study Selection

The case study analysis covers Australia, Chile, and the United States. This analysis focuses on the national level rather than state level, as the mining industry is often subject to an array of federal and state policies. In addition, a national focus allows me to look at best practices across multiple states and highlight the most effective ones.

The three countries have been selected because they have established mine reclamation programs that incorporate pollution prevention measures or mitigation strategies for long-term environmental risk. These cases are also top mining producers and rank highly on several environmental indexes, including the Environmental Performance Index and the Resource Governance Index. Australia and the US both have extensive mining histories and are considered leaders in mining regulations. Meanwhile, Chile is an emerging mining jurisdiction where sustainable efforts have notably improved mining standards in the past two decades. Each case is assessed based on its pollution prevention practices, particularly ones that promote integrated mine planning and sustainable technologies.

6.2. Evaluation Framework

The evaluation framework is based on literature on effective mine reclamation and pollution prevention. Characteristics have been adapted from a framework on
pollution prevention for mining (ELI, 2000) and a sustainable mining sourcebook that outlines regulatory and participatory tools for environmental protection (UNDP & UNEP, 2018). As shown in Table 3, the four major dimensions evaluated are project planning, regulatory requirements, public participation, and market-based instruments (MBIs).

The four dimensions were selected for several reasons. First, project planning processes are important tools for environmental management that allow environmental controls and mitigation measures to be established for mining projects (ELI, 2000). These processes include environmental assessments (EAs), as well as closure plans and permits. Second, regulatory requirements are a core legal mechanism that enforces pollution prevention practices in the mining industry. Regulations can set limits on pollution emissions or prescribe specific mine design techniques and performance standards. Third, public participation is important as it provides entry points into the mining project and can lead to decisions that are more sustainable, transparent, and equitable (Ghorbani & Kuan, 2017). Modes of public engagement can range from information-sharing to consultation and collaboration (UNDP & UNEP, 2018). Fourth, market-based instruments are an alternative to traditional regulatory approaches that can incentivize companies to adopt greener technologies and make use of innovative practices (UNDP & UNEP, 2018).

Table 3. Evaluation Framework

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Characteristics</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Planning</td>
<td>Environmental Assessments (EAs)</td>
<td>Do EAs incorporate pollution prevention and/or cumulative effects into the project evaluation?</td>
</tr>
<tr>
<td></td>
<td>Closure Plans &amp; Permits</td>
<td>Are companies required to address pollution or environmental risks in their reclamation/closure plans or mining permits?</td>
</tr>
<tr>
<td>Regulatory Requirements</td>
<td>Regulations</td>
<td>Do mining regulations prescribe the use of pollution prevention measures or require certain technology or performance standards?</td>
</tr>
<tr>
<td>Public Participation</td>
<td>Participation in Decision Making</td>
<td>Are there opportunities for citizens and non-governmental organizations to participate in decision-making processes?</td>
</tr>
<tr>
<td>Market-Based Instruments</td>
<td>Economic or Other Instruments</td>
<td>Are there market-based instruments in place that encourage mining companies to adopt more sustainable technologies or to innovate?</td>
</tr>
</tbody>
</table>
6.3. Limitations

This study had several limitations that restricted its scope and findings. First, the case study design focused on policy instruments that would have direct effects on pollution prevention and long-term environmental impacts, and as such, it did not explore a broad range of options. Future research may wish to explore instruments such as legal liability, land use restrictions, disclosure requirements, and performance bonds. Second, the scope was restricted to early interventions at the mine planning stage, rather than ones that are implemented during the reclamation stage. Further research on reclamation-specific interventions would complement the recommendations in this study (e.g., monitoring and inspections, performance evaluations, and rehabilitation funds). Third, although primary data is accessible through government websites and reports, finding specific pollution prevention programs was difficult. Secondary sources such as academic literature and grey literature were used to fill the gaps; however, these sources did not always provide the most up-to-date information. I cross-referenced with government websites where possible, but this remains a limitation. Fourth, Chile’s regulations and ministry websites were predominately in Spanish, so there was a stronger reliance on English sources for this case, restricting the breadth of this research. Finally, the lack of performance indicators on mine reclamation and pollution prevention made it difficult to evaluate the effectiveness of policy instruments. As such, I had to rely on the literature to estimate their performance.
Chapter 7. Case Study Analysis

This chapter presents the analysis for each dimension across the three cases. Key findings are summarized in Table 4 at the end of the chapter. Characteristics that are present in all jurisdictions are compared to the existing policy framework in BC and then further examined in the secondary analysis.

7.1. Project Planning

7.1.1. Environmental Assessments

Australia has EA regimes at the federal, state, and territory level that aim to improve environmental outcomes. A leading jurisdiction is Western Australia, which has adopted innovative approaches in its EA process. The state promotes risk-based EAs that employ environmental risk analysis throughout all stages of the evaluation process (Macintosh, 2010a). Mining companies are also encouraged to use strategic environmental assessments (SEAs) to evaluate cumulative project impacts (Macintosh, 2010a). SEAs have a broader focus than individual project EAs, as they assess multiple development proposals through a regional perspective. The process is currently voluntary in Western Australia, but it is appealing to companies with multiple mining projects, as it reduces their need to obtain EAs later on (Arnold & Hanna, 2017).

In Chile, environmental impact assessments (EIAs) are an important tool for pollution prevention. Mining companies must either submit an Environmental Impact Study for projects with major impacts on natural resources or landscapes, or an Environmental Impact Statement for projects with smaller effects. Chile’s environmental review process requires project proponents to develop broad pollution prevention measures and include a plan to reduce or counteract environmental risks or harms (ELI, 2000). However, while prevention measures must be specifically outlined in EIAs, they do not specify what mitigation or monitoring activities are required (ELI, 2000).

The US is a pioneer in the mine approvals process, being the first country to introduce EIAs. Under the National Environmental Policy Act (NEPA), an environmental impact statement must be prepared for mining projects that have the potential to significantly affect the environment (ELI, 2000). During the process, federal agencies
must assess the feasibility and impacts of a range of alternatives, rather than simply the proposed action (EPA, 2017). Recent regulations also require government agencies to publish a record of its decision and consider a project’s cumulative and indirect impacts (Moorman et al., 2020). While NEPA has a limited focus on pollution prevention, the EPA provides guidance on incorporating pollution prevention into the environmental review process for mining projects.

7.1.2. Closure Plans & Permits

Australia has pollution prevention provisions integrated into the planning process. Over the past two decades, the Government of Australia has established a national strategy and handbook on mine closure that underline the importance of preventing long-term environmental damage (Roche & Judd, 2016). Alongside the national framework, states and territories have mine closure policies that require companies to develop rehabilitation plans for approval (Mining, Minerals and Sustainable Development, 2002). For example, Western Australia’s Guidelines for Preparing Mine Closure Plans has key principles that recommend early mine planning and a risk-based approach that considers long-term stability of mine infrastructure and landforms, public safety, and environmental risks to nearby ecosystems (Environmental Protection Authority of Western Australia & Department of Mines and Petroleum, 2015). Mining companies are also encouraged to undertake progressive reclamation where possible and to focus on preventing and minimizing ARD (Environmental Protection Authority of Western Australia & Department of Mines and Petroleum, 2015). Despite the emphasis on mine planning, some Australian mines still lack appropriate closure plans (Roche & Judd, 2016).

Chile sets requirements for pollution prevention in closure plans and environmental permits. In 2011, Chile introduced new legislation that increased requirements for mine closure, stating that closure plans are expected to include a risk evaluation and environmental commitments for the closure phase. The core idea behind this legislation is that mine closure should be implemented progressively and reduce environmental and health hazards where possible. Mining companies must also deliver a management plan for authorization to start building tailings facilities or waste piles. In addition, Chile has a number of environmental permits that are required for operations in certain protected areas, watershed zones, or within city limits (ELI, 2000).
In the US, states with significant mining operations require closure plans and some contain pollution prevention provisions (ELI, 2000). According to Danielson & Nixon (1999), the US experience with closure planning has been positive in most respects, with significant environmental benefits achieved through advanced planning and pollution prevention techniques. In most states, mining companies are required to design their operations in a way that minimizes environmental risks, such as tailing dam leakages or failures (Thomashausen et al., 2018). These requirements range from engineering plans for wastewater disposal to specific permits for tailings facilities. However, while many federal and state permits set guidelines for pollution control, few require pollution prevention measures (ELI, 2000).

7.2. Regulatory Requirements

Australia has several regulations that target pollution prevention at mine sites. While regulatory requirements may vary between states, there are common principles that apply for tailings deposition and management, pollution control, and water discharge (Australian Government, 2016). In Western Australia, mining companies are required to undertake a rigorous design process for tailings storage facilities. To support this, the Department of Mines, Industry Regulation and Safety (2019a) has developed a code of practice that defines outcomes for tailings storage facilities, variables to demonstrate that facilities are stable and non-polluting, and a recommended hazard management process. In particular, the code provides a systematic method of classifying the adequacy of tailings storage facilities under normal and worst-case scenarios. Tailings storage facilities are ranked according to three categories and facilities with potential to cause prolonged or permanent environmental damage require regular inspection and auditing (Department of Mines, Industry Regulation and Safety, 2019b).

Chile has regulations that promote pollution prevention in tailings management. Since 1970, the Chilean government has enacted two core regulations on tailings deposits. The first was Supreme Decree No. 86, which established geotechnical requirements for the design and construction of tailings facilities. Although tailings practices improved under this regulation, some deficiencies remained, and a new decree was enacted in 2007 (Villavicencio et al., 2014). Supreme Decree No. 248 establishes a series of new requirements and safeguards that improve the design and operation of tailings facilities. For example, the regulation prohibits tailings dams constructed using
the upstream method and introduces new requirements for monitoring, stability analysis, and emergency planning (Villavicencio et al., 2014).

The US has regulations that set pollution prevention requirements for mining activities, with varying levels of specificity in design and performance standards. Federal regulations cover broad areas such as water pollution, dust emissions, chemicals, and hazardous waste. Regulatory standards for pollution prevention are also developed by state agencies (American Geosciences Institute, 2020). Some states, such as Arizona, rely heavily on performance standards and best available demonstrated controlled technology (BADCT) for the design and maintenance of mining facilities. Arizona’s BADCT requirements include a rigorous six-step process where applicants must select the mine design with the lowest estimated pollution (ELI, 2000). Meanwhile, states like Colorado and Wisconsin have taken a strict approach to water pollution and do not allow mining operations that require long-term water treatment (AGBC, 2016).

7.3. Public Participation

Australia encourages public participation throughout the mining lifecycle. At the planning and approval stage, the EIA process provides a forum for the public to participate in decision-making. Mine closure plans and environmental management plans (EMPs) may also be subject to public review, and some Australian states require that mining companies provide a formal response to public submissions (Arnold & Hanna, 2017). In Western Australia, the closure plan and EMP are ‘living documents’ that can be periodically reviewed and include ongoing participation with affected stakeholders (Arnold & Hanna, 2017). Some states also have requirements to form a Community Consultative Committee, which ensures that community and stakeholder groups are consulted on the development of mining projects (Kabir et al., 2015). Despite Australia’s efforts to improve public participation, environmental groups and the general public have expressed frustration in their ability to meaningfully influence decision-making processes and project outcomes (Macintosh, 2010a).

In Chile, the EIA process allows organizations and individual citizens to provide comments up to 60 days following the publication of an EIA in the official government record (ELI, 2000). Environmental councils reviewing EIAs must take public comments into consideration and notify public interest groups of their observations (ELI, 2000).
Notice of water applications must also be announced in local newspapers and the radio, so that citizens with objections can contest the application (Thomashausen et al., 2018). While there is some public participation in Chile, there have been calls for an approach that is closer to local communities and allows for more meaningful engagement. Lostarnau et al. (2011) suggest that the commentary period should be extended and given greater weight in the final project design.

US law has provisions that enhance public participation in environmental protection. The EIA process provides an opportunity for written comments from the public and government agencies are generally required to consider such comments (ELI, 2000). Public participation in the US is also supported by information sharing and legal mechanisms. Most of the major environmental statutes, including those governing pollution, allow individuals or non-profit groups to bring citizen suits against polluters alleged to have violated the statute (ELI, 2000). Citizen suits have improved the enforcement of environmental laws in the US and remain an important component of modern environment law. However, the future of civil litigation remains uncertain under the current political climate (Adelman & Glicksman, 2019).

### 7.4. Market-Based Instruments

Australia provides a range of MBIs for mining companies that promote innovation. This includes tax incentives, infrastructure support, and reclamation requirements through the tax system (Cowan et al., 2010). A key mechanism is the R&D incentive, which offers a tax offset up to $4 million per annum for companies investing in eligible R&D projects (Deloitte, 2019). The Australian Government also provides innovation funding through CSIRO, a national science agency, and recently announced $50 million in funding for the mining and resources sector to help manage future industry challenges (Ministers for the Department of Industry, Science, Energy and Resources, 2018). Despite the presence of several funding initiatives, Australia has relatively weak innovation outcomes compared to other counties and performs poorly in translating research into commercial outcomes (Koutsogeorgopoulou & Park, 2017).

Chile offers a variety of MBIs for mining innovation, including a tax credit for R&D expenditures and funding programs. A key innovation driver in the country is the National Council on Innovation and Competitiveness, which has three large funding
programs allocated to science, technology, and innovation (IGF, 2018). The funding tools are financed though mining royalties and support other government agencies, including the Comisión Nacional de Investigación Científica y Tecnológica (CONICYT) (IGF, 2018). This agency is responsible for the promotion of science and technology in Chile and funds private sector research in mining and other priority areas (Mullin et al., 2000). Although Chile has achieved higher levels of innovation in recent years, it underperforms in technology transfer and commercialization (Simpson et al., 2014). More emphasis is given to basic research rather than commercial-oriented research, and there is limited investment in internal R&D (Simpson et al., 2014). Commercial mining solutions are also more often focused on digital technologies and occupational safety than environmental impact demands and tailings (Fundación Chile, 2019).

The US has limited MBIs targeted at mining innovation, particularly at the national level. One source of federal funding is the Advanced Manufacturing Office in the Department of Energy, which provides cost-sharing for innovative technology R&D. The federal government also provides a non-refundable tax credit for research expenses that are incurred in the country (Expande Mineria, 2019). Aside from federal programs, several states provide research grants for mining technologies and mine-waste remediation (National Research Council, 2002). However, despite the presence of several innovation hubs and research institutes in the country, direct funding by the US government is relatively small and unfocused (National Research Council, 2002).

7.5. Analysis of Key Findings

As illustrated in Table 4 below, the analysis reveals that all characteristics are present in the three cases. Where the cases vary is in the degree to which pollution prevention is integrated into the different characteristics, as well as the type of policy approach adopted by each jurisdiction. For example, some characteristics have clear, direct pollution prevention goals or requirements, while others have indirect measures.
### Table 4. Summary of Case Study Findings

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Characteristic</th>
<th>Australia</th>
<th>Chile</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Planning</td>
<td>Environmental Assessments (EAs)</td>
<td>Yes - EA includes risk analysis &amp; cumulative impacts</td>
<td>Yes - EA has broad pollution prevention measures</td>
<td>Yes - EA includes range of alternatives &amp; cumulative impacts</td>
</tr>
<tr>
<td></td>
<td>Closure Plans &amp; Permits</td>
<td>Yes - closure plans w/ risk-based approach</td>
<td>Yes - closure plans w/ risk evaluations, permits for protected areas</td>
<td>Yes - closure plans designed to minimize risks, permits for tailings facilities</td>
</tr>
<tr>
<td>Regulatory Requirements</td>
<td>Regulations</td>
<td>Yes - regulations &amp; code of practice on tailings facilities</td>
<td>Yes - regulations on tailings facilities</td>
<td>Yes - regulations on BADCT &amp; perpetual water treatment</td>
</tr>
<tr>
<td>Public Participation</td>
<td>Participation in Decision Making</td>
<td>Yes - in EA &amp; mine planning process</td>
<td>Yes - in EA process &amp; public notices</td>
<td>Yes - in EA process, info-sharing &amp; legal mechanisms</td>
</tr>
<tr>
<td>Market-Based Instruments</td>
<td>Economic or other Instruments</td>
<td>Yes - tax credit, funding programs &amp; other support</td>
<td>Yes - tax credit &amp; funding programs</td>
<td>Yes - cost-sharing program, tax credit &amp; funding programs</td>
</tr>
</tbody>
</table>

The strongest and most direct pollution prevention measures are observed in mining regulations and environmental assessments, followed by closure plans and permits. The analysis reveals that countries have a range of regulations that target pollution prevention, including safeguards and requirements for tailings facilities, performance standards, and restrictions on perpetual water treatment. Countries also have pollution prevention embedded within the EA process, either through specific provisions, evaluations of cumulative project impacts, or risk analysis. In some cases, the planning process indirectly contributes to pollution prevention through risk-based approaches adopted in closure plans or special permits for mine facilities.

Meanwhile, there are moderate market-based instruments and limited public participation observed in the cases. Each country offers a variety of MBIs that encourage technological advancement and R&D in the mining industry, including tax credits and government grants. Despite the presence of MBIs, market support for innovation remains small and unfocused in some cases, with challenges around translating research into commercial outcomes. Public participation is also widely encouraged in the EA process; however, public input is generally given little weight in decision-making.
Applicability of Findings to BC

Each of the characteristics are present in BC, but the extent to which pollution prevention is clearly defined and required is limited. Under BC’s existing regulations, mining companies are encouraged to develop a policy statement with commitments to focus on pollution prevention, implement a site-specific pollution plan, and integrate progressive reclamation into their closure plan. Companies must also consider best available technology for tailings facilities and establish their own independent review panel to advise on tailings operations. However, many of these practices are treated as guidelines and do not outline specific pollution prevention provisions, such as technology or performance-based standards. In addition, the provincial government only provides broad innovation funding for the natural resources sector and does not offer specific incentives for mining innovation.

With respect to project planning, BC has a well-established EA process that provides opportunities for pollution prevention and public participation. In 2018, BC’s Environmental Assessment Act was revised with new rules surrounding project notification, early engagement, and increased public participation. In particular, the revised act requires the establishment of one or more Community Advisory Committees and provides practical tools for recognizing the jurisdiction of Indigenous Nations. While the new EA process enhances public participation, it still has some shortcomings with respect to pollution prevention. Environmental assessments often occur on a reactive and project-to-project basis, while cumulative impacts are rarely accounted for. Based on these conclusions, the secondary analysis will further explore opportunities for pollution prevention in three key areas: project planning, regulatory requirements, and market-based instruments.
Chapter 8. Secondary Methodology

For the secondary methodology, empirical studies and technical reports are used to assess the effectiveness of policy instruments identified in the case study analysis. The three variables evaluated are project planning, regulatory requirements, and market-based instruments. These policy instruments are selected because they are present in all three jurisdictions and have limited application in BC’s policy framework.

8.1. Project Planning

Project planning is an integral part of pollution prevention and allows for the integration of concrete actions to prevent or mitigate environmental impacts from mining. The literature has made explicit linkages between project planning tools and enhanced environmental protection, highlighting the importance of early prevention measures (Arnold & Hanna, 2017). There are many different planning tools available; however, the most widely adopted ones are EAs and closure plans. EAs are a decision-making mechanism that provides proponents, government regulators, and the public with knowledge on project impacts and performance (Arnold & Hanna, 2017). This process enhances mine planning by identifying opportunities to mitigate or eliminate adverse impacts before a project begins. Fully integrated closure plans also enable companies to make better decisions in areas such as geotechnical, geochemical, and water quality in order to reduce long-term environmental risks (Doig, 2016).

In the mid-1990s, a major international review of the effectiveness of EAs was conducted and demonstrated a wide range of benefits (UNEP, 2004). Although the benefits did not occur uniformly, many jurisdictions experienced more environmentally sensitive decisions and reduced environmental damage (UNEP, 2004). Other studies have also evaluated how EAs promote environmental outcomes and identified a range of potential benefits. Most of the studies attribute improved outcomes to the EA’s ability to deliver high quality information on project impacts and to facilitate greater information exchange between all parties (Macintosh, 2010a). Closure plans have not undergone the same kind of performance evaluation as EAs, but a recent study of eight mining jurisdictions identified environmental benefits from this planning tool (Morrison-Saunders et al., 2016).
While EAs continue to be an important planning tool, international literature has raised questions about their ability to directly improve environmental outcomes. According to some theorists, the EA process is inherently subjective, and the information provided has a limited impact on decision-making (Macintosh, 2010a). International research on EAs supports these observations and has found modest influence on project outcomes and small changes in design (Cashmore et al., 2008). In a survey on Australia’s EA regime, 62% of respondents reported that the process did not improve the environmental outcomes of their project, while only 11% reported significant improvements (Macintosh, 2010b). However, some studies have found that EA regimes generate indirect impacts through stakeholder participation and the promotion of environmental values (Jay et al., 2007; Macintosh, 2010a). This indicates that EAs are a necessary part of project planning and yield far-reaching benefits, but they may be insufficient to ensure environmental protection.

### 8.2. Regulatory Requirements

Regulations can be an effective tool for pollution prevention by prescribing the use of mining techniques or technologies. This can be achieved through either technology standards or performance-based standards. Both types of standards encourage mining companies to reduce the release of harmful pollutants and lower the risk of environmental damage (EPA, 2018). Aside from providing technical and operational guidance to industry, regulations enhance environmental protection in many other ways. In some instances, for example, compliance with regulations can spur innovation and prompt companies to develop new technology or invest in R&D (Sustainable Prosperity, 2015). Regulations also provide a yardstick to government regulators, companies, and the general public to know what pollution prevention measures are required and whether they are being met (Organisation for Economic Co-operation and Development [OECD], 2000).

A recent study by the Cowles Foundation for Research in Economics demonstrates the effectiveness of regulations in emissions reduction in the US (Williamson, 2016). The study found that changes in environmental regulations beginning in 1990 accounted for most of the air emissions reductions in the following 20 years (Williamson, 2016). More specifically, the economic model found that environmental regulations were largely responsible for the observed 60 percent
decrease in manufacturing emissions from 1990 to 2008, a period during which manufacturing output had increased (Williamson, 2016). Regulations have also been cited as a primary reason for behavioural change in the private sector. In a survey by KPMG Management Consultants (1996), 90% of businesses and municipalities surveyed stated that their primary motivation for establishing environmental management systems was compliance with regulations.

At the same time, regulations have disadvantages that may reduce the overall effectiveness of pollution prevention. With prescriptive regulations, companies are encouraged to only reduce pollution to a regulated level, and sometimes this level is not high enough to achieve the desired environmental outcome (EPA, 2018). Certain types of regulations may also inhibit innovation and provide limited incentives to explore new technologies or production processes (EPA & National Center for Environmental Economics [NCEE], 2010). In addition, regulations may have enforcement and compliance issues that undermine regulatory outcomes and lead to uneven application (EPA & NCEE, 2010). Regulations generally place a higher burden on government agencies to monitor and enforce industries, which can be challenging if the agency lacks the capacity to do so (EPA & NCEE, 2010). Nevertheless, regulations remain a core instrument for pollution prevention and environmental protection.

8.3. Market-Based Instruments

Market-based instruments are becoming increasingly popular tools for environmental management and pollution prevention. These instruments influence industry behaviour through economic or other incentives that encourage companies to reduce their pollution levels and improve environmental performance (EPA, 2018). MBIs are also widely used to encourage innovation and investment in more sustainable technologies by industry (Calel, 2011). Some economists favour market-based policies over traditional command-and-control policies because they are generally more cost-efficient and place lower regulatory burden on government (EPA & NCEE, 2010). Other cited advantages are that they improve price signals and allow companies to have greater flexibility in meeting environmental objectives (EPA & NCEE, 2010). Examples of MBIs include marketable permit systems, environmental taxes or charges, and subsidies.
A growing body of empirical work has examined the effectiveness of MBIs in environmental management. In particular, MBIs have been important in accelerating new technologies for renewable energy and reducing point-source pollution (European Environment Agency [EEA], 2005; Henderson, 2010). In the Netherlands, wastewater effluent charges had an incentive effect on industrial water polluters and were responsible for half of the 90% reduction in water pollution across 14 industries over a six-year period (EEA, 2005). European Union subsidies have also helped build infrastructure for wastewater treatment plants, while air pollution charges have stimulated pollution abatement in countries such as Sweden (EEA, 2005). Aside from these cases, there are other areas in which MBIs have provided environmental benefits, including acid rain, clean fuels, and fisheries (EEA, 2005).

Although MBIs offer incentives for companies to improve environmental performance, they have some drawbacks as well. Aside from tradeable permits, most MBIs do not guarantee a given environmental outcome or performance level, which may lead to lower environmental effectiveness than regulations (EEA, 2005). International case studies confirm this observation and show mixed results in effectiveness, particularly for non-point source pollution and biodiversity management (Henderson 2010). Certain instruments may also have perverse effects and increase environmental harm, thereby undermining environmental objectives (EEA, 2005). Lastly, MBIs often require ongoing monitoring and require charges/taxes to be set at the optimal level, which can be difficult for governments to determine (EEA, 2005). Nevertheless, this policy instrument is becoming more widely adopted across the world and is considered a more cost-efficient alternative to prescriptive regulations.

In summary, regulations and market-based instruments are found to be the most promising practices to target pollution prevention at mines and improve reclamation outcomes. Each of these inform the policy options presented in the next chapter.
Chapter 9. Policy Objectives, Criteria, and Options

There are three primary objectives at the core of the analysis. The first is to improve mine reclamation outcomes in British Columbia and to return affected areas, as near as possible, to a safe and environmentally sound state. The second is to ensure the protection and conservation of BC’s natural resources, including habitats and watersheds of ecological and cultural importance. The third is to support a more sustainable mining industry that promotes world-class practices and innovation.

This policy analysis focuses on short- and long-term options to integrate pollution prevention into mining practices. As mentioned in Chapter 4, pollution prevention is an important factor in reducing long-term environmental risks at mine sites. Reclamation is a complex and long process, but early planning and prevention strategies can improve reclamation outcomes and reduce negative impacts on the environment and local communities. This may require greater upfront investment and capital expenditures by industry, but it can also lead to cost-savings at the reclamation stage. Adopting pollution prevention measures may also bring greater stability and sustainability to the mining industry, by better reflecting the true costs of mining.

9.1. Evaluation Criteria

This section outlines the criteria and measures used to assess the policy options considered in this study. The goal of evaluating policy options is to identify their relative strengths and trade-offs in order to determine the most favourable policy for the BC mining industry. The four criteria are: effectiveness, cost, administrative ease, and stakeholder acceptance. Each criterion has measures that correspond to a numerical score between 1 and 3, with 3 being the highest score yielding positive results and 1 being the lowest score. Criteria with multiple measures are divided to ensure that they have the same weight as other measures. Effectiveness is not divided, however, as it is a principle consideration that corresponds to the main policy objectives. Each policy option is then evaluated and receives a score under each criterion, with the highest total score indicating the most favourable policy. Information for the evaluation is obtained from the literature, case studies, and secondary analysis. Table 5 provides a summary of the criteria and measures used in the policy analysis.
Table 5. Criteria and Measures Matrix

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Definition</th>
<th>Measure</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Effectiveness</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reclamation outcomes</td>
<td>Extent to which policy will promote improved mine reclamation outcomes</td>
<td>Significant improvement</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moderate improvement</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Little to no improvement</td>
<td>1</td>
</tr>
<tr>
<td>Behavioural change</td>
<td>Extent to which policy will change behavior of mining companies toward more sustainable outcomes</td>
<td>Strong behavioural change</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moderate behavioural change</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weak behavioural change</td>
<td>1</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost to government</td>
<td>Average annual cost to the provincial government</td>
<td>Less than $1 million</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$1 to $3 million</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>More than $3 million</td>
<td>1</td>
</tr>
<tr>
<td><strong>Administrative Ease</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of implementation</td>
<td>Ease of implementing policy based on changes to existing policy framework, government practices, and intergovernmental coordination</td>
<td>Easy to implement</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moderate to implement</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Difficult to implement</td>
<td>1</td>
</tr>
<tr>
<td><strong>Stakeholder Acceptance</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local communities</td>
<td>Extent to which policy will be accepted by local communities</td>
<td>Support</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neutral</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oppose</td>
<td>1</td>
</tr>
<tr>
<td>Mining industry</td>
<td>Extent to which policy will be accepted by the mining industry</td>
<td>Support</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neutral</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oppose</td>
<td>1</td>
</tr>
<tr>
<td>Stakeholder Total /2 = Score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL SCORE /15</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9.1.1. Effectiveness

The effectiveness criterion provides an estimate of the policy option’s performance with respect to two dimensions: reclamation outcomes and behavioural change. The first dimension is improved reclamation outcomes. Policies are evaluated based on their potential to prevent or minimize long-term environmental risks that arise at the reclamation stage, such as ARD or tailings facility failures. If the policy is expected to significantly improve reclamation outcomes across the majority of mine sites, it receives a 3. Moderate improvement at some mine sites receives a 2 and little or no improvement receives a 1.

Second, this criterion also evaluates the extent to which the policy promotes positive behavioural change among mining companies. That is, does the policy provide incentives for mining companies to reduce the risk of pollution and environmental harm
and to engage in environmentally responsible behaviour? If the policy is expected to strongly influence the behaviour of mining companies, it receives a 3. Moderate behavioural change receives a 2 and weak behavioural change receives a 1.

9.1.2. Cost

The cost criterion evaluates the budgetary impact of the policy option. This is measured in terms of average annual cost to the provincial government in dollar value, including the cost of policy administration and enforcement. In 2018, the provincial government committed $2 million to meet regulatory requirements at tailings storage facilities at abandoned mines. This serves as a proxy for the provincial government’s willingness to spend on similar programs and provides a mid-range benchmark for annual budgetary costs. If the policy is expected to cost less than $1 million per year, it receives a 3. Annual costs between $1 million and $3 million receive a 2 and annual costs over $3 million receive a 1.

9.1.3. Administrative Ease

The administrative ease criterion examines the ease of implementing the policy option. This criterion considers the level of changes required to the existing policy framework and government practices, along with the need for intergovernmental coordination. If the policy is easy to implement and does not require intergovernmental coordination, it receives a 3, while some difficulty in implementation and coordination receives a 2, and a lot of difficulty and coordination receives a 1.

9.1.4. Stakeholder Acceptance

The stakeholder acceptance criterion evaluates the extent to which the policy will be accepted by relevant stakeholder groups. As identified in Chapter 5, the key stakeholder groups are local communities situated close to mine sites and the mining industry. This criterion is measured by examining academic and news sources for evidence of acceptability by stakeholder groups. Mining industry acceptance incorporates compliance costs and other considerations such as reputational impacts. Compliance costs refer to all expenses that mining companies incur to adhere to policy requirements, including costs associated with implementation, administration, and
If a policy receives broad support from a stakeholder group, it receives a 3. Neutrality towards a policy receives a 2, while opposition receives a 1.

9.2. Policy Options

There are three policy options that emerged from the case study analysis and secondary analysis. These include regulations on perpetual water treatment and tailings facilities, as well as market-based instruments for mining innovation. The options all contain elements of pollution prevention, as this has been the focus of my study.

9.2.1. Option 1: Prohibit Mines with Perpetual Water Treatment

The first policy option is to prohibit mining operations that will likely require perpetual water treatment. As mentioned previously, mines that require water treatment in perpetuity pose an ongoing risk to local communities and create a financial risk for the provincial government and taxpayers (AGBC, 2016). These risks continue long after the mine has closed and if water treatment ceases, serious environment damage could occur. The Tulsequah Chief case is illustrative of the long-term environmental legacies of mining and the dangers of ARD. The mine ceased operations in 1957 and continues to pollute the Taku watershed today. Prohibiting mining projects with perpetual water treatment could therefore help minimize environmental and financial risks at the reclamation and post-closure stages. This has been recognized in mine reclamation guidelines in other jurisdictions such as the Northwest Territories, and has been adopted in legislation by Manitoba, the Yukon, Colorado, and Wisconsin (AGBC, 2016).

This policy option would only apply to new and proposed mining projects currently in the exploration, permitting, or environmental assessment stage. The regulatory approach is adopted from the IRMA Standards for Responsible Mining and provides some flexibility for industry in strictly defined circumstances. Reliance on perpetual water treatment would only be permitted if: (1) the untreated water poses no significant risk to nearby communities, waterways, or critical habitats, (2) the company has made all reasonable efforts to reduce the volume of water treated, and (3) the company provides full financial assurance upfront to cover the costs of water treatment. Under this option, mining projects would undergo extensive evaluation of site selection and facility design, as well as a characterisation of ARD and leaching potential. The
approval process would be integrated into BC’s Environmental Assessment Process and subject to approval and oversight by the Ministry of Energy, Mines and Petroleum Resources.

9.2.2. Option 2: Strengthen Regulations on Tailings Storage Facilities

The second policy option is to strengthen regulations on tailings storage facilities. More specifically, this option establishes a phased approach to eliminate the use of wet tailings storage at new mines in BC. In the wake of the Mount Polley mining disaster and other international cases, industry experts have recommended that BC move to safer ways of storing tailings (IEEIRP, 2015). In 2018, the provincial government implemented regulations that encourage mining companies to consider best available technology for tailings facilities and establish an Independent Tailings Review Board. Despite the changes, four large mining projects have proposed to use the same wet tailings approach as Mount Polley (Berchtold & Price, 2018). Alternative options, such as dry stacking or thickened tailings, could provide a safer way of storing tailings that reduces long-term environmental risks and enables progressive reclamation throughout the mining lifecycle.

Under the phased approach, new mining projects would have to incorporate best available technology for tailings storage using alternatives to wet tailings facilities. Mining companies would only be permitted to adopt wet tailings impoundments in instances where it can be demonstrated in a risk assessment that a wet tailing approach poses less long-term risk to the environment and public safety than thickened or filtered tailings. Financial risks may be considered, but cost should not be a determining factor, as recommended by the Mount Polley Expert Panel. For existing tailings impoundments, operators will be encouraged to adopt best available practices for the remaining active life and adopt dry closure when mining operations cease.

9.2.3. Option 3: Introduce Funding Program for Mining Innovation

The third policy option is to introduce a provincial funding program for the research and development of mining technologies aimed at pollution prevention. As previously mentioned, the mining industry continues to underinvest in innovation and technology (Stano, 2012). This funding program can help address some of the barriers
to innovation and provide support for companies engaging in R&D activities. Building a culture of innovation in the mining industry is not only important for minimizing long-term risks associated with the design, operation, and closure of mine sites, but also for addressing future challenges associated with climate change and lower grade ores. Presently, BC has limited funding opportunities geared toward mining-specific innovation and instead provides broad innovation funding for the natural resources, applied sciences, and engineering sectors.

This program would provide $4 million per year in provincial innovation funding over five years. Eligible projects must focus on preventing pollution in the mining industry and can cover a variety of areas such as data analytics, prediction and monitoring tools, infrastructure design, and the application of new technologies. BC is home to the world’s largest concentration of exploration companies and has the potential to become a global hub for innovative mining solutions. Providing innovation incentives could entice mining companies already situated in the province to invest in new technologies and contribute to technical progress in a variety of areas, including ARD and tailings management.
Chapter 10. Evaluation of Policy Options

This section provides an evaluation of the policy options using the criteria and measures outlined in Table 5. Findings are based on the case study analysis and insights from the literature and government studies. The results of the evaluation are presented in Table 6 at the end of the chapter.

10.1. Option 1: Prohibit Mines with Perpetual Water Treatment

Effectiveness

For reclamation outcomes, this option is expected to provide moderate improvements. As previously mentioned, ARD and leaching are serious environmental hazards that can reduce reclamation outcomes at mine sites. Although this new regulation would not stop perpetual water treatment at existing mines, it could prevent new high-risk mines from obtaining permits and promote true ‘walk-away’ scenarios. Treating ARD is also more expensive and difficult than early prevention, so this option could greatly reduce reclamation costs (Kuyucak, 2002). Despite the cited benefits, this option has technical challenges that may undermine its effectiveness. Due to the variability and unique mineralogy of rock materials, predicting ARD can be difficult, costly, and of questionable reliability in some cases (EPA, 1994). There have been several instances where ARD potential was not identified in early planning stages but developed later on (Green, 2001). Prediction tools can help mitigate some of these challenges; however, this option receives a 2 due to technical uncertainty.

For behavioural change, this option is expected to promote moderate change. Regulations generally provide more certainty in behavioural response than other market-based mechanisms (OECD, 2000). Moreover, this regulation can create incentives for companies to reduce environmental risks and innovate in acid prediction technologies, mitigation measures, and water treatment systems. At the same time, overly technical, complex, and stringent rules can encourage evasion and creative compliance by regulatees (OECD, 2000). For example, mining companies may understate ARD or leaching concerns at mine sites in order to pass the approval stage or they may look for loopholes in the regulation. Therefore, this option scores a 2.
Cost

In terms of cost, this option is expected to have an average annual cost of $1.6 million for the provincial government. This budgetary impact is estimated based on the Regulatory Impact Analysis Statement (RIAS) for national mine effluent regulations that provides a cost-benefit analysis over a 10-year period (Metal and Diamond Mining Effluent Regulations, 2018). This regulation is used as a proxy since it strengthens effluent quality standards and requires companies to change their water treatment methods. The RIAS estimates that average annual government costs will be $0.3 million for enforcement and $0.5 million for administration, with a total of $0.8 million annually (Metal and Diamond Mining Effluent Regulations, 2018). Since this policy option will likely require more rigorous technical review and site inspection than the effluent regulation, I have doubled the administrative and enforcement costs. This leads to an adjusted budgetary impact of $1.6 million annually, which corresponds to a score of 2.

Administrative Ease

This policy option ranks low on administrative ease, as it would likely require a substantial amount of changes to the existing policy framework. The option would introduce a new regulation that would need legislative approval and would change the policy framework considerably. It would also require coordination across different provincial agencies, including EMPR, ECCS, and the BC Environmental Assessment Office. Lastly, the regulation would add a layer of difficulty in evaluating and permitting mines, given the level of technical knowledge required to assess ARD and leaching potential. Therefore, this policy option receives a 1 on this measure.

Stakeholder Acceptance

This option is likely to receive strong support from local communities. Many Indigenous communities across the province have joined advocacy movements and reform networks with the aim of protecting water ecosystems and strengthening mining regulations (e.g., Stand for Water, BC Mining Law Reform Network). The BC First Nations Energy and Mining Council (2016) has also expressed that the provincial government should ensure true ‘walk-away’ scenarios, where mining companies have no monitoring or water treatment requirements upon closure. The Council is composed of representatives of the BC Assembly of First Nations, the First Nations Summit, and the
Union of British Columbia Indian Chiefs. As a result, this option receives a 3 for community acceptance.

At the same time, there is a strong likelihood that the mining industry will oppose this option. Similar legislation was enacted in Colorado and Wisconsin and was met with strong industry resistance. Under the new regulation, mining companies would undergo a more rigorous permitting and approval process. This would likely require additional resources for acid prediction technology, technical experts, risk assessments, and environmental impact studies to demonstrate that future projects do not have potential for perpetual water treatment (Wisconsin Department of Natural Resources, 1995). Mining companies would also incur higher administrative costs to interpret the regulation and higher costs during the exploration and planning stages associated with site selection and facility design (Wisconsin Department of Natural Resources, 1995). As a result, this option scores a 1 for industry acceptance.

10.2. Option 2: Strengthen Regulations on Tailings Storage Facilities

Effectiveness

For reclamation outcomes, this option is expected to deliver strong improvements. As previously mentioned, tailings facilities are susceptible to long-term failures that can have catastrophic consequences for the environment and local communities (ICMM, 2020). Tailings are also a large source of mining waste that needs to be adequately managed after mine closure. While there is no one-size-fits-all solution for tailings storage, wet tailings facilities are generally riskier and less favourable for progressive reclamation (Carneiro & Fourie, 2018). Eliminating the use of wet tailings facilities and promoting alternatives such as dry stacking or thickened tailings could therefore lead to improved reclamation outcomes. Both alternatives have a more straightforward rehabilitation process and lower post-closure care requirements (Carneiro & Fourie, 2018). Another advantage is that the regulation extends to existing mines and encourages stronger tailings management practices at these sites. As a result, this option receives a score of 3.

For behavioural change, this option is expected to encourage strong change among mining companies. As noted earlier, command-and-control regulations provide
greater certainty in behavioural change than other approaches, including performance-based regulations (OECD, 2000). In particular, this regulation prompts companies to seek out alternatives to conventional tailings storage, which may spur innovation in mine design and lead to more environmentally sustainable practices. Although this regulation discourages the use of wet tailings facilities, it still provides some flexibility for mining companies, as they can select from at least three different storage methods or explore new methods. Since the regulation is not as stringent as option 1, it would likely not encounter the same compliance issues and therefore scores a 3 on this measure.

Cost

In terms of cost, this policy option is expected to have an average annual cost of $0.8 million for the provincial government. This budgetary impact is estimated based on the same RIAS for national mine effluent regulations as option 1. This regulation is used as a proxy since it requires mining companies to adopt new technologies. The RIAS estimates that average annual government costs will be $0.3 million for enforcement and $0.5 million for administration, with a total of $0.8 million annually (Metal and Diamond Mining Effluent Regulations, 2018). This corresponds to a score of 3.

Administrative Ease

This option ranks moderate for administrative ease, as it would likely require some changes to the existing policy framework. The provincial government already introduced regulations in 2018 on best available technology for tailings facilities and this would simply be an amendment to those regulations. However, this new regulation would have a larger scope and require greater oversight and evaluation by the provincial government. This would likely necessitate coordination between EMPR and the BC Environmental Assessment Office. As a result, this option receives a 2.

Stakeholder Acceptance

This regulation is likely to receive strong support from local communities. In the wake of the Mount Polley Mine Disaster, Indigenous and local communities alike have called on the provincial government to address tailings breaches and to shift to newer and safer tailings storage methods. In 2015, a group of BC First Nations, local businesses, scientists, and others signed a letter asking the provincial government to halt the permitting of wet tailings facilities for new and proposed mines (Botham, 2015).
Some Indigenous communities have also expressed concerns about the wider implications of tailings dam failures and the long-term impacts on water, land, and the environment (Shandro et al., 2016). As a result, this option receives a score of 3 for community acceptance.

At the same time, the mining industry will likely oppose this policy option. While there is increasing interest by the industry to develop alternatives to large tailing ponds, mining companies generally do not like filtering or dry stacking options because they have higher capital and operating costs (Carneiro & Fourie, 2018). However, many project estimates do not consider the long-term benefits that alternative options deliver at the reclamation stage. According to an Australian study, rehabilitating a dry stack is 1.6 times cheaper than a wet slurry option (Carneiro & Fourie, 2018). The study also indicates that with recent developments in filtration technology, dry stacking could become cheaper than conventional methods (Carneiro & Fourie, 2018). A few mining companies have already recognized the sustainability and reputational benefits of alternative methods, but there is still some resistance in the industry (Hoekstra, 2015). As a result, this option scores a 1 for industry acceptance.

10.3. Option 3: Introduce Funding Program for Mining Innovation

Effectiveness

For reclamation outcomes, this option is expected to provide moderate improvements. Although long-term planning and stewardship are key components of effective mine reclamation, innovation has an important role to play as well. In particular, targeted R&D investments can help the mining industry address key reclamation challenges, including the long-term management of mine waste and toxic drainage (Stano, 2012). Research predicts that ARD concerns will continue to grow as lower-grade ore is exploited at BC’s mine sites (Stano, 2012). Innovation funding can also help the mining industry overcome barriers to greater R&D and commercialization. At the same time, this option would be less immediate and directly targeted than a new regulation, as R&D benefits accrue over a longer time period (Anderson, 2004). It also does not guarantee that innovative solutions will be commercialized and widely disseminated in the mining industry (Carraro, 2000). Therefore, this option scores a 2.
For behavioral change, this option is expected to produce moderate change among mining companies. MBIs such as subsidies are often used by governments to support a variety of environmental activities, including pollution prevention (Anderson, 2004). These instruments influence behavior through economic incentives that encourage companies to innovate and invest in more sustainable technologies (EPA, 2018). However, the voluntary nature of subsidies can make behavioural change less certain. The core challenge with subsidies is they do not guarantee that investment in R&D will be undertaken by companies and can sometimes create perverse incentives that undermine pollution prevention goals (Carraro, 2000; EEA, 2005). As a result, this option receives a score of 2.

Cost

In terms of cost, this policy option is expected to have an average annual cost of $4.25 million for the provincial government. This budgetary impact was estimated based on government expenditures on similar R&D funding programs in other jurisdictions such as Québec. The Government of Québec currently provides $4 million annually in funding to support R&D in the mining industry (Gouvernement du Québec, 2019). Due to the similar prominence of the mining industry and levels of mineral production in both provinces, the funding program is modelled after Québec’s funding allocations. The average annual cost also includes an upfront cost of $0.5 million to launch and promote the program and ongoing administrative costs of $0.2 million, leading to an average cost of $4.25 million annually. This cost corresponds to a score of 1.

Administrative Ease

This option performs well for administrative ease, as it would be relatively easy to implement. The funding program could be introduced under the existing policy framework and administered by EMPR under a dedicated team. Lastly, there would be some initial coordination between the provincial and federal government to ensure there is no overlap in funding, but coordination would not be required once the program has been launched. Therefore, this option scores a 3.

Stakeholder Acceptance

This policy option is likely to receive a neutral response from local communities. For economic instruments, perceptions of legitimacy are an important requirement,
particularly when public funds are being allocated to an industry. Subsidies for environmental management are sometimes criticized for helping bear the cost of what should be the responsibility of the polluter (Anderson, 2002). However, since this fund is dedicated to research in mining innovation, the public will likely not react strongly in either support or opposition. Therefore, this option scores a 2 for community acceptance.

On the other hand, there is a strong likelihood that the mining industry will support this policy option. The Mining Association of BC, which advocates on behalf of coal, metal, and industrial metal producers in the province, has publicly shown support for similar funding initiatives in the past. Moreover, mining companies will likely support the funding program as it can improve market competitiveness and deliver reputational benefits that enhance their social license to operate (Warhurst & Bridge, 1996). It would also be low cost for mining companies to participate in the program, as the only direct costs would be administrative expenses related to the application process. As a result, this option receives a score of 3 for industry acceptance.

Table 6. Policy Option Evaluation

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Option 1: Ban Perpetual Water Treatment</th>
<th>Option 2: Strengthen Tailings Regulations</th>
<th>Option 3: Innovation Funding Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reclamation outcomes</td>
<td>Moderate improvement (2)</td>
<td>Significant improvement (3)</td>
<td>Moderate improvement (2)</td>
</tr>
<tr>
<td>Behavioural change</td>
<td>Moderate change (2)</td>
<td>Strong change (3)</td>
<td>Moderate change (2)</td>
</tr>
<tr>
<td>Cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost to government</td>
<td>$1.6 million/year (2)</td>
<td>$0.8 million/year (3)</td>
<td>$4.25 million/year (1)</td>
</tr>
<tr>
<td>Administrative Ease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of implementation</td>
<td>Difficult to implement (1)</td>
<td>Moderate to implement (2)</td>
<td>Easy to implement (3)</td>
</tr>
<tr>
<td>Stakeholder Acceptance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local communities</td>
<td>Support (3)</td>
<td>Support (3)</td>
<td>Neutral (2)</td>
</tr>
<tr>
<td>Mining industry</td>
<td>Oppose (1)</td>
<td>Oppose (1)</td>
<td>Support (3)</td>
</tr>
<tr>
<td>Stakeholder total /2</td>
<td>2</td>
<td>2</td>
<td>2.5</td>
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<tr>
<td>TOTAL SCORE /15</td>
<td>9</td>
<td>13</td>
<td>10.5</td>
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</table>
10.4. Recommendation

There are two recommendations for the Government of British Columbia. The first is to strengthen regulations on tailings facilities and phase out wet tailings storage in the province. Under the phased approach, new mining projects would be required to adopt best available technology for tailings storage using alternatives to wet tailings, while existing mines would be encouraged to adopt best available practices for the remaining active life and closure. As illustrated in the policy analysis, this option is the highest performing overall and helps meet the policy objectives of protecting the province’s natural resources and supporting a more sustainable mining industry. Above all, the option excels in effectiveness for both improved reclamation outcomes and behavioural change. It promotes tailings management practices that are safer and easier to rehabilitate, which can help reduce the likelihood of tailings failures and lower requirements for post-closure care. This option would also be relatively low cost to implement and would likely receive strong support from local communities. The main drawback is that it would create higher capital and operating costs for the mining industry and would likely receive opposition. However, this option could deliver cost savings to the industry in the long run through lower reclamation costs.

Despite the innovation potential from this regulation, there are still limited incentives for the mining industry to invest in R&D and technological innovation. As shown in the case study analysis, innovation has an important role to play in adopting a preventative approach to reclamation. Regulations alone may not be enough to encourage more widespread innovation in the mining industry. Therefore, my second recommendation is to introduce a 5-year funding program that provides $4 million per year for eligible innovation projects. These projects must be focused on pollution prevention in the mining industry and can cover a range of activities. While this program may not directly contribute to reclamation outcomes, innovation funding is essential to removing R&D barriers and stimulating new mining practices and technologies that offer solutions to reclamation challenges. Although this option would have a higher cost to the provincial government, this would be a fixed-term option, with the opportunity to extend the program for another 5 years, if necessary. The funding program would also be low cost to industry, easy to implement, and would likely receive acceptance from both stakeholder groups.
With respect to implementation, the two options can be implemented simultaneously. The regulatory changes should be accompanied by a compliance promotion strategy by the provincial government to help mining companies understand their regulatory requirements and how to best meet them. The provincial government should also provide additional training for enforcement officers and conduct a five-year evaluation to measure the effectiveness of the new regulation. In addition, the funding program will require a communications and marketing strategy for the initial launch and subsequent promotion. Lastly, the implementation of both policies should be accompanied by stronger messaging from the provincial government about the importance of progressive reclamation and pollution prevention practices.
Chapter 11. Conclusion

Mine reclamation is a complex process that can have widespread and lasting effects on the environment and local communities. How the mining industry manages its long-term legacies is of critical importance to the safe and sustainable production of mineral resources. By taking a holistic, integrated approach that considers early prevention and provides the right incentives to companies, the government can help mitigate the challenges of premature mine closure and inadequate reclamation. This imperative exists not only for governments, but for mining companies as well, who will continue to face pressure from civil society groups, local communities, and the public to improve their environmental performance and adopt more sustainable practices.

The options recommended in this study provide an alternative approach to the current gaps in BC’s mine reclamation regime. They target some of the highest risk structures at mines, while providing support for mining companies to adopt better technologies and explore new practices. Best management practices show that responsible mine closure should be proactive and occur progressively throughout the lifecycle of a mine. This starts with predicting the environmental risks of mining projects and taking appropriate measures to prevent or mitigate these impacts at the outset. Together, these options can guide the mining industry to a more sustainable future and help preserve our land and resources for generations to come.

Future Considerations

Aside from the two recommendations, there are other areas the provincial government may wish to explore in the future. This study has revealed a number of gaps in BC’s reclamation regime that require further consideration. These policy interventions are not directly targeted at pollution prevention and were therefore outside the scope of my analysis, but they may contribute to a more effective and holistic reclamation regime.

First, the provincial government should eliminate the threshold for environmental assessments and make it mandatory for all mines to acquire one. This approach could be modelled after Chile, where projects with smaller anticipated impacts go through a more simplified process. Second, the provincial government should develop performance indicators for mine reclamation and closure. Performance indicators
measure how effectively mining companies are meeting their commitments and can help identify critical gaps in reclamation practices. Third, EMPR and ECCS should continue to build internal capacity for monitoring and enforcement, as these are important tools that promote an effective regulatory system. One suggestion for enhancing monitoring of closed sites is to introduce independent reclamation monitoring led by community members, civil society groups, or other stakeholders. Finally, the provincial government should continue to seek more effective and meaningful ways of engaging with local communities affected by mining activities, as they often bear the greatest burden of environmental damage.
References


