Mitigating Non-Point Source Pollution in the Abbotsford Sumas Aquifer: An Evidence Based Evaluation of the Effectiveness of the BC Action Plan to Tackle Non-Point Source Water Pollution

by

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Abstract

At the turn of the 20^{th} century, BC completed its first public status report on the quality of water and found that 10% of the water sources monitored had poor water quality caused primarily by non-point source pollution. The Abbotsford-Sumas Aquifer (ASA) was mentioned in this report and it has had persistent and significant nitrate contamination, primarily from agriculture, for decades despite mitigation efforts. This poses significant public health, ecological and economic risks to the region. In 1999, the BC Action Plan to tackle non-point source (NPS) water pollution was released which focused on six key initiatives including (a) education and training (b) prevention at the site (c) land use, planning and coordination (d) assessment and reporting (e) economic incentives and (f) legislation and regulation. The following capstone evaluates to what extent the BC Action Plan was implemented to mitigate contamination of the ASA and how effective the key initiatives were at reducing NPS pollution. Evidence for this evaluation was collected through academic data base and targeted web based searches, and the capstone is informed by a range of resources, such as government documents, meeting minutes and scholarly journals. This evaluation allowed for the development of four key recommendations for actions moving forward to improve water quality in the aquifer and minimize negative public health impacts. These recommendations include strengthening the implementation of Beneficial Management Practises (BMPs) for agriculture, stricter legislation and tighter enforcement, increased coordination and commitment of local stakeholders and increased public awareness. As there will be increased focus on water quality in BC as the regulations under the Water Sustainability Act are implemented, and global pressure on water resources continues to build , there will be an increased urgency to prioritize collaborative efforts to protect our shared natural resource.

Keywords: Abbotsford Sumas Aquifer; Non-Point Source Pollution; Groundwater Protection; Nitrate Contamination

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Table of Contents

List of Figures

List of Tables

List of Acronyms

ASA	Abbotsford Sumas Aquifer
ASAITF	Abbotsford Sumas Aquifer International Task Force
ASASG	Abbotsford Sumas Aquifer Stakeholders Groups
BMPs	Beneficial Management Practices
EFP	Environmental Farm Program
IJC	International Joint Commission
NPS	Non-Point Source
NMP	Nutrient Management Plan

1. Introduction

1.1. Groundwater in British Columbia

1.1.1. Importance of Groundwater Protection in British Columbia

Groundwater, water present beneath the earth's surface, accounts for ~31% of freshwater globally, which is essential for the survival of most living things (ECCC, 2013). In Canada, nearly 30% of the population relies on groundwater for drinking water, and as global pressure on water resources increases due to overuse, pollution and climate change, many consider groundwater one of Canada's most important natural resources (CoCA, 2009).

British Columbia (BC) uses more groundwater than any other province in Canada, except for Ontario (Brentwood and Robar, 2004). The majority of groundwater extracted in the province is for agriculture and industry (Brentwood and Robar, 2004). However, municipalities also utilize a significant amount, with over 25% of BC citizens (excluding Greater Victoria and Vancouver) relying on groundwater as a primary drinking source (Foweraker, 1994). The total groundwater use in BC per day was estimated at 630 million litres (Association of Professional Engineers of BC, 1985). More recent estimates are ~275 million litres/day for municipal withdrawal with an additional 646 000 litres/day from combined groundwater/surface water sources (Rutherford, 2004) Private residents, agricultural and industrial well users were not historically required to report their water use and therefore there is a lack of recent data on total groundwater use in the province; however, groundwater use has likely increased since the initial estimate in 1985 (Golder Associates, 2012).

Until recently, use of this vital resource was unregulated and uncontrolled in BC leaving this essential resource highly vulnerable. The province has recently increased its efforts to protect water resources. In 2008, the "Living Water Smart: British Columbia's Water Plan" was released_which refers to groundwater as "our hidden treasure" and commits to protecting groundwater from pollution and overuse (BC MoE, 2008). The *BC Water Act* was replaced on January 29th, 2016 by the *Water Sustainability Act* which is significantly more comprehensive in its protection of water resources, including groundwater. Regulations for the protection of groundwater, the introduction of groundwater licensing, and additional provisions to conserve groundwater and prioritize its use during times of scarcity were released on February 29th, 2016 (BC, 2016a, 2016b). The release of this legislation is an important milestone for the protection of groundwater in the province.

1.1.2. Groundwater Contamination in British Columbia

Inadequate protection of groundwater can lead to quality and quantity issues which can have negative impacts on public health, ecosystem stability and agricultural and industrial economies. Contamination of groundwater can have immediate impacts on those using it as a source of drinking water but it can also carry contaminants and pollutants to surface waters causing further harm to local ecosystems and public health.

Contamination of groundwater can either originate from the surface of the ground (ex. fertilizers, dumps, accidental spills), in the ground above the water table (ex. septic tanks, underground storage tanks, graveyards) or below the water table (ex. mines, drainage wells) (US EPA, 1990). Another common differentiation for contamination is whether it is from a point source or a non-point source. Point source pollution stems from an easily identifiable site like a landfill or storage tank. These sources can cause significant damage but are more straightforward to mitigate (Brentwood and Robar, 2004). Non-point source pollution often comes from broad areas, like storm runoff or fertilizer runoff, and can be difficult to identify (Brentwood and Robar, 2004). This type of contamination is often more challenging to reduce since the area can be very large (thousands of square kilometres of farm fields) and it is difficult to identify successful strategies for its mitigation (Brentwood and Robar, 2004).

At the turn of the century BC's primary efforts to protect water quality involved regulating point discharges from industrial and municipal outfalls (MoELP, 1999). These efforts were generally effective, resulting in overall high water quality throughout the majority of the province. In 1996, the first public status report on the quality of BC's water was released which determined that approximately 10% of BC's water bodies had borderline or poor water quality and the cause was primarily non-point source (NPS) water pollution (MoELP, 1996, 1999). A more recent report of selected water bodies found that for groundwater, 20% of monitored areas had deteriorating trends (MoELP, 2000).

The Abbotsford Sumas Aquifer is one example of a water source that has suffered inadequate water quality due to non-point source pollution. It remains one of the most heavily contaminated aquifers in BC even though significant efforts have been made to reduce pollution. This aquifer is an excellent case study to study efforts made in BC to protect groundwater from NPS pollution as it has had poor water quality for several decades, has been the subject of significant research, has had extensive monitoring, and has also had many stakeholders collaborate in an attempt to remediate the shared water source.

1.2. Abbotsford-Sumas Aquifer

1.2.1. Aquifer Use

Groundwater from the Abbotsford-Sumas Aquifer (ASA) is utilized mainly by two regions in BC, the City of Abbotsford and the Township of Langley, in addition to Whatcom County in the State of Washington (Figure 1) (Golder Associates, 2012). It serves as a primary drinking water source for thousands of residents on both sides of the border and as a secondary source for many others (approximately 150 000 in Canada and 37 000 in the US) (Norman and Melious, 2004).

Figure 1. Location of Abbotsford-Sumas Aquifer (from Norman and Melious, 2004)

The aquifer also has a high economic importance due to its use for industry and agriculture on both sides of the border (Golder Associates, 2012). The farming communities and agri-businesses rely on it for watering, irrigation and processing. Many other food processing industries and other non-food related industries rely on it as well, including the multi-million dollar Fraser Valley Trout Hatchery (Golder Associates, 2012).

The ASA is also ecologically important as it discharges into many watercourses to maintain steam flow and moderate stream temperature for fish and other aquatic life (Golder Associates, 2012).

1.2.2. Aquifer Characteristics

The ASA covers approximately 160 square kilometres, of which 90 square kilometers are located in BC (Golder Associates, 2012). It is composed primarily of sand and gravel of glacial origin which is porous and allows it to act as an underground reservoir that is continuously recharged by heavy rainfall (Zebarth, Ryan, Graham, Forge & Neilsen, 2015). The majority of this rainfall (approximately 70%) occurs between October and March (Zebarth et al., 2015).

It is an unconfined aquifer, meaning that it has no overlying impermeable layer of silt or clay (Golder Associates, 2012). In many areas the aquifer is not very thick, mostly being less than 15 m even though some areas are up to 70 m (Zebarth et al., 2015; Carey and Cummings, 2012). The water table is quite shallow, varying from 2 to 25 m below the ground surface depending on the location and season (Kohut, 1987).

All of these factors contribute to the high level of vulnerability of the ASA to pollution from land use. Heavy seasonal rains wash surface contaminants through the porous ground to the shallow water table. This causes the ASA to have the highest vulnerability rating in the BC Aquifer Classification System (Golder Associates, 2012).

It is noteworthy that the flow of the groundwater in the ASA is primarily sub horizontal and towards the south across the international border between Canada and the United States (Norman and Melious, 2004). This means a significant portion of pollution entering the ASA in BC impacts groundwater quality in Washington as well.

1.2.3. Aquifer Contamination

The high vulnerability of the ASA to contamination therefore poses a significant challenge due to the high ecological, public health and economic reliance on this groundwater. Over the past several decades, nitrate has been the most persistent and significant contaminant detected in the aquifer (Figure 2). The current recommended guideline value from the World Health Organization is 50 mg/L nitrate (or 10 mg/L as nitrate-nitrogen) (WHO, 2011). The limit in Canada is 45 mg/L as nitrate (or 10 mg/L as nitrate-nitrogen) and the limit in the U.S.A. is 10 mg/L as nitrate-nitrogen (Health Canada, 2013; USEPA, 2016).

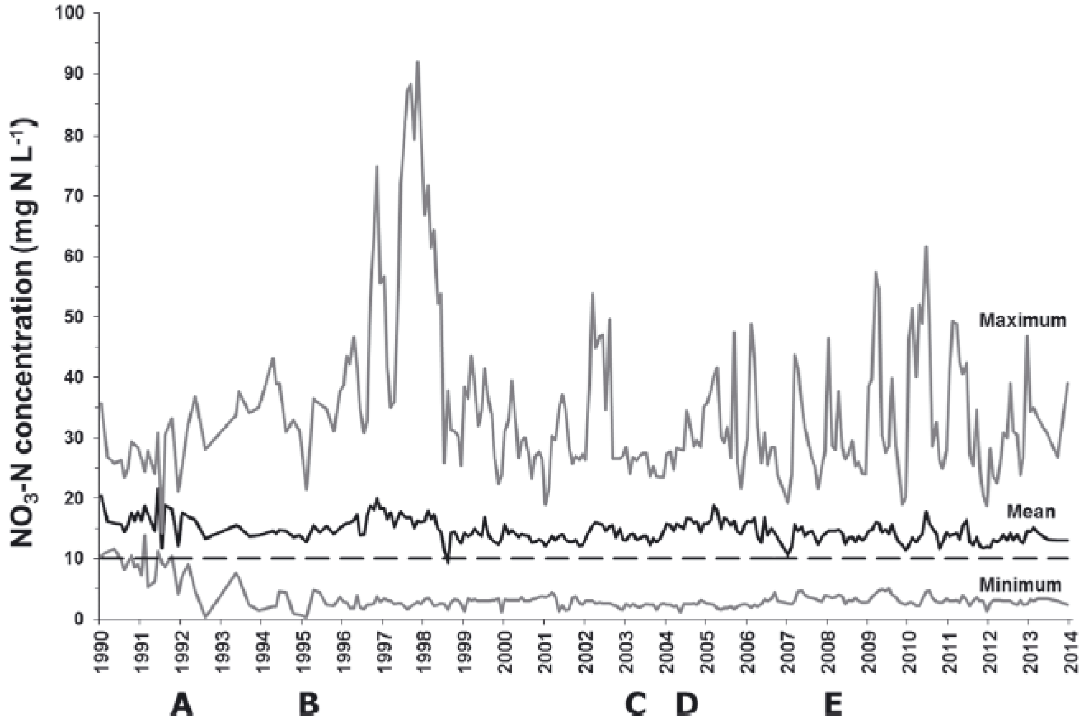

Figure 2. Historical Nitrate Contamination Trends in the British Columbia portion of the ASA-Maximum, minimum, and mean nitrate concentrations measured in the Environment Canada monitoring network since 1990, relative to the 10 mg N L−1 drinking water guideline for nitrate (dashed line) (Environment Canada, unpublished data).Letters indicate implementation of agricultural BMPs or programs: (A) Code of Agricultural Practice for Waste Management was established, initiation of BMPs including covering manure piles stored on fields over winter and fall planting of alley cover crops in raspberry production to trap residual nitrate; (B) initiation of program by Sustainable Poultry Farming Group program to transport manure away from the aquifer area, initiation of raspberry manure and fertilizer N recommendations based on post-harvest soil testing; (C) initiation of Environmental Farm Plan Program with optional Nutrient Management planning supported by federal Agricultural Policy Framework (APF); (D) mass culling of poultry due to outbreak of avian influenza; (E) renewal of APF under federal Growing Forward Program. (from Zebarth et al., 2015).

According to findings from Environment Canada in 1997, the annual mean concentration of nitrate was 15.3 mg/l (nitrogen) with little change since 1991. Nitrate concentrations fluctuate seasonally and with groundwater depth (ASASG, 2000). Approximately 70% of all samples collected between 1991 and 2007 exceeded the drinking water guideline, with the highest level reported being 91.9 mg/L (CoCA, 2009).

According to studies by the Washington State Department of Ecology and the U.S Geological Survey, over the past 30 years, 29% of sampled wells of in the ASA exceeded this nitrate maximum contaminant level (Carey and Cummings, 2012). Thirty-six percent (36%) of wells that were less than 40 feet deep exceeded this limit, as did 20% of the deeper wells (Carey and Cummings, 2012). Fourteen percent (14%) of the wells had concentrations of more than double the recommended limit, and the highest documented concentration in domestic drinking water from this aquifer is 73 mg/L, measured as nitrate-nitrogen (Carey and Cummings, 2012).

In 1995, pesticides and synthetic hydrocarbons were also detected in the ASA and coliform bacteria have also since been detected, but these are not monitored for as regularly (BC Ministry of Health et al., 1995; Environment Canada et al., 2006). It has been suggested that the presence of nitrate contamination may be an indicator that the groundwater is still vulnerable to contamination from other sources such as pesticides and bacteria (Interagency Planning Team, 2009). The presence of nitrate contamination does suggest that agricultural runoff is likely reaching groundwater, which is a risk factor for other contaminants as well.

A study of pesticides in 2009 looked for 78 different pesticides in groundwater in the Lower Fraser Valley and found that even though 24 different pesticides were detected they were all below the drinking water quality criteria set by the World Health Organization (Woudneh, Ou, Sekela, Tuominen and Gledhill, 2009). This study included several samples from the ASA; therefore, it is likely that the risk of contamination by pesticides is low.

Recent research has found that the risk of bacterial contamination to the aquifer is low, likely due to the differential transport of coliforms and the effectiveness of the soil at reducing bacterial loads (Cey and Mellor, 2012).

Other potential contaminants from agricultural sources include parasites such as *Cryptosporidium parium* and *Giardia lamblia* .Cryptosporidium can travel as an oocyst which is quite resistant through soil, increasing their chance of reaching groundwater. Giardia can survive as cysts which are also quite resistant. Literature suggests, however, that both organisms may be too large to move significant distances in groundwater and therefore are not a common problem

(AWWA, 2002; Chappelle, 2001). However, some studies have suggested that this is not always the case and there is the potential for cryptosprodim oocysts and giardia cysts to contaminate groundwater (Darnault, Garnier, Kim, Oveson, Steenhuis, Parlange, Jenkins, Ghiorse, Baveye., 2003; Rose, Daeshner, Easterling, Curriero, Lele and Patz, 2000). Regular testing of these parasites can be expensive (Auditor General, 1999).

Enteric viruses are also very resistant microorganisms and are very small. Many cannot be cultured therefore *E.coli* is more commonly monitored to indicate the presence of these viruses (Fong and Lipp, 2005). They can be transported through groundwater, and studies have shown cases where enteric viruses are present even though bacterial indicator standards are met (Fong and Lipp., 2005).

The BC Ministry of Health recently released the second version of its guidelines which help regulators determine whether groundwater is “at risk”, “at risk from viruses only” or at “low risk” for containing pathogens (MoH, 2015). A recent drinking water report from local health authorities mentioned plans to begin screening wells to determine which tests are required (FH, 2012). Recent reports from Abbotsford/Mission, however, have yet to show evidence of groundwater testing for the parasites and viruses mentioned above (AMWSC, 2014). The literature, therefore, has mixed evidence regarding the potential contamination of the ASA from these sources, and thus the level of risk to public health.

1.2.4. Sources of Nitrate Contamination

The land use above an aquifer, especially immediately surrounding a well, can have a significant impact on which contaminants reach groundwater. This is especially relevant for the ASA due to its high vulnerability to pollution from the surface and the intense agriculture that occurs in the region.

Nitrate often reaches groundwater from agricultural activities such as excess application of inorganic nitrogenous fertilizers and manures or from the oxidation of nitrogenous waste products from mammals (WHO, 2011). Nitrate is mostly uptaken by plants during their growth but the surplus can percolate through the ground to aquifers (WHO, 2011).

Abbotsford, the city covering a large majority of the ASA in BC, is one of the most intensively farmed areas in Canada and generates 21% of all agricultural revenues for BC (Zebarth et al., 2015). The primary cropped land overlying the aquifer in Abbotsford includes 31% raspberry and 22% blueberry crops with poultry broiler production being the primary animal production land use overlying the aquifer (Zebarth et al., 2015). Other studies have stated that across both sides of the Canada-U.S.A border the main agricultural land use is raspberry fields (80%), poultry operations and dairy farms (Wassenar et al., 2006).

At the end of the 20th century, research determined that the nitrate pollution in the ASA was characteristic of non-point agricultural contamination (Mitchell, Babcock, Gelinas, Nanus & Stasney, 2003). The source of the nitrate was primarily poultry manure with some traces of inorganic, commercial fertilizers (Wassenaar, 1995; Zebarth, Hii, Liebscher, Chipperfield, Grove & Szeto, 1998). However, more recent isotope studies have shown a shift with increasing levels of contamination from inorganic fertilizers compared to animal manure (Wassenaar, Hendry and Harrington, 2006). Researchers have suggested this may be due to changes in farming practices over this time period which will be discussed in later sections.

1.3. Public Health Impacts of Nitrate Exposure from Drinking Water

There have been multiple negative health impacts associated with exposure to nitrate in drinking water at levels above the recommended limit. The current recommended limit is primarily based on risks of methaemoglobinaemia; however, studies have also found an association between exposure and carcinogenicity among other negative health impacts. Therefore it is possible that the current drinking water limit does not account for the range of risks to public health.

1.3.1. Methaemoglobinaemia

The toxicity of nitrate is mainly attributable to its reduction in the human body to nitrite. Nitrite oxidizes hemoglobin to methemoglobin which cannot transport oxygen to the tissues. When methemoglobin concentration reaches 10% of hemoglobin levels, the condition methaemoglobinaemia clinically manifests which can cause cyanosis and potentially asphyxia.

Infants are more susceptible to this condition as they have lower levels of reduced nicotinamide adenine dinucleotide (NADH)–cytochrome b5–metHb reductase which plays a key role in reducing methemoglobin back to hemoglobin (IARC, 2010). In addition, infants tend to consume a higher intake of fluid per body weight. Pregnant women and people deficient in glucose-6-phosphate dehydrogenase or metHB reductase are also at a higher susceptibility (Health Canada, 2013). Studies which showed an association between clinical cases in infants and nitrate in drinking water often saw impacts at levels between 44.3-88.6 mg/l or higher (Walton, 1951). Others have suggested that levels must be in excess of 100 mg/l to cause issues (WHO, 2011). Another literature review conducted for the World Health Organization suggested that no exposure response relationship between levels of nitrate in drinking water and methaemoglobinaemia could be found (Fewtrell, 2004).

1.3.2. Carcinogenicity

The ingestion of nitrates from drinking water can result in the formation of N-nitroso compounds and many of these compounds are carcinogenic in all animal species tested (WHO, 2011). Many studies have found associations between nitrate intake and various cancers (IARC, 2010). However, the majority of these studies lacked individual exposure data and/or had the potential for confounding factors which makes it difficult to determine the strength of these associations (IARC, 2010).

No clear evidence yet exists to link nitrate in drinking water with gastric tumours, brain tumours or urinary tract tumours. Several studies showed limited evidence for an association between nitrate in drinking water and non-hodgkin lymphoma, but results were inconclusive (IARC, 2010). A slight association was found between high nitrate levels in drinking water and colon cancers (IARC, 2010). One study found elevated risk for bladder cancer among subjects who had high levels of exposure to nitrate in drinking water for a long period (Espejo-Herrera, Cantor, Malats, Silverman, Tardón, García-Closas, Serra, Kogevinas & Villanueva, 2014). The study did lack individual exposure data and had the potential for confounding factors. Another study found an increased risk of thyroid cancer with higher average nitrate levels in water supplies and long consumption, but the limitations mentioned above were present (Ward, Kilfoy, Weyer, Anderson, Folsom and Cerhan, 2010). However, overall there are insufficient, well designed epidemiological studies for any single cancer site which limits the ability to draw clear conclusions (Health Canada, 2013).

Nitrates ingested from drinking water are currently classified as *probably carcinogenic to humans (Group 2A)* by the International Agency for Research on Cancer (2010). There is limited evidence of its carcinogenicity in humans but there sufficient evidence of its carcinogenicity in experimental animals and strong evidence that the mechanism of carcinogenesis in animals operates similarly in humans.

1.3.3. Other Health Effects

Some studies have suggested an association between exposure to nitrates in drinking water and spontaneous abortions, intrauterine growth restrictions and various birth defects (Manassaram, Backey, Moll, 2007). However, similarly to carcinogenicity, these studies cannot rule out confounders and often lack individual exposure assessments. Therefore, no clear evidence of a causal relationship has yet been determined (Manassaram, Backey, Moll, 2007).

Other studies have reported that high exposure to nitrates in drinking water may be associated with increased thyroid volumes or thyroid function but results also have been inconsistent across studies (Health Canada, 2013).

1.4. Public Health Impacts from Other Contaminants

Pesticides and bacteria were found to be present below water quality standards in the ASA, and therefore pose negligible risks to public health.

Enteric viruses can cause a wide range of diseases and symptoms in humans when consumed through drinking water (Fong and Lipp, 2005). These are primarily linked to diarrhea and gastroenteritis but they have also been linked to respiratory infections, conjunctivitis and hepatitis with additional risks for those who are immunocompromised (Fong and Lipp, 2005). Cryptosporidum and Giaridi are also linked to forms of diarrheal disease (Rose, 2000). These pathogens are all particularly dangerous due to their low infectious dose. Their lack of regular monitoring in groundwater means that risks to public health may remain.

1.5. Prioritizing Public Health Action

Even though further research is still required to ascertain the relationship between nitrate exposure through drinking water and various health impacts, the evidence thus far suggests that there is the potential for various negative health impacts. There is also a risk from other potential contaminants that are yet to be monitored as extensively. While research is ongoing on potential health impacts, action should be taken to reduce risks to public health. According to the WHO publication, *Protecting Groundwater for Health,* when prioritizing groundwater contamination with respect to urgency of response, planners must consider the extent of the pollution and the public health burden (WHO, 2006). The severe extent of the pollution of the ASA and the size of the population exposed therefore raise the urgency of responding to the issue.

1.5.1. BC Action Plan to Tackle Non-Point Source Pollution

As noted in section 1.1.1, in the late 1990s, non-point source pollution, such as is prevalent in the ASA, was found to be present in various water bodies throughout BC and the province therefore turned its attention to limiting this pollution and protecting valuable natural resources.

An Action Plan to tackle non-point source water pollution in BC was therefore drafted by the Ministry of Environment, Lands and Parks (now called the Ministry of Environment). The Action Plan addresses the provincial government's role in addressing NPS pollution. Its creation involved public consultation, input from several government agencies and field studies on NPS water pollution (MoELP, 199). There has been no notice of any updates or reviews of this Action Plan since its release.

The Action Plan contains six key initiatives including: (a) education and training (b) prevention at the site (c) land use, planning and coordination (d) assessment and reporting (e) economic incentives and (f) legislation and regulation (MoELP, 1999). Many components of these key initiatives have been implemented in the region surrounding the ASA over the past two decades.

1.6. Objectives

Using a review of relevant evidence collected through academic database and targeted web based searches, the following capstone evaluates to what extent the BC Action Plan for tackling NPS water pollution has been implemented to mitigate contamination of the ASA. It identifies implementation gaps and evaluates the effectiveness of the various key initiatives utilized to tackle NPS pollution. This process allows for the development of recommendations for actions moving forward to improve water quality in the aquifer and minimize negative public health impacts.

2. Methods and Limitations

2.1. Methods

2.1.1. Evidence Review

In order to be thorough in documenting all efforts to reduce NPS pollution over the ASA, information for this capstone was drawn from a wide range of resources. Resources drawn from included government documents, meeting minutes, technical reports, scholarly journals, grey literature, reference books, conference presentations, newspaper articles, and personal communication. The search was conducted from November 2015- March 2016, therefore any resources published after this date were not considered.

Academic databases were searched using a combination of keyword searches. The following databases were searched: EBSCOhost, Google Scholar and Web of Science. Keywords utilized included: “Abbotsford Sumas Aquifer”, “Abbotsford Aquifer”, “Sumas Blaine Aquifer”. Additional searches included the terms “British Columbia” or “Washington” with a combination of the terms, “nitrate”, “nitrate contamination”, “groundwater”, “aquifer”, “groundwater contamination”, “non-point source pollution” and “agriculture”. The title and abstracts of the search results were reviewed for relevancy and those which were, were downloaded for more detailed review. Further sources were identified from the reference lists of relevant articles during the initial search.

Targeted web based searches were also used to access information from other resources listed above. A significant amount of time and weight in the research process was given to this search. Even though significant amounts of research have been conducted on the ASA, governments, local coordinating bodies, industry groups and communities have played a significant role in action to mitigate pollution in this area and not all of this information is reflected in academic literature.

Evidence regarding efforts to reduce pollution in BC were set as the primary inclusion criteria; therefore, all initiatives conducted in Washington were excluded. Some research from Washington that focused on pollution in the U.S.A. originating in Canada, however, was included due to its focus on pollution in BC.

2.1.2. Evaluation

Information gathered from the above evidence review on actions to reduce NPS pollution in the ASA were sorted into the six key initiatives recommended by the BC Action Plan and are reported in the findings section.

Gaps in implementation of the action plan were then evaluated as well as their effectiveness. The challenges in regards to implementation, as well as, actual reduction in pollution are also discussed (see section 4). Recommendation for future action were then developed based on this evaluation (see section 5).

2.2. Limitations

2.2.1. Lack of Revision of Government Document

The BC Action Plan was developed 17 years ago and no efforts to revise it or update it with relevant information on controlling NPS pollution have been made. There is no recorded evidence of what steps were made to implement it nor what its current status is. A recent literature review noted that there is lack of analyses in North America of NPS policies and limited efforts are made to reduce implementation barriers of these Action Plans, demonstrating that this is not a limited issue (Dowd-Uribe, Press & Huertos, 2008). New regulations were recently released for the new *Water Sustainability Act* in BC; however, they have limited provisions that detail actions to mitigate NPS pollution (BC, 2016a, 2016b). One limitation to this capstone is therefore the reliance on a potentially outdated governmental document. It is noteworthy, however, that the key initiatives recommended by the BC Action Plan do still have significant overlap with more recent Action Plans from other jurisdictions.

For example, Washington recently released a “Water Quality Management Plan to Control Nonpoint Sources of Pollution” and it considers many of the same strategies. It focuses on regulations and enforcement, preventing NPS pollution, building partnerships for coordination, using financial incentives and monitoring (DoE, 2015). The major difference being Washington’s lack of emphasis on promoting public awareness of the importance of protecting water sources from NPS but it does mention supporting education and outreach as a potential strategy.

Another study comparing approaches for handling NPS pollution in the U.S.A. and New Zealand focused on legislation, monitoring, beneficial management practices (prevention at the site), incentives and outreach and education (Caruso, 2005).

Therefore even though a potential limitation of this capstone is its lack of recent updates to the BC Action Plan, the similarities between its key tenets and those of other policies to reduce NPS pollution enhance confidence in its usefulness.

2.2.2. Lack of Attention to U.S.A. Efforts or Regulations

The fact that the ASA is a transboundary aquifer has increased interest in the efforts that have gone into managing its water quantity and quality. It is a potential limitation of this capstone that it focuses primarily on efforts that have been made only in BC even though water flows freely across the border. However, as groundwater largely flows north to south in ASA and the main focus of this capstone is on how effective key tenets of the BC Action Plan has been at mitigating NPS pollution in the ASA, this limitation was deemed acceptable.

2.2.3. Reliance on Online Searches

Research primarily relied on evidence that could be found online with limited input from active stakeholders. This is a potential limitation of this capstone in that efforts made at the local level may not have been documented online and a clearer picture of efforts to reduce NPS pollution may have been drawn by more active evidence searches rather than relying primarily on online sources.

3. Findings

3.1. Education and Training

3.1.1. Action Plan Key Initiative

Non-point source water pollution is caused by many individuals and businesses and their commitment to reducing this pollution is therefore necessary to protect water quality in BC. According to the BC Action Plan, communication, education and training are the most important strategies to reduce NPS pollution. The primary action recommended is to implement a public awareness strategy including widespread education for government, community organizations, businesses, industries, First Nations and other individuals. The action plan suggests that by informing citizens of the impacts of their actions, the economic and health benefits of pollution prevention and alternative options to reduce pollution, sustainable behavioral change can be achieved (MoELP, 1999).

An emphasis is also placed on education, training and certification of relevant industry associations such as agricultural groups. Suggestions included collaborating to develop beneficial management practices (BMPs) and training materials and to launch pilot projects (MoELP, 1996).

3.1.2. Implementation of Education and Training for ASA

Various initiatives have attempted to raise public awareness of the contamination of the ASA over the past two decades and it is likely that these efforts will continue.

Public Awareness

There are a number of programs that have been aimed to educate the general public. Project WET is a water science and conservation program that has delivered workshops in Abbotsford (HCSP, 2002). It aims to promote awareness in children on the importance of water resources and their management. Pacific Streamkeepers is another habitat conservation and stewardship program that aims to develop local capacity to protect fish habitat (HCSP, 2002). It has been active in Abbotsford, and through its training it raises awareness on groundwater protection. In 2000, Pacific Streamkeepers hosted a public forum on groundwater that was attended by 80 residents (HCSP, 2002). These are only a few examples of programs targeted specifically at youth to engage them in the protection of groundwater, which can indirectly raise awareness among many other community members.

The Abbotsford-Sumas Aquifer Stakeholder Group, which became active in 1995, also sponsored public education campaigns such as signage, environmental pledge booklets and school presentations (COCA, 2009). The environmental pledge booklets were released in 2000 and contained everyday tips to protect the aquifer such as lawn care, management of weeds, pests, household cleaning products and beneficial management practices for farm and rural properties (ASASG, 2000c). Residents who agreed to pledge to utilize some of these tips received a fridge magnet as appreciation (ASASG, 2000c). The signage was installed in 2001 and was to keep businesses and the broader public informed regarding safe disposal of hazardous products and reminders of their impacts on the aquifer (Figure 3; ASASG, 2002b). A groundwater educational kit that included a booklet and video for students in grade 4-7 was also created and distributed to select school districts (ASASG, 2002b). The materials were distributed in 2003 and were encouraged to be used in conjunction with the Pacific Streamkeepers educational model (ASASG, 2003).

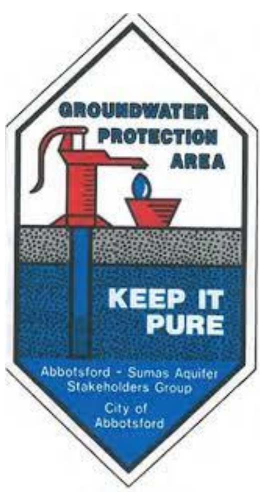

Figure 3. Public signage installed by the ASASG

The Abbotsford Sumas Aquifer Stakeholder Group held a meeting in 2007 which was attended by over 100 participants with a technical interest in groundwater, and then the first public forum was held in 2009. In 2012, the second Abbotsford Groundwater Forum was held which increased awareness in the community and further engaged stakeholders like water and health specialists, groundwater researchers, government staff, industry representatives and community members. Governance options and the foundation for protection strategy were discussed (BC, 2015).

A small portion of the aquifer also underlies the Township of Langley (ToL) which launched the Water Wise program in 2002 to educate residents on the importance of water conservation. ToL has used door to door campaigns (over 25 000 homes), attended community events (over 150) and presented workshops in schools (over 2000 students) (LEPS, 2015).

Other provincial initiative also exist to engage communities in protecting their groundwater. The province of British Columbia, Environment Canada and the British Columbia Groundwater Association created a Well Protection Toolkit with the aim of encouraging communities to utilize it to develop well protection plans for their water supply. One of the objectives of the toolkit is "to educate water supply system owners, communities, and local governments about the benefits of ground water protection" as well as "to raise awareness and encourage personal responsibility by providing information to the general public on well water protection" (MoELP, MoH, 2000). This toolkit aims to delineate a well protection area, identify potential contaminants, and then develop a contingency plan to manage activities that can lead to contamination (MoELP, MoH, 2000). Approximately 40 well protection plans have been established in BC. Another toolkit was produced by the Okanagan basin, the Groundwater Bylaws Toolkit which aims to provide local governments with land management tools to protect groundwater resources (OBW Board, 2009). It is unclear to what extent these toolkits have been implemented in the region of the Abbotsford-Sumas aquifer.

Industry Focused

Education and training of industry stakeholders promotes awareness of the importance of implementing beneficial management practices and helps establish collaboration to launch pilot projects. The Sustainable Poultry Farmers Group is an example of one industry that has been quite successful at raising awareness as it facilitates environmental initiatives that are beneficial for the poultry industry. The group has been particularly instrumental in implementing changes to comply with the *Agricultural Waste Control Act*, as discussed in the following section (Prevention at the Site).

The Agriculture Environment Partnership Initiative (AEPI) has also provided funding to a number of industry groups over the last decade to raise awareness. One example is the Nutrient Management and Environmental Stewardship in Raspberry Production project which was completed in 2006 which aimed to provide feedback to raspberry producers on the impact of their nutrient management practices on soil nitrate levels. The AEPI also funded the Sustainable Poultry Farming group until 2000 to provide education and awareness on environmentally sustainable uses for poultry manure (AEPI, 2010). An evaluation of AEPI projects found that their public awareness projects were generally well received by the public, farmers and industry and that they helped the public understand the contribution of farmers to the economy and environmental sustainability (Eisen, Frick & Vitens, 2011). They found that Abbotsford and Langley communities are much more supportive of the farmers now (Eisen et al., 2011).

Compliance assessments have also been regularly carried out, and when compliance issues were noted, further education has been provided. For example, farms overlying the aquifer where issues were noted were advised of their legal requirements, of their area of non-compliance and the potential consequences they faced. They were also provided with information on how to prevent pollution from farming to ensure compliance (EPRO, 2005). They were often advised of current governmental programs that can help them align with regulations. Programs such as the Environmental Farm Plan program offer support to many industries and are discussed in the following section on Beneficial Management Practices. Substantial progress has been made with BMPs as well, which aids to educate industry.

Recently, the City of Abbotsford had a Groundwater Management Strategy created which aims to preserve and enhance groundwater quality in the aquifer. The highest priority protection measure that was recommended for groundwater sustainability was public education (Golder Associates, 2012). The township of Langley has also created a draft Water Management Plan (discussed in more detail in section 3.3) and one of their key aspects is public awareness and education on groundwater issues. They suggest that it can encourage creative solutions and build partnerships to protect groundwater (Interagency Planning Team, 2009). Therefore, moving forward it appears that this key initiative will continue to be a high priority.

3.2. Prevention at the Site

3.2.1. Action Plan Key Initiative

Education is a key step in preventing pollution at the source since NPS is generally caused by many, localized minor activities that are difficult to regulate and enforce. One strategy to build off public education is to develop and implement beneficial management practices (BMPs) that inform stakeholders of the beneficial available methods to prevent pollutants from human activities reaching the water table. The BC Action Plan suggests that these BMPs can either be legislated or just general guidelines. They also note that water conservation is key since water over-use, specifically for irrigation, can contribute to surface runoff, soil erosion and nitrate infiltrating into groundwater. They suggest measures for water allocation, licensing and fees, and regulation of private utilities should be implemented (MoELP, 1999).

3.2.2. Implementation of Prevention at the Site for ASA

Beneficial Management Practices (BMPs) are evidence based guidelines that allow stakeholders to meet required standards and protect the environment. They allow stakeholders to comply with legislation, regulations and policies in order to meet the required objective, which in this case includes preventing further pollution of the ASA. BMPs for various land uses over the aquifer can include methods to ensure excess nitrates are not leaching into the groundwater from fertilizers or animal waste.

In 1992, the regulatory *Code of Agriculture Practice for Waste Management* was released which legislated several beneficial practices to ensure NPS pollution was limited. These included mandating that storage of animal waste was in contained facilities, waste was to be stored on site for less than two weeks, waste stored outside had to be covered between October-March and manure and fertilizer application had to be optimized for crops (Wassenar, 2006). It was believed that over 90% of farmers at the time complied with these guidelines, but farming also intensified during this period which led to an increase in manure production (Gleeson, Alley, Allen, Sophocleous, Zhou, Taniguchi & VanderSteen, 2012).

The Sustainable Poultry Farming Group was established at this time to raise awareness among producers and to begin looking for markets for their excess manure to reduce on site storage (Zebarth, 2015). This initiative aimed to move these surplus of nutrients to areas with a deficit to limit excess nutrients impacting the soil. As of 2003 they had hauled about 50 000 cubic yards, approximately 50% of their excess manure to distant markets (Borderline News, 2003).

From 1998-2000, the BC Investment Agriculture Foundation program funded the manure storage expansion program which provided grants to producers to invest in infrastructure to store manure properly (Dolberg & Hertgers, 2005). In 2000, improper manure storage over the aquifer was a continuing problem (ASASG, 2000b). Following this, the Agriculture Environment Partnership Initiative launched the Sustainable Management Manure program in 2001 to further improve storage capacity on farms (Dolberg & Hertgers, 2005). This program allowed for a reduced risk of excess nutrients to contaminate soil and water.

In 2005, a compliance assessment was conducted which examined all the farms over the ASA, as well as the nearby Hopington aquifer, in regards to the *Agricultural Waste Control Regulation* (EPRO, 2005). In general, high levels of compliance were found but primary issues included improper storage of manure and improper spreading on field. However, follow up studies found 88% compliance with manure spreading recommendations (MoE, 2006). An evaluation in 2010 found that 75% of livestock producers had adequate manure holding capacity (Eisen et al., 2011).

The BC Ministry of Agriculture provides producers with manure spreading advisories which provides guidelines for when and where to spread manure in order to minimize environmental risks (MoA, 2016). The same committee that produces these advisories is now proposing to pilot a risk assessment system that was developed in Whatcom County, Washington that allows them to consider soil, weather and crop conditions when deciding when to spread manure (ANWG, 2015). These assessments are thought to complement nutrient management plans (NMP) to be discussed further below.

The raspberry industry also implemented beneficial management practices which included switching from poultry manure to inorganic fertilizers, diversifying crops to include blueberries, and planting between row cover crops (Wassenar, 2006). Several other industries have also developed and complied with BMPs, such as the BC auto recyclers association (Norman & Melious, 2004).

As noted in earlier sections, public fora to discuss the ASA were held in 2009 and 2012 and involved many industrial actors. In 2012, they aimed to develop three key action items that could be implemented to reduce nitrate contamination within ten years. These included developing a compost production and distribution systems to use in the raspberry sector to replace organic amendments, developing and implementing BMPs to reduce nitrate leaching from raspberry crops, and improving regulations and enforcements (ANAG, 2012b). The initial goal had been to present these action items to the Partnership Committee on Agriculture and the Environment, which serves as an industrial advisory committee for the Environmental Farm Program; however, several industries still had concerns that the local farmer's perspective was not being adequately considered (ANAG, 2012b).

The Environmental Farm Program (EFP) aims to reduce pollution by sending a qualified planning advisor to conduct risk assessments with farmers in order to create confidential Environmental Farm Plans. Afterwards the farmer can be eligible for project funding through the Beneficial Management Practices Program to take actions recommended from the assessment. The EFP assessment can determine whether or not a Nutrient Management Plan, a form of BMP, should be produced but it is recommended that a NMP be made for "any producer of livestock or intensively managed outdoor horticultural crop over a moderately or highly vulnerable aquifer that is used for drinking water" (MoA, 2010). This would therefore include all producers with land over the ASA. The aim of nutrient management planning is to apply the right amount of the right nutrients at the right place at the right time for economically optimal crops in terms of yield and quality while minimizing the risk of pollution (MoA, 2010). A Nutrient Management Reference guide was produced by the province in 2005 and updated in 2010 (MoA, 2010). There is now also a nutrient management guide for commercial berry growers in British Columbia (MoA, 2012b). As of 2012, 147 nutrient management plans had been produced in BC but according to the 2011 agriculture census, a relatively small proportion of BC farms applied these plans (Eisen, 2011). As of 2005, 24% of the farms over the ASA were thought to be operating NMP (EPRO, 2005).

It is worth noting that a Canadian evaluation of BMPs has found they require a significant investment to implement (AAC, 2012). Approximately 75% of BMPs evaluated did show some on-farm benefits but it was unclear whether they offset the cost of implementation. BMPs such as nutrient management also led to economic costs from lower crop yields due to lower nutrient availability (AAC, 2012). Another research study that evaluated the social, economic and environmental outcome of BMPs found that overall environmental outcomes have been positive but often rely on ongoing maintenance and upkeep of the BMPs and the major barrier to their adoption has been cost (Kitchen, 2012). It is important for sustainable agriculture that governments and local bodies consider these costs when developing BMP policies and programs to ensure implementation success. Economic incentives, as discussed in later sections, may therefore be required to ensure agriculture producers capacity to pay for BMPs in the long term. Effective practices may require regulations, regular monitoring and incentives for farmers to follow BMPs.

It is also essential that agricultural producers can feel confident that BMPs adequately mitigate nitrate contamination in order to warrant the economic cost. For example, when raspberry growers followed BMPs and switched from manure to inorganic fertilizers as requested, nitrate contamination remained high but the source of nitrate merely switched. These historical trends can limit producers' motivation to comply with BMPs. Direct monitoring after implementation of BMPs is therefore necessary so adjustments can be made if required to ensure progress.

Tools have begun to be developed to ensure that efforts by producers, deliver results. Methods have been developed to track water from specific wells back to the surface areas which impacted it and this allows for more thorough monitoring of the impacts of BMPs on farms. A subcommittee of the Abbotsford Sumas Aquifer Stakeholder Group supported a project starting in 2006 to look at historical data on capture zones of several wells with either, high or low nitrate levels (ASCA, 2007). The project found it difficult to obtain historic farm management practice information. They found it likely that they could draw connections between specific practices on farms and nitrate concentrations in groundwater but indicated that further detailed work was required (ASCA, 2007). Additional information on effective monitoring will be discussed in the monitoring and assessment section.

Overall, there has been significant action to develop BMPs for reducing nitrate contamination over the ASA. There has yet to be any significant reduction but methods have begun to be developed which will allow for quicker feedback on the efficacy of specific BMPs in order to adapt accordingly.

For the first time in BC, the new BC *Water Sustainability Act* will include regulations for groundwater licensing and fees (BC, 2015b). These regulations were recently released and as of February 29th, 2016 all non-domestic users of groundwater are required to apply for a water licence (BC, 2016c). The next three years are to be a transition period while the ~20 000 non-domestic users are brought into the water licensing scheme (BC, 2016c). The rental rates vary by the amount of water authorized and the specific water use, and they begin to accrue as of the day the regulations came into force, regardless of when the licence application is filed (BC, 2016c). Licensing was recommended in the Action Plan in order to conserve water as overuse can contribute to surface runoff, soil erosion and nitrate infiltrating into groundwater. These new regulations have been considered long overdue by many; however, others still think that the fees should be higher as they remain among the lowest in the country (Carr-Wilson, Brandes & Dobell, 2015). There are concerns that the rates are not yet high enough to influence user behaviour to ensure water use efficiency and overall conservation (Carr-Wilson, Brandes & Dobell, 2015).

3.3. Land Use Planning, Coordination and Local Action

3.3.1. Action Plan Key Initiative

The Action Plan recommends that land use planning take into account water resource management goals. This would involve incorporating strategies to prevent NPS pollution into Regional Growth Strategies and Official Community Plans. The plan also suggests that water management plans be created for all critical areas. The provincial government aimed to support local governments in the creation of these plans and in protecting key conservation areas, such as those that recharge aquifers. It is also suggested that effort go towards government coordination and community-based waterbody protection initiatives should be supported (MoELP, 1999).

3.3.2. Implementation of Land Use Planning, Coordination and Local Action for the ASA

Land Use Planning and Water Management Plans

Much of the land use planning in Abbotsford has already been established and this poses a challenge for groundwater protection measures. Approximately 75% of the Township of Langley and the City of Abbotsford is in the Agricultural Land Reserve (MoA, 2012). The provincial government established the Agricultural Land Reserve in 1973 to protect agricultural land from non-farm uses (Green, 2006). This serves to protect the provinces land from development pressure and allows for significant economic generation from agriculture. It is estimated that 91.7% of farmland available in Abbotsford is farmed, making it the most intensely farmed area in Canada (MoA, 2012). There has been some tension in recent years with Abbotsford attempting to rezone some of this land to industrial with many arguing that the purpose of the ALR is to protect the land from development (Green, 2006). It is therefore challenging for governments to suggest that alternate land use occur over the ASA to protect groundwater

Water management plans (WMPs) were introduced in 2004 under the old *Water Act* but are only enabled if the Minister of Environment determines that a plan is required (FBC, 2016). These plans involve a comprehensive and integrated approach to water and watershed planning and would be legally binding once developed. There are no approved WMPs currently in effect in BC but the Township of Langley has submitted a draft to the Minister of Environment for review in 2009. As of 2011, it were the only local government asked to do so (FBC, 2016). The new *Water Sustainability Act* has recently replaced these plans with “water sustainability plans” however the regulations for these new plans which may outline what will trigger their creation, what resources are available for their development and who will implement them, have yet to be released (BC, 2016c). Therefore the water management plans discussed below are still some time away from becoming legally binding.

The Township of Langley water management plan provides a series of recommendations to protect the aquifers from overuse and contamination (Interagency Planning Team, 2009). Some relevant ones include locally enforceable agricultural practices to minimize the risk of groundwater contamination, comprehensive monitoring and research programs, and municipal planning initiatives that ensure that new land developments do no impact groundwater (Interagency Planning Team, 2009).

The Abbotsford/Mission Water and Sewer Commission had a groundwater management strategy prepared by Golder Associates but it is not legally binding. Some of their key recommendations include restricting land use and chemical storage through municipal zoning bylaws, increasing stewardship programs and BMPs, and enhancing monitoring and assessment (Golder Associates, 2012). These recommendations however do not appear to have been uptaken by the City Council.

Community Based Water Body Coordination

There are a number of agencies responsible for the management of the ASA and their coordination has been difficult over the years. Environment Canada is one of the primary actors since it is responsible for managing any impacts that Canadian practices and water contamination could have on U.S.A. waters. They have played a role in monitoring the aquifer and also sat on the Abbotsford Sumas Aquifer International Task Force (to be discussed below). The BC Ministry of the Environment is responsible for preventing and controlling water pollution. The Fraser Valley Health authority is responsible for public health and the impacts of drinking water contamination. The local governments are responsible for land use planning and for managing drinking water. Therefore all of these actors are responsible in some way for the protection of the ASA. The transboundary nature of the aquifer introduces even more actors that need to be coordinated. Several coordinating bodies have acted to bring together many stakeholders to mitigate pollution of the ASA (see table 1).

Table 1. Coordinating Bodies to mitigate pollution of the ASA

Coordinating Bodies	Year of Creation	Primary Role
International Joint Commission	1909	Examine transboundary water use, investigate water pollution issues between Canada and the US and mitigate any potential water conflicts
Abbotsford Sumas Aquifer International Task Force	1991	Define the aquifer, determine any land use issues, identify any water resource or health issues, gather technical data and identify any educational needs
Abbotsford Sumas Aquifer Stakeholder Group	1997	Disseminate information, coordinate public awareness, monitor stakeholder initiatives and develop local non-regulatory solutions
Nutrient Management Action Plan Working Group – Fraser Basin Council	1999	Reduce contamination of Fraser Basin watershed

The International Joint Commission (IJC) was created in 1909 in order to look at transboundary water use, investigate water pollution issues between Canada and the U.S.A. and mitigate any potential water conflicts (Norman and Melious, 2004). The IJC has recently began focusing on the ASA. The Environmental Cooperation Council (ECC) works specifically on shared natural resources between BC and Washington, and ensures coordinated action and information on environmental issues (Norman and Melious, 2004). They formally establish task forces for shared initiatives, one of which is the ASA (Norman and Melious, 2004).

In 1991, the Abbotsford Sumas Aquifer International Task Force was created which aimed to define the aquifer, determine any land use issues, identify any water resource or health issues, gather technical data and identify any educational needs (Gleeson, 2012). This task force included a number of governmental divisions, First Nations groups and industries, among other stakeholders (Gleeson, 2012). The task force is responsible for reporting its findings bi-annually to the ECC. By 2003, the task force began to suffer from low attendance (Norman and Melious, 2004). It was reconvened under the council in 2012 in order to develop an action plan to address water management of the ASA (WS-BC, 2012). Meetings with a strong attendance were held again in 2013 to discuss what efforts had been occurring on either side of the border (ASAITF, 2013). No meetings have been held since.

In 1997, the Abbotsford Sumas Aquifer Stakeholder Group began which involved many of the same representatives including federal, provincial and local government agencies, agricultural and industry groups, NGOs and Washington State participants (Norman and Melious, 2004). It acts as a stewardship board to disseminate information, coordinate public awareness, monitor stakeholder initiatives and report to the Council. According to its meeting minutes, its primary mandate is “local home-grown non-regulatory solutions” and “to encourage community involvement in educating residents and businesses about protection of the aquifer” (ASASG, 2003). According to the minutes, the ASAITF has value in providing science but the ASASG is more effective for developing and facilitating implementation of action for change (ASASG, 2001b). This group is comprised of all volunteers and is open to the greater public (Norman and Melious, 2004). The group held bi-monthly meetings in the City of Abbotsford (Norman and Melious, 2004). Only minutes up until 2006 are available publicly and at this particular meeting there was discussion of the loss of industry stewardship groups from meetings and how they could expand stakeholder engagement (ASASG, 2006). Minutes from other local group meetings suggest they last met in 2009 and were summoned to regroup in 2011 with the creation of the Groundwater Management Strategy (EAC, 2011).

The Nutrient Management Action Plan Working group, established by the Fraser Basin Council continues to be active in attempting to reduce groundwater contamination and involves many of the Canadian stakeholders that were involved in the previous two groups. The Fraser Basin Council is a local nongovernmental agency established in 1997 to address the decline in environmental quality within the watershed (Norman and Melious, 2004). The council is divided into five regions, one of which is the Fraser Valley within which the ASA is located (Norman and Melious, 2004). The working group was instrumental in producing nutrient management strategies and an action plan which led to the creation of BC’s Environmental Farm Plan program which was discussed earlier. This working group continues to meet and the most recent minutes available are from mid-2015 (ANWG, 2015). At this meeting were several guests from U.S.A.

stakeholder groups, but the level of coordination between transboundary actors was not as prevalent as in earlier years of the effort to reduce contamination (ANWG, 2015).

3.4. Assessment and Reporting

3.4.1. Action Plan Key Initiative

Regular monitoring of water quality impacted by NPS pollution is required to direct preventative and remedial action. The BC Action Plan recommends modernizing field measurement methods and seeking partnerships and community volunteers to strengthen monitoring efforts. It states that monitoring allows stakeholders to adjust pollution controls. Reporting to the public on provincial water quality issues and trends can also play a key role in awareness (MoELP, 1999).

3.4.2. Assessment and Reporting on the ASA

There are a number of agencies currently monitoring the ASA on the Canadian side including Environment Canada, the provincial Ministry of the Environment, the Canadian Watershed Research Consortium as well as regular municipal well testing (Golder Associates, 2012).

Prior to 1990 Environment Canada performed limited testing in the area but over 63% of the wells that had been sampled had nitrate levels above the recommended limits. A groundwater monitoring program was therefore initiated to monitor spatial and temporal changes in the contamination and track its extent (Hii, Liebscher & Mazalek., 1999). The program involved 60 monitoring points at 26 locations (Zebarth et al., 2015). This data is not regularly published anywhere publically available but is issued periodically in reports. An additional 117 domestic wells have been included in the monitoring program when needed as well (Golder Associates, 2012).

The Fraser Health Authority has worked alongside the BC Ministry of Environment as well to monitor water quality from the ASA. They publically publish data from six wells on the MoE website as part of the Observation Well Network which dates back to the 1970s. Monitoring was fairly sporadic originally but since the early 2000s regular monitoring occurs. Five of these wells offer real time monitoring (MoE, 2016). According to an audit of MoE work to protect groundwater, the observation well network will be expanded with the addition of 50-75 observation wells over the next 15 years (Auditor General, 2010). This may increase the monitoring network over the ASA.

The Private Well Network, which is currently limited to the Township of Langley, is a community based initiative that encourages private well owners to conduct regular testing of their well water quality and share the results. Residents receive a discount on water testing when they agree to have their results included in the Private Well Network. The initiative attempts to empower well owners to improve their water quality and therefore protect common groundwater (ToL, 2016). A subsection of these wells overlay the ASA and therefore add to the monitoring network.

Field instruments and methods have also became more advanced over the past decades. Researchers are now attempting to use monitoring data to identify specific sources of nitrate in the groundwater to identify means of mitigating this contamination. Research has shown a relationship between high nitrate levels and intensive agriculture but they have not allowed for a direct link between the nitrate levels and individual farm scale management practices which would be ideal to improve BMPs (Wassenaar 1995; McArthur and Allen, 2005; Zebarth, 2015). Some researchers have begun constructing models to attempt to assess BMPs prior to their implementation (Kuipers, Zebarth & Ryan, 2013; Malekani, Ryan, Zebarth & Loo, 2011; Chesnaux, Allen & Graham, 2007). Modeling is difficult, however, as there are a number of factors that can affect the relationship between BMPs and nitrate leaching such as field size, rates of groundwater flow and climate variability that should also be considered when monitoring the impact of BMPs (Chesnaux, Allen & Simpson, 2011; Graham, Allen & Finkbeiner, 2014).

A recent study by SFU funded by the AEPI attempted to build a farm management history for the capture zones of several wells above the ASA (ASCA, 2007). There was evidence of likely connections between farm management practices and nitrate concentrations but it was difficult to obtain historic farm management practices to accurately study this relationship farther (ASCA, 2007). Ideally, moving forward farm management practices for areas overlying the ASA will be recorded so that monitoring information can take into account these practices as well as, how the factors mentioned above (i.e. climate, groundwater flow) impact nitrate contamination in order to determine which prevention strategies and BMPs are the most effective.

3.5. Economic Incentives

3.5.1. Action Plan Key Initiative

The Action Plan recommends the use of economic incentives to encourage the prevention of NPS pollution. Following BMPs may result in extra costs for producers and this needs to be recognized. Economic incentives can be a tool to encourage abidance (MoELP, 1999).

3.5.2. Economic Incentives Implementation for the ASA

The Environmental Farm Program, as discussed in section 3.2, allows farmers to apply for funding to improve their property through the Beneficial Management Practices Program. It is operated through the BC Agriculture Research and Development Corporation (ARDCorp). Funding and cost sharing incentives can be used for fencing, drainage, soil integrity, building upgrades, waste management, air quality control, emissions control or water control (ARDCorp, 2015). Funding come from *Growing Forward 2* which is the federal agricultural policy framework from 2013-2018. Between April and July, 2012, $220 500 was released for the EFP and $274 100 was released for the Beneficial Management Practices Program (Contributor, 2012). From July, 2014 until the end of the year, $2 233 477 was released for the EFP and BMPP (MoA, 2015).

There is detailed list on the program website of how much funding can be provided for various BMP projects, but in general each farm has a cap of $70 000 (ARDCorp, 2015). There is also the opportunity for multiple producers, all of whom have completed their EFP, to apply for funding for pooled projects such as to address water quality or nutrient management. As an added incentive, farmers who complete the EFP receive a sign to display to demonstrate their environmental sustainability which can help those producers who sell directly to the public (Shore, 2013) (Figure 4).

Figure 4. Logo for the BC Environmental Farm Plan Program

As of 2013, 4000 farms in BC (21%) has completed a plan which is the lowest participation rate across the country (Shore, 2013). However, the EFP was only rolled out in 2004 in BC and it was launched earlier in other provinces. The program is voluntary and many farmers who have smaller plots are generally thought to be less motivated to enroll (Shore, 2013). The Township of Langley has three quarters of its agricultural lands being relatively small, and according to the executive director of the BC Agricultural Council this makes these producers challenging to reach (Shore, 2013). It is unclear what percentage of farms over the ASA have utilized this resource.

3.6. Legislation and Regulation

3.6.1. Action Plan Key Initiative

When the action Plan was launched in 1999 there was no legislation in place to control groundwater and the *Water Act* was out of date. The action plan therefore covered many other types of legislation that could potentially impact NPS pollution. The action plan recommended implementing the Water Quality Provisions of the *Fish Protection Act*, the *Local Government Statutes Amendment Act* and the *Waste Management Act* in order to minimize NPS pollution. The plan also recommended the creation of a new agricultural NPS pollution management policy. It suggested that new legislation be created to fill gaps in the existing legislation (MoELP, 1999).

3.6.2. Legislation and Regulation Impacts on ASA

There is no one authority body or legislation with complete control over the protection and regulation of the ASA. There are a number of actors and legislation that control various aspects of its protection on both sides of the border (see Table 2). However progress has been made in terms of legislation since the release of the Action Plan.

Table 2. Federal and Provincial Regulation of groundwater in BC

Level of Legislation	Title of Legislation	Date entered into Force	Main goal in relation to groundwater
Federal	Canadian Environmental Protection Act	1999	Prevents pollution and protects the environment and human health from toxic substances
	Canada Water Act	1970	Enables government to monitor, collect data and establish inventories of water resources and designate water quality management agencies
	Fisheries Act	1985	Prohibits introducing deleterious substances in fish-bearing waters
Provincial	Agricultural Waste Control Regulation	1992	Ensure good agricultural practices are followed to protect groundwater and enhance and improve water quality
	Drinking Water Protection Act	2001	Ensures minimum water treatment and quality standards are being monitored and met to ensure British Columbians receive safe drinking water
	Environmental Management Act	2004	Regulates the introduction of waste into the environment
	Fish Protection Act	1997	Protect and remediate fish habitat
	Water Sustainability Act	2016	Aims to protect water resources so that a sustainable supply of fresh clean water will be able to meet the needs of current and future B.C residents

Federal

The Canadian *Environmental Protection Act* which came into force in 1999 aims to prevent pollution and protect the environment and human health through sustainable development (EPA, 1999). Other federal legislation which can protect groundwater include the *Canada Water Act,* which enables the federal government to work alongside provincial governments to manage water resource quality and the *Fisheries Act*, which prohibits pollution water that can impact fish habitat (CoCA, 2009).

Provincial

As noted throughout this report, agricultural practices have a significant impact on groundwater quality and agricultural regulation can therefore have a significant impact. The *Agricultural Waste Control Regulation* was first released in 1992 and describes agricultural practices for using, storing and managing agricultural waste in an environmentally sound manner. It was amended in 2004 and in 2008 to align with other regulations that had been released. Since 2009, it has been undergoing review in consultation with agricultural industry representatives, provincial ministries and other stakeholders. The BC Government intends to create a new policy, revise regulations under the *Environmental Management Act* and create new guidance documents, such as BMPs (MoE, 2015). Its policy goals include improving water quality, facilitating appropriate use and storage of manure and other nutrient sources and protecting groundwater. This policy aims to benefit farmers as well through the efficient use of nutrients from manure and other materials (MoE, 2015).

The *Environmental Management Act* was introduced in 2004 and replaced the *Waste Management Act* and the *Environment Management Act* (Golder Associates, 2012). This act contains provisions that prohibit individuals from introducing pollutants into the environment which would include all land owners above the ASA. The crown asserts ownership of the groundwater and regulates its use to some extent through the *BC Water Sustainability Act* and the *BC Drinking Water Protection Act*. The latter demands that drinking water quality must be protected and cannot be contaminated but does not state specific pollution prevention measures (Golder Associates, 2012). The *Fish Protection Act* also ensures that water sources that can impact fish habitat are not to be polluted.

Historically, the BC *Water Act* contained no regulations for groundwater. The *Environmental Assessment Act* demanded an assessment of any new wells that would extract more than 75 litres per second but that was the sole regulation regarding groundwater (Golder Associates, 2012). In 2005, *BC's Groundwater Protection Regulation* came into place which set standards for water well construction, maintenance and deactivation (*Water Act*, 2004). These provisions aim to protect well owners water supply and shared groundwater resources. However, the *BC Water Act* has recently been replaced, after many decades by the *Water Sustainability Act* (Figure 5). The act aims to address groundwater protection and regulation more comprehensively and grants the government more authority to regulate protection of the resource (BC, 2015b). The government solicited feedback from a wide range of stakeholders throughout the process and critics demanded that the government "include strict pollution controls, strong conservation regulations and stringent monitoring" (CoC, 2015). The first phase of regulations included the updated Groundwater Protection Regulation and the Water Sustainability Regulation were enacted on February 29th, 2016. The second phase of regulations will be announced later in 2016 (BC, 2016c). As noted earlier, one major change will be the requirement of non-domestic groundwater users to apply for licences and pay fees for their usage (BC, 2015b, BC, 2016b).

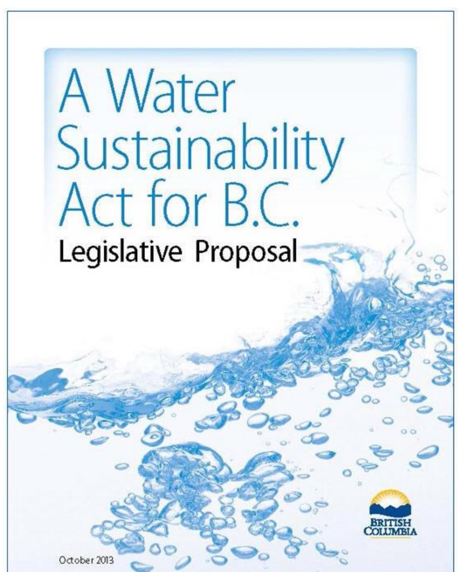

Figure 5. Cover for the Legislative Proposal for new BC Water Sustainability Act. The Act came into force on February 29, 2016.

The new Groundwater Protection Regulation integrates the past regulation with extra provisions to enhance well construction requirements, restrict new well pits, increase maintenance obligations for owners and require mandatory well reports (BC, 2016a). The regulations state that users need to ensure that no foreign matter is left within 3 m or travels to within 3 m of a water supply well (BC, 2016a).

Future regulations will include provisions for dedicated agricultural water as well as water sustainability plans (BC, 2016c).

Local

Local government has no formal regulations but they do have the ability to manage their resources through regulation of land use, zoning and municipal by laws. As noted above, local governments are somewhat limited in their control over land use and zoning due to the inclusion of large areas of land over the ASA in the ALR. The new *Water Sustainability Act* will include additional regulations, which are still under development, however that water sustainability plans can be created at the local water planning level in order to address the needs of various water users while protecting water quality (BC, 2016c). These new plans may become legally binding and offer local solutions that take into account the region and have the potential to be more responsive and implementable than federal or provincial legislation.

4. Discussion

The key initiatives prescribed by the BC Action Plan have all been implemented to some degree to minimize pollution of the Abbotsford-Sumas Aquifer. It is difficult to evaluate individually the effectiveness of the initiatives since they all share the same objective to reduce NPS pollution and it is difficult to attribute reductions in contamination to a particular initiative. Reduction in nitrate contamination is also a long term outcome and newer initiatives therefore may be difficult to evaluate at this stage. With these challenges in mind, the following section aims to evaluate if there were any implementation gaps for the various initiatives, what the major challenges were and how effective they have been at reducing pollution.

One challenge that impacts implementation of the majority of the key initiatives is the lack of unified governance body responsible for the ASA. As noted, a range of stakeholders at various levels are involved in its protection which means planning for interventions and financing is not necessarily well integrated. According to minutes from the ASASG, there is no way for a single stakeholder group or government agency to take lead on a groundwater management plan due to the various responsibilities to groundwater held by each stakeholder (ASASG, 2003b). They also note that all government agencies faced severe resource constraints so combining resources was needed (ASASG, 2003b). The collaborative nature of this governance and its intertwined funding can make its effort difficult to evaluate.

4.1. Education and Training

Various public awareness strategies have been implemented in the past few decades aiming at community members, businesses, governments and industry representatives. These strategies have included public fora, public signage, door to door campaigns and tabling at community events. Engagement with industry associations has also occurred to ensure they are aware of current regulations and to encourage their use of BMP. Evidence of strong implementation of this initiative therefore exists.

One challenge, as mentioned above, is that efforts are being made by a number of stakeholders, some with limited funding, and collaboration is therefore needed to ensure strong awareness campaigns. A collaborative approach with industrial actors is also required rather than just providing information. As current programs to reduce pollution are voluntary, it is essential that BMPs and other information shared with agricultural producers are current and partnered with support to improve uptake.

An evaluation by the Agriculture Environment Partnership Initiative found that public awareness in the region has increased public support of farmers and the contribution they make to environmental sustainability. There has been no formal evaluation to assess the initiatives effectiveness at ensuring higher public awareness and reducing non-point source pollution. There has been low enrollment in the EFP and low use of NMP but it is unclear whether this is due to lack of public awareness.

A thorough evaluation may be able to ascertain which subgroups of the population are aware of measures to protect groundwater and in particular how aware industries and farmers are of BMPs and programs like the EFP. An evaluation may be beneficial to focus future public awareness campaigns and enhance pollution prevention. It is expected that these education efforts will be strengthened and continue moving forward as education remains a key protection measure included in the water management plans for Langley and Abbotsford.

4.2. Prevention at the Site

Initial BMPs to reduce nitrate contamination had high levels of uptake and implementation. BMPs have been created and released for a wide range of industries and agricultural producers, such as auto recyclers and berry farms. Significant progress was made in terms of manure management. More recent BMPs such as NMP and the EFP program have shown much lower levels of implementation however. New regulations that regulate groundwater use were brought into force several weeks ago therefore implementation is just beginning.

These low levels of implementation of the EFP program may be due partly to lack of awareness but economic cost was also perceived as a major barrier to agricultural producers.

Another challenge has been that some of the BMPs promoted and used were ineffective at reducing nitrate contamination. For example, early BMPs for the raspberry industry included switching from manure to inorganic fertilizers. However research is now showing that this did not reduce nitrate contamination but merely switched the source of the pollution. This can lead to frustration in agriculture producers who spend time and money on these BMPs if the desired results are not achieved. As noted in the above section, engagement with producers and industrial groups in the developments of these BMPs is important to encourage high levels of implementation. Another major challenge is accurately evaluating the impact of BMPs on nitrate contamination short term. It is therefore essential that new BMPs be regularly monitored and that new modeling tools that can account for additional factors be developed in order to accurately determine their impact on nitrate contamination.

Thus far, BMPs have not been very effective at reducing NPS pollution but as new research methods are being developed to directly monitor the impacts of BMPs on groundwater it is hopeful that new BMPs will minimize nitrate contamination.

4.3. Land Use Planning, Coordination and Local Action

Land Use Planning was difficult to implement due to the ALR. However, a water management plan has been drafted for Langley and a groundwater management strategy has been created for Abbotsford; however only the former was under review to become legally binding. They are both currently halted while new regulations are drafted for water sustainability plans. In regards to coordination and local action, there was strong implementation at the turn of the century with the creation of the ASAITF and the ASASG but recently there has been reduced coordination among actors across the border. There is still evidence of some cross border collaboration such as the recent attention of the IJC to the ASA and the launch of collaborative pilot projects. Even though it appears that that in recent years there has been relatively less coordination ongoing, there is still the prospective for the regrowth of these coordinating bodies.

Challenges with coordination and local action include the need to account for the diverse needs and priorities of many stakeholders. For example, the most recent groundwater forum attempted to decide on three main priorities to reduce nitrate contamination but certain industrial groups were still not in agreement with the final choice as they felt the agricultural producers' perspective was not adequately taken into account. The lack of progress at reducing nitrate contamination may also have led to a lack of motivation which could be a challenge to resilience of coordinating bodies and have played a role in the lack of attendance of some ASAITG and ASASG meetings. Budget cuts and changes in staffing can also impact involvement in voluntary collaborative projects. The need to integrate the priorities of various stakeholders is also a challenge in the creation of water management plans that adequately protect groundwater from NPS pollution,

Coordination and local action have been effective at building partnerships, sharing knowledge and launching pilot projects. However, their effectiveness at limiting nitrate contamination is still low since a significant reduction has yet to be seen. The water management plans are too recent to evaluate their effectiveness, as they have yet to be fully implemented.

4.4. Assessment and Reporting

There has been implementation of regular monitoring of groundwater in the ASA but reporting has not been as comprehensive. There are some publically available databases that provide information but data collected from all sources is not published online. More advanced monitoring methods have begun to be implemented as researchers enhance the ability to monitor groundwater contamination to identify its source.

One major challenge is integrating data from the number of sources currently monitoring the ASA. In addition, integration of data from BC with data from Washington poses an additional challenge. Researchers have identified particular barriers in this challenge including different data formats and quality, database structure and the need for cooperation (Schuurman, Deshpande & Allen, 2008). Another challenge is the difficulty definitively linking NPS pollution to its source.

This initiative has been effective in that it has provided some evidence regarding the efficacy of various preventative measures at mitigating NPS pollution. Feedback on some initiatives were not as timely as required but monitoring challenges posed this barrier to efficacy.

4.5. Economic Incentives

Economic incentives have primarily been implemented through the EFP and BMP program. These programs have yet to gain widespread implementation across BC, and the region overlying the ASA.

Major challenges likely includes lack of awareness of the public and ecological health impacts of nitrate contamination, but also a lack of interest of agricultural producers due to added bureaucracy, or to avoid a risk assessment that may potentially demand they switch their current practises. Farmers may be wary that BMPs could hurt them economically if compliance reduces their crop yield or quality. It is challenging that these programs are voluntary, therefore producers need to see the incentives outweighing any potential costs. It is also a challenge that the funding for these programs only goes until 2018. This could pose a challenge if implementation of economic incentives ends after that period. Cost is a major barrier to the implementation of BMPs and offering economic incentives is therefore essential.

It is difficult to effectively evaluate the use of economic incentives as they have yet to be widely implemented across the ASA. However, even if they were well implemented, it would be essential to ensure BMPs being promoted can be linked to significant reductions in nitrate contamination. However, economic incentives will likely be necessary to ensure that future BMPs which can mitigate pollution will be taken up by agricultural producers.

4.6. Legislation and Regulation

There have been improvements to regulations to reduce non-point source pollution over the ASA. The Agricultural Waste Control Regulation is currently being updated, the *Environmental Management Act* was introduced and the provincial *Water Act* has been replaced with the *Water Sustainability Act* which aims to strengthen groundwater regulations.

A major challenge to this process, similarly to the creation of water management plans, is the diversity of stakeholders with varying priorities and perspectives on the creation of these regulations. Public consultation and engagement with various actors during the updates to these pieces of legislation has been significant but it is challenging to integrate all of the feedback. The

Water Sustainability Act in particular has replaced the *Water Act* which was in effect for over a century and this new piece of legislation is therefore a significant change for the province with significant expectations from many actors. Major challenges after the all the regulations are finalized, however, will include raising public awareness, as well as, developing an effective mechanism of enforcement.

Many of these new improvements to these legislation have yet to be fully implemented, yet alone enforced, so it is also difficult to ascertain their effectiveness but they all show promise to reduce pollution, improve management of nutrient sources and regulate protection of groundwater.

5. Recommendations

Even after several decades of efforts to mitigate nitrate contamination of the ASA, minimal improvements have been seen. Regardless, all of these efforts have added to the knowledge base regarding reducing NPS pollution from agricultural sources and will aid future efforts to mitigate contamination of the ASA as well as other sources of groundwater. There is currently significant attention on water quality in BC due to the recent revisions to the *Water Act* and increasing global pressure on water resources due to overuse, pollution and climate change, and this momentum can be drawn upon to further efforts to mitigate NPS pollution of the ASA. The following four recommendations serve to guide efforts in BC, and particularly the region surrounding the ASA on effective measures to mitigate NPS pollution and improve groundwater quality.

5.1. Strengthen the Implementation of Beneficial Management Practices

The Environmental Program offers incentives to agricultural producers to increase uptake of beneficial management practices on their farms. These programs should have significant campaigns to raise awareness of their benefits throughout Langley and Abbotsford. If there remain additional barriers to implementation then efforts should be made to collaborate with producers to ensure the benefits outweigh the cost. This may involve additional economic incentives.

This implementation should be paired with effective monitoring as well that can collect data on the efficacy of specific beneficial management practices at reducing nitrate contamination so that the implementation and monitoring serves as a feedback loop.

5.2. Ensure Strong, Effective Legislation and Tight Enforcement

The Agricultural Waste Control Regulation and new groundwater regulations in the *Water Sustainability Act* both hold promise of having a significant impact on the reduction of groundwater pollution. As these two pieces of legislation are undergoing revisions it is essential that all stakeholders engage and provide their perspective in order to ensure thorough legislation is created. It is also essential, however, that there are no concessions made regarding the demand for strict pollution controls and stringent monitoring.

The voluntary approach that has been utilized to date to limit NPS pollution has not been effective. Therefore, to ensure these pieces of legislation have a significant impact they will also need to be paired with strong public awareness, monitoring and tight enforcement.

The work done thus far on the water management plans for Abbotsford and the Township of Langley should be utilized to create water sustainability plans under the new Water Sustainability Act once new regulations are introduced and the plans therefore made legally binding. This should provide additional safeguards against groundwater pollution and ensure local solutions are being implemented that take into account the socioecological and economic realities of the local water source.

5.3. Increase Coordination and Commitment of Stakeholders

Diverse stakeholders such as industry groups, various levels of government and the community all have different priorities and bring different knowledge bases to efforts to mitigate NPS pollution. Effective coordination among these various actors is needed to find workable, efficient and sustainable solutions. Coordination of local actors ensures that solutions are relevant and appropriate for the local situation. Coordinating bodies exist in this case, the ASASG and the ASAITF and the increased commitment of stakeholders to these efforts is required to ensure the other recommendations are upheld. A strong collaborative effort will be the most effective at ensuring the successful implementation and enforcement of legislation and BMPs. Public fora allow space for stakeholders to integrate pollution mitigation efforts and determine what actions they can take, their level of involvement and what they can contribute to efforts to mitigate pollution.

5.4. Increase Public Awareness

Public awareness on the health and ecological impacts of groundwater pollution, the importance of protecting groundwater and strategies for its protection is necessary so that polluters can have the necessary skills to make informed decisions and have the capacity to take actions to reduce their polluting activities. This recommendation plays a key role in all of the others. Promotion of BMPs will require industrial groups and agricultural producers to have a thorough understanding of the benefits of BMPs and what support exists to ease their use. Community members also need to be aware of ongoing revisions to key pieces of legislation so that they can play an active role in providing feedback. After legislation is finalized it will also require public campaigns to ensure all those impacted have a clear understanding of their responsibilities under these regulations. Through active engagement with the general public, collective efforts to protect groundwater from NPS pollution can be strengthened. This will also increase coordination and commitment of stakeholders.

6. Conclusion

The Abbotsford-Sumas aquifer demonstrates how challenging it can be to reduce non-point source pollution, specifically from agricultural sources. Significant efforts have been made in the past few decades to mitigate nitrate contamination with marginal success. There are a number of aquifers across British Columbia and the world that face similar issues and the successes and failures of the efforts made in this case study can be of use to others facing similar challenges. Key recommendations from this local context included increasing implementation of Beneficial Management Practices (BMPs), stricter legislation and tighter enforcement, increased coordination and commitment of local stakeholders and increased public awareness. As global pressure on water resources increases, prioritizing collaborative efforts to protect our shared natural resources becomes even more urgent.

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Appendix A. Reflection

Through this capstone process I have had the opportunity to drawn on knowledge and experience from my academic coursework, as well as my practicum in order to explore my role as a public health practitioner facing a local environmental health management issue. As noted throughout the capstone, pressure on water resources is increasing globally as well as locally and various stakeholders at a range of levels need to work collaboratively find a solution to protect public health. As efforts continue to reduce pollutions of the ASA, the aim is that this document can serve as a synthesis of material from many sources that can prove valuable to current and future researchers and public health practitioners in this area.

Throughout the MPH coursework, an emphasis was placed on utilizing systems thinking in order to explore the dynamic interactions between humans and social systems and this skill was required when considering the many groups impacted by pollution of the ASA. Courses also explored identifying appropriate partners to address public health issues. This was a key factor in identifying the many actors trying to mitigate NPS pollution of the ASA. Community organization and empowerment was also emphasized and this was apparent in the region surrounding the ASA. In one course the link between environmental factors and negative health outcomes was explored which was useful throughout this process. Major skills utilized throughout the program that were required for this project included critically analyzing and synthesizing literature and evaluating potential program and policy options to improve public health.

Many of these skills were utilized throughout my practicum experience where I worked for an environmental non-governmental organization. Through that project I also synthesized background research, identified and built appropriate partnerships with stakeholders around an environmental management issue and evaluated potential policy and program options to provide high quality recommendations. This experience was international in keeping with my concentration in global health but many of the skills and knowledge bases that were required transferred between the two regions.

This capstone process has therefore allowed me to utilize skills and experience developed through this program and explore how I can utilize them as a public health practitioner. Moving forward I would like to continue working in the field of environmental health and this process helped solidify this for me and build confidence in the skills and knowledge I have gained throughout my MPH.