Towards a tailored vision of water security in the North: A case study of the Inuvialuit Settlement Region in the Canadian Arctic

by

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ABSTRACT

Globally, the interest in water security is on the rise. Canada is fortunate to have an abundance of freshwater, and almost 20% of this is found in the Northwest Territories (NWT). Particular concern for the implications of climate change on the Mackenzie Delta, and the influence of land claims on water governance, make the Inuvialuit Settlement Region (ISR) in the NWT an important case study. Using a systematic literature review, thematic content analysis of 116 documents was conducted to understand how water is used and managed across scales in the ISR. A number of unique challenges emerged for the ISR in comparison to the Canadian water security context. Thus, a more tailored vision of water security needs to account for: cultural practices and well-being tied to uses of water/snow/ice, financial and capacity challenges related to remote locations, Indigenous land claims and governance complexities, ice as infrastructure, and high latitude sensitivities to climate change and contamination.

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AANDC – Aboriginal Affairs and Northern Development Canada
AEMP – Aquatic Effects Monitoring Program
CCME – Canadian Council of Ministers of the Environment
CEAA – Canadian Environmental Assessment Agency
CEAM – Cumulative Effects Assessment and Monitoring Program
CIMP – Cumulative Impact Monitoring Program
DAAIR – Department of Aboriginal Affairs and Intergovernmental Relations
DFO – Fisheries and Oceans Canada
EC – Environment Canada
EIRB – Environmental Impact Review Board
EISC – Environmental Impact Screening Committee
ENR – Department of Environment and Natural Resources
FJMC – Fisheries Joint Management Committee
GLWB – Gwich'in Land and Water Board
GNWT – Government of the Northwest Territories
HC – Health Canada
HSS – Department of Health and Social Services
HTC – Hunters and Trappers Committee
ICC – Inuvialuit Community Corporation
ICCP – Inuvialuit Community Conservation Plan
ICSP – Integrated Community Sustainability Program
IFA – Inuvialuit Final Agreement
IGC – Inuvialuit Game Council
ILA – Inuvialuit Land Administration
INAC – Indian and Northern Affairs Canada
IRC – Inuvialuit Regional Corporation
ISR – Inuvialuit Settlement Region
IWB – Inuvialuit Water Board
LUSF – Land Use Sustainability Framework
MACA – Department of Municipal and Community Affairs
MVEIRB – Mackenzie Valley Environmental Impact Review Board
MVLWB – Mackenzie Valley Land and Water Board
NEB – National Energy Board
NWTWS – Northwest Territories Water Strategy
PC – Parks Canada
PWS – Department of Public Works and Services
SWAP – Source Water Assessment and Protection Plan
TC – Transport Canada
TK – Traditional Knowledge
WMAC (NWT) – Wildlife Management Advisory Council, Northwest Territories
WMAC (Yukon) – Wildlife Management Advisory Council, Yukon

CHAPTER 1: INTRODUCTION

Water is a natural resource upon which all life on Earth depends. As there is no substitute, water conservation and management is vital to the survival of all species on the planet, including humans. The United Nations recognizes water as a basic human right (Gordon Foundation, 2011). In Canada, the federal government acknowledges the importance of freshwater for satisfying basic human needs, economic development and sustaining the natural environment (Environment and Climate Change Canada [ECCC], 2013).

Less than one percent of the water on the planet is available as freshwater, but this is further reduced by pollution, which makes water unfit for human use (Cott, Sibley, Murray Somers, Lilly & Gordon, 2008). Canada is fortunate to have an abundance of freshwater: approximately 20% of the global freshwater supply and about 7% of the world's total renewable water (Brisco, Short, van der Sanden, Landry & Raymond, 2009; Schindler & Smol, 2006). Almost 20% of Canada's freshwater (133 300 km^2) is found in the Northwest Territories (NWT) and Nunavut, most of which is concentrated in lakes, not including the glaciers on territorial land and Arctic islands (165 000 km^2) (Prowse, Furgal, Bonsal & Peters, 2009). Most renewable water in the North is found within the major river networks that originate in southerly headwaters (Prowse *et al*., 2009).

While water is in abundance, the widely dispersed and remote nature of northern communities presents a unique challenge to the continual treatment, distribution and management of water resources. Some challenges facing northern Inuit communities include: a changing landscape as a result of climate change, the threat of pollution and contamination of water resources, the remoteness and small populations of northern communities, and challenging terrain (Furgal & Seguin, 2006; Prowse & Furgal, 2009; Rouse *et al*., 1997; Schindler & Smol, 2006). Increased temperatures as a result of climate change may impact the landscape in numerous ways, such as: reducing the length of the snow season, reducing seasonal run-off, altering the timing of peak flow and increasing the length of the ice-free season (Rouse *et al*., 1997; Vincent & Pienitz, 1996).

Arctic deltas, such as the Mackenzie Delta, are particularly sensitive to climatic changes, which affect the hydroclimatic conditions that control ice break-up and jamming, the main source of recharge for many arctic lakes (Goulding, Prowse & Bonsal, 2009; Schindler & Smol, 2006). The sensitivity of the landscape to changing climatic conditions has an impact not only on water but also the communities living in the Delta. Four of the six Inuvialuit (Western Canadian Inuit) communities that make up the Inuvialuit Settlement Region (ISR) are located within the Mackenzie Delta, while the other two are found in the Arctic Archipelago (Figure 1.1). In the ISR, water is managed at multiple levels of jurisdiction, including: federal, territorial, municipal, local (individual), and under the Inuvialuit Final Agreement (IFA). The IFA is the Comprehensive Land Claim Agreement (CLCA) between the Inuvialuit, Canada and the Northwest Territories that addresses the land and water rights of the Inuvialuit in the northern Northwest Territories and the northern Yukon (INAC, 2010a). Water in this region has supported many generations of Inuvialuit (Community of Inuvik, Wildlife Management Advisory Council [WMAC] (NWT) & Joint Secretariat, 2008). Changes that have the potential to disrupt the ability to distribute freshwater resources among northern populations challenge water security in remote Inuit communities, such as the Inuvialuit communities located in the Mackenzie Delta and Arctic islands.

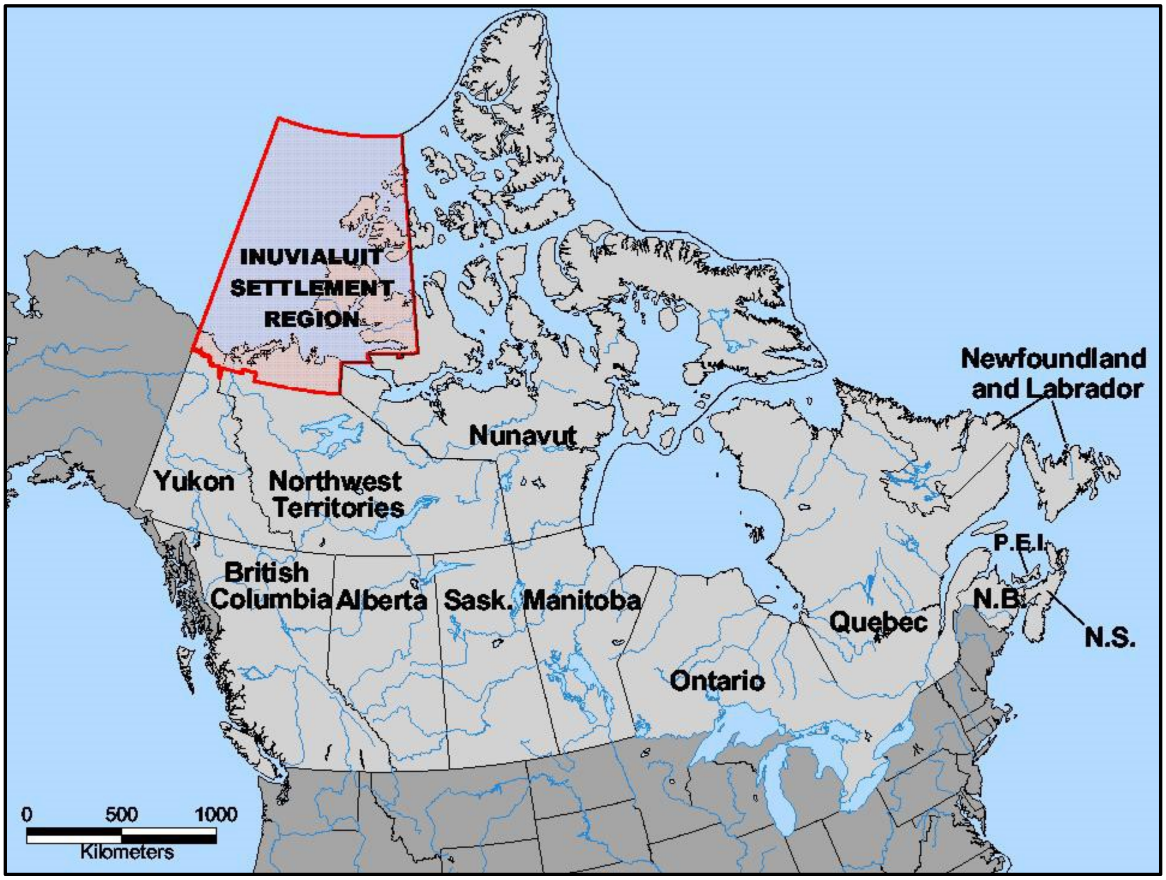

Figure 1.1 Map of the Inuvialuit Settlement Region relative to the rest of Canada. (Environmental Impact Review Board, N.D. a).

The concept of water security is relatively new in academia (Bakker, 2012). In Canada, water security has been broadly defined as the "availability of water in adequate quantity and quality in perpetuity to meet domestic, agricultural, industrial and ecosystem needs" (Cook & Bakker, 2012, p. 97). This thesis uses a systematic literature review to explore the concept of water security in a northern context. The ISR was chosen as a case study because of the unique environmental challenges associated with its location, the fact that the ISR was the first comprehensive land claim to be settled in the Canadian Arctic, and personal interest in the region. Systematic literature reviews of academic and grey literature are useful for identifying key themes and gaps in understanding in the literature (Ford & Pearce, 2010) The main goal of the thesis is to refine the broader concept of water security provided by Cook and Bakker (2012) to arrive at a more tailored vision for water security in the ISR that accounts for the environmental, economic, socio-cultural and political conditions of the region. The following objectives are designed to help achieve this goal:

- Determine the relevant governing bodies and their responsibilities with regards to water in the ISR;
- Characterize how water is used and managed across different scales relevant to the ISR, accounting for key environmental, economic, cultural, social, and health considerations in the region; and,
- Identify water security challenges unique to the ISR.

The objectives of this thesis are addressed in five chapters. Chapter 2 provides important context about the ISR and the general concept of water security. It begins with some background on the ISR, including occupation of the region and an explanation of the land claim agreement and its implications related to water management. The second section addresses water management, including how water governance is understood in the Canadian context, ideas about how water should be managed and challenges in water management planning and implementation. The final section explores the concept of water security, how it is defined and its social and environmental impacts. Chapter 3 outlines the theoretical context and methods used in the systematic literature review and thematic analysis of the content. This chapter begins by describing political ecology (PE), the theoretical perspective that helped formulate this project, and how some of the core concepts were used in the analysis to aid with the overall objectives. Building on this foundation, the remainder of the chapter describes the approach used in the collection and analysis of the literature. Results emerging from the systematic literature review within the main themes are addressed in Chapter 4. Chapter 5 contains a discussion of the themes, tying together the common concepts emerging across them. This is done through a comparative analysis of Canadian perspectives with unique challenges highlighted through the literature related to the ISR (Norman, Bakker & Dunn, 2011). Finally, Chapter 6 aims to articulate the more tailored vision of water security, highlighting important insights learned from the literature and recommendations for future research directions.

CHAPTER 2: BACKGROUND

2.1 INUVIALUIT SETTLEMENT REGION

The Inuvialuit have long occupied the Western Arctic lands. The Western Arctic has been home to the Inuvialuit for a thousand years (Morrison, 2003). The Inuvialuit are descendants of the Thule people who spread across the Arctic islands from Alaska at the beginning of the first millennium (White, 2009). More recently, they are descendants of the Alaskan Iñupiat and Mackenzie Delta Eskimos (Urlbacher-Fox, 2009). The population of the Mackenzie Delta Eskimos fluctuated throughout the 1800s as a result of disease epidemics, such as influenza and tuberculosis, to near extinction in the early 1900s, at which point the Alaskan Iñupiat moved into traditional territories for hunting and trapping purposes (Urlbacher-Fox, 2009; Morrison, 2003).

Today, Inuvialuit engage in a combination of wage and subsistence based activities. Hunting, fishing and trapping hold great cultural significance and remain important sources of low-cost, nutritious food for the region and people (Morrison, 2003; White, 2009). They speak English or Inuvialuktun but practice of the traditional language is declining, despite programs operated by the Inuvialuit Regional Corporation (IRC) and the GNWT to improve language use (Urlbacher-Fox, 2009; White, 2009). Inuvialuit communities are not experiencing as rapid a population growth as other northern communities; most communities with reliable data are either stable or declining in population (White, 2009). However, they maintain active memberships in national and international organizations, such as the Inuit Tapiriit Kanatami (ITK) and the Inuit Circumpolar Council (ICC) (Urlbacher-Fox, 2009).

The ISR was created with the signing of a comprehensive land claim agreement, The Western Arctic Claim: Inuvialuit Final Agreement (IFA), between the six Inuit communities and the federal government in 1984 (Pearce *et al*., 2010; GNWT DAAIR, 2011b; Wootton *et al*., 2008). The six communities in the ISR include: Inuvik, Paulatuk, Aklavik, Tuktoyaktuk, Sachs Harbour, and Ulukhaktok (Figure 2.1) (Government of the Northwest Territories [GNWT]. Department of Aboriginal Affairs and Intergovernmental Relations [DAAIR], 2011b; Urlbacher-Fox, 2009; White, 2009; Keeling, 1989). The largest of the six communities is Inuvik, with almost half of the population residing there (3,265 permanent residents in 2015) (GNWT Bureau of Statistics, 2016).

The IFA was a result of a settlement between the Inuit of the NWT, the GNWT and the federal government. This agreement dealt with issues such as land and harvesting rights, environmental and wildlife management, boundaries of the settlement area, applications of laws, and resource management (Inuvialuit Final Agreement [IFA], 1984; GNWT DAAIR, 2011b; GNWT, 1998a). The boundaries of the ISR cover much of the land originally occupied by the Inuvialuit, including: the northern part of the Northwest Territories, Banks Island, part of Victoria Island and the Parry Islands, some of the Beaufort Sea, and the northern tip of the Yukon Territory (Figure 2.1) (Keeling, 1989).

The IFA was the first comprehensive land claim agreement settled for a region whose territory falls completely in the Canadian Arctic (Ayles & Snow, 2002; Cournoyea, 2009) and the first to include both surface and sub-surface land ownership and beds of water bodies (Pearce *et al*., 2011). Land claims are land and resource agreements negotiated under the federal Comprehensive Land Claims Policy (GNWT DAAIR, 2011b). The purpose of comprehensive land claim agreements is to clarify rights

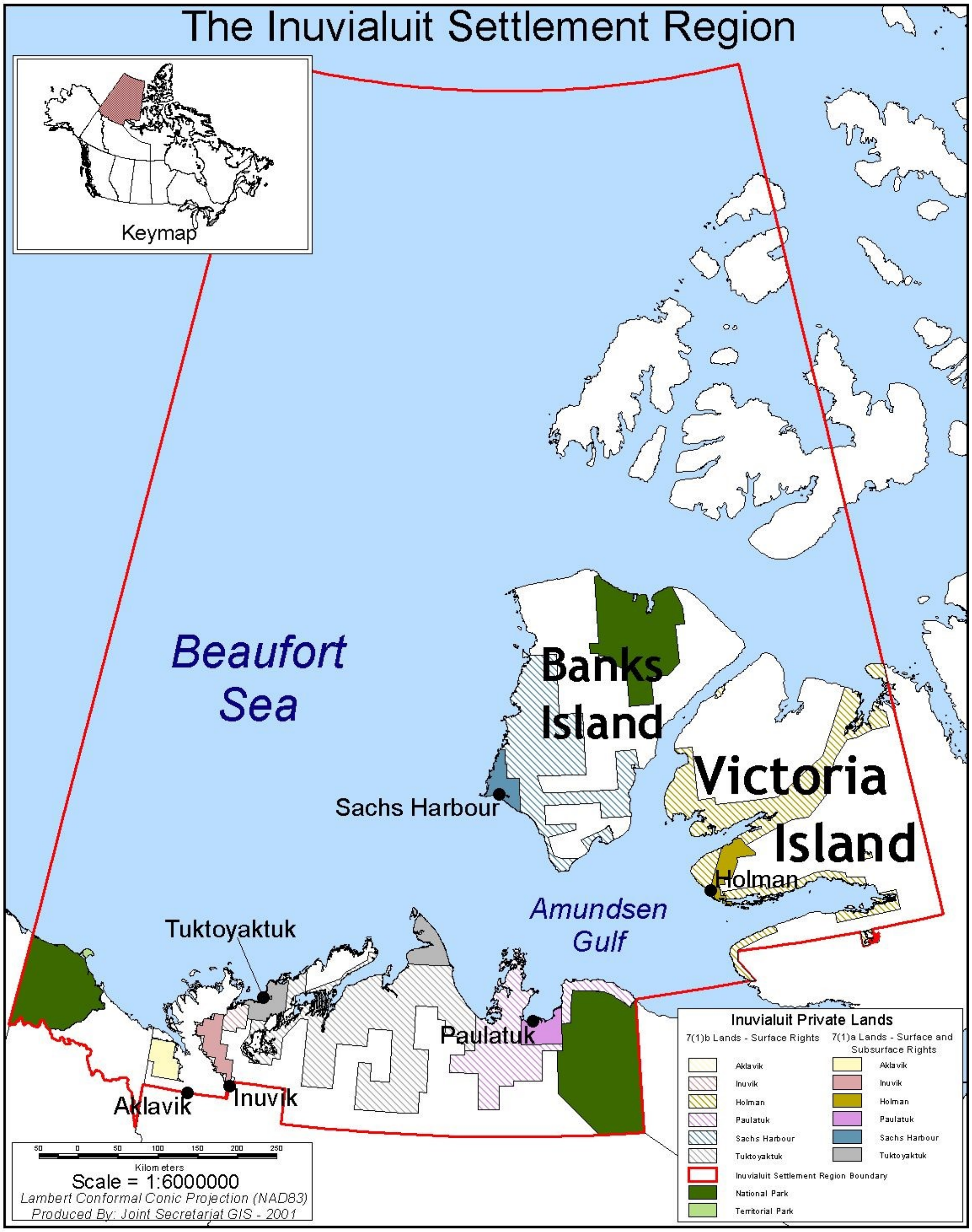

Figure 2.1: Map of the Inuvialuit Settlement Region communities and private lands (Environmental Impact Review Board, N.D. b).

in regards to ownership of land and resources, use of land and resources, rights related to environmental management, economic development, hunting, fishing and trapping , and often involve some type of financial payment and outline how resource revenues are to be shared (GNWT DAAIR, 2011c). Final agreements outline the legal obligations of each of the parties and are legally binding (GNWT DAAIR, 2011c; Rosenberg Forum, 2009). Land claims and self-government agreements allow Indigenous peoples to develop some of their own laws, regulations and policies (GNWT DAAIR, 2011a).

In the IFA, the legal title of approximately 216,000 square kilometers of land were transferred to the Inuvialuit (IFA, 1987; Keeling, 1989; White, 2009). As per the agreement, the Inuvialuit received only surface rights to some of these lands, including the beds of water bodies, and in others both surface and sub-surface rights, including mineral resources. However, they did not receive ownership of the water bodies nor the exclusive rights to fish and other resources in the water bodies (IFA, 1987; Keeling, 1989). Most of the ISR lies above the treeline; the mainland is mostly low-lying and flat while the islands have high cliffs and wide plains (White, 2009).

The IFA addresses water specifically in a couple of ways. Firstly, it addresses the representation and participation rights of the Inuvialuit in the land use planning process. Rights granted under this section include equal representation of Inuvialuit representatives to government representatives in land use planning for the Beaufort Sea Region and any other regions adjacent to the ISR which would directly impact Inuvialuit interests (IFA, 1984). The second section of the IFA dealing specifically with water is the section on land management. This section outlines the management responsibilities of both the Inuvialuit and the federal government, addresses the rights surrounding access to water and the use of waters, waterways, beds of rivers, lakes and water bodies. In general, the federal government retains management rights for several purposes in the region, including:

- management of fish, migratory game birds, migratory non-game birds, and migratory insectivorous birds and their habitat;
- carrying out government functions related to navigation, transportation, flood control or other similar matters;
- establishing and operating new meteorological and climatological stations (subject to compensation); and,
- controlling the use of some waters and water beds and adjacent lands to ensure the protection of community water sources from contamination (IFA, 1984).

The Inuvialuit, represented by the Inuvialuit Regional Corporation (IRC), are also in the process of negotiating a self-government agreement with the Government of the Northwest Territories (GNWT) and Canada that would give them more control over their territory (GNWT DAAIR, 2011b). Self-government agreements are generally negotiated at a community or regional level under the federal Inherent Rights Policy (GNWT DAAIR, 2011b). The self-governance negotiations began as a joint venture in 1996 when both the Inuvialuit and Gwich'in signed the Beaufort/Delta Self-Government Negotiations Process and Schedule Agreement, which eventually led to a self-government Agreement-in-Principle in 2003. The Gwich'in are a First Nation group whose traditional territory spans across the NWT, Yukon and Alaska, and whose land claim overlaps with the ISR in Aklavik and Inuvik. During negotiations in 2005, the Gwich'in Tribal Council decided to disengage from the negotiations while the Inuvialuit chose to continue negotiations, resulting in a new Inuvialuit Self-Government Negotiations Process and Schedule Agreement in 2007 (GNWT DAAIR, 2011b). As of 2015, the Inuvialuit have now signed an Agreement-in-Principle (INAC, 2015).

2.2 WATER MANAGEMENT

One of the main issues in dealing with water governance is that the term governance itself is a broad and loosely defined concept. Across disciplines, "governance" has generally been used to describe government. In Human Geography however, the definition of governance is extended to include "the sum of the many ways individuals, institutions, public and private, manage their common affairs… and encompasses the activities of governments, but also includes the many other channels through which "commands" flow in the form of goals framed, directives issued, and policies pursued" (Weiss, 2000, p. 796). Tortajada (2010) also describes governance as a "complex process that considers multi-level participation beyond the state, where decision-making includes not only public institutions, but also the private sector, civil society and society in general" (p. 298). In this broad sense, governance goes beyond government to include other key actors such as NGOs, public interest groups and the general public.

Water management and the potential for water crises are a global concern. Increasingly, governance and politics are being seen as both the problem and the solution for water crises (Tropp, 2007). In light of this view, a robust and widely applicable definition for water governance is needed. However, since the term governance itself is still evolving, so too is the definition for water governance. The Global Water Partnership (GWP) describes water governance as "the range of political, social, economic and administrative systems that are in place to develop and manage water resources, and delivery of water services, at different levels of society" (Rogers & Hall, 2003, p. 7). Tortajada (2010) adds to that definition by also describing water governance as being concerned with the ways in which institutions operate and their subsequent impacts on political actions and societal concerns. In other words, water governance is concerned with the internal functions, balances and structures of the water sector (Rogers & Hall, 2003) as well as the process of decision-making, both horizontally between the urban and rural sectors, and vertically from the local to international scale (Tropp, 2007).

There are a number of schools of thought about the way in which water should be managed or governed. Some believe that the governance of water should be dealt with at a local level, as one would need to understand the needs and rights of the local residents in order to effectively address issues, while others believe it should be governed at a national level, for the benefit of the national economy (Pahl-Wostl, Gupta & Petry, 2008). Furthermore, there are those who believe that water should be governed at the basin level, which would provide the opportunity to address issues based on the natural, physical boundaries of the geographic landscape (Pahl-Wostl *et al*., 2008). Still, others believe that water should be governed at a global level (Hoekstra, 2006; Pahl-Wostl, Holtz, Kastens & Knieper, 2010). This school of thought came about, in part, due to the fact that "a large proportion of watersheds are transected by international boundaries" (Norman & Bakker, 2009, p. 103).

The GNWT is moving towards Integrated Watershed Management (IWM), a system that requires individual local resource management decisions to be evaluated based on an overall set of coordinated water management goals that consider all water uses and water values throughout a watershed (GNWT ENR & INAC, 2008; GNWT ENR, 2014). This system strives to account for the risk and uncertainty of different management decisions based on the precautionary principle (GNWT ENR & INAC, 2008). Fundamentally, the different schools of thought about water governance are differentiated primarily by the spatial scale at which they think water governance should take place.

As Moss and Newig (2010) point out, the field of water management is particularly sensitive to spatial scale as the biophysical and hydrological processes that impact the quality and availability of water can range from a small catchment to a large river basin. Other issues related to scale, particularly in Canada, are associated with the multiple levels of governance (i.e. federal, provincial, local). Bakker and Cook (2011) refer to this as jurisdictional fragmentation because both federal and provincial governments share authority over water in Canada. This is particularly problematic since these levels of government do not generally fit the relevant physical scales at which they are intended to govern (Moss & Newig, 2010). Further complicating the already fragmented structure of governance is the fact that many of the water management initiatives in Canada are community-based and involve local actors (Norman & Bakker, 2009). In fact, the water supply in Canada is largely managed at the municipal level, which has resulted in: a higher degree of decentralization of water management than other areas of resource management in the country; a duplication of efforts; poor data collection and sharing; and, inadequate monitoring and enforcement (Bakker & Cook, 2011). The issue of scale for water governance, including rescaling, is critical for management and is explored in greater depth in later chapters.

A further consideration for the water management in the ISR is the issue of devolution, which resulted in changes to the political structure of the NWT and the ISR (GNWT, 2012a). Devolution is the transfer of ownership and responsibility of natural resources from the federal government to a territorial or provincial government, in this case the GNWT (GNWT DAAIR, 2011a). The process of negotiation took several years and came into effect on April 1st, 2014 (GNWT Devolution, N.D.), within the timeframe of this thesis research. This means a reduced role for the federal government and an increased role in water management for the GNWT. The GNWT is assuming the obligations of the federal government with respect to land and resource management in the NWT. For example, the GNWT is taking responsibility for the management and remediation of waste sites wholly created after the transfer date, while the federal government remains responsible for the management and remediation of waste sites created wholly before the transfer date (INAC *et al*., 2013). In the event that any part of the devolution agreement is in conflict with pre-existing land claims or self-government agreements, the conditions of the land claim or self-government agreement would take precedence (INAC, 2013). This means that the water management structure in the ISR will not change at the land claim level, but that its level of interaction with the GNWT in negotiating water management challenges will increase.

2.3 WATER SECURITY

Much like water governance, water security is a loosely defined term of which there are many different explanations. Water security is generally described as the measurement of the level of accessibility of a reliable quantity and quality of water for health and livelihood (Grey & Sadoff, 2007). Some definitions, such as that provided by Cook and Bakker (2012) (Chapter 1), are kept intentionally broad so as to remain inclusive. Narrower, operational definitions of water security can then be developed to account for the geographic and political distinctions of a given region (Cook & Bakker, 2012). One of the most comprehensive definitions of water security is that provided by the United Nations (UN)-Water (2013), which accompanies a diagram depicting the interconnected challenges associated with achieving water security (Figure 2.2):

> "The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability."

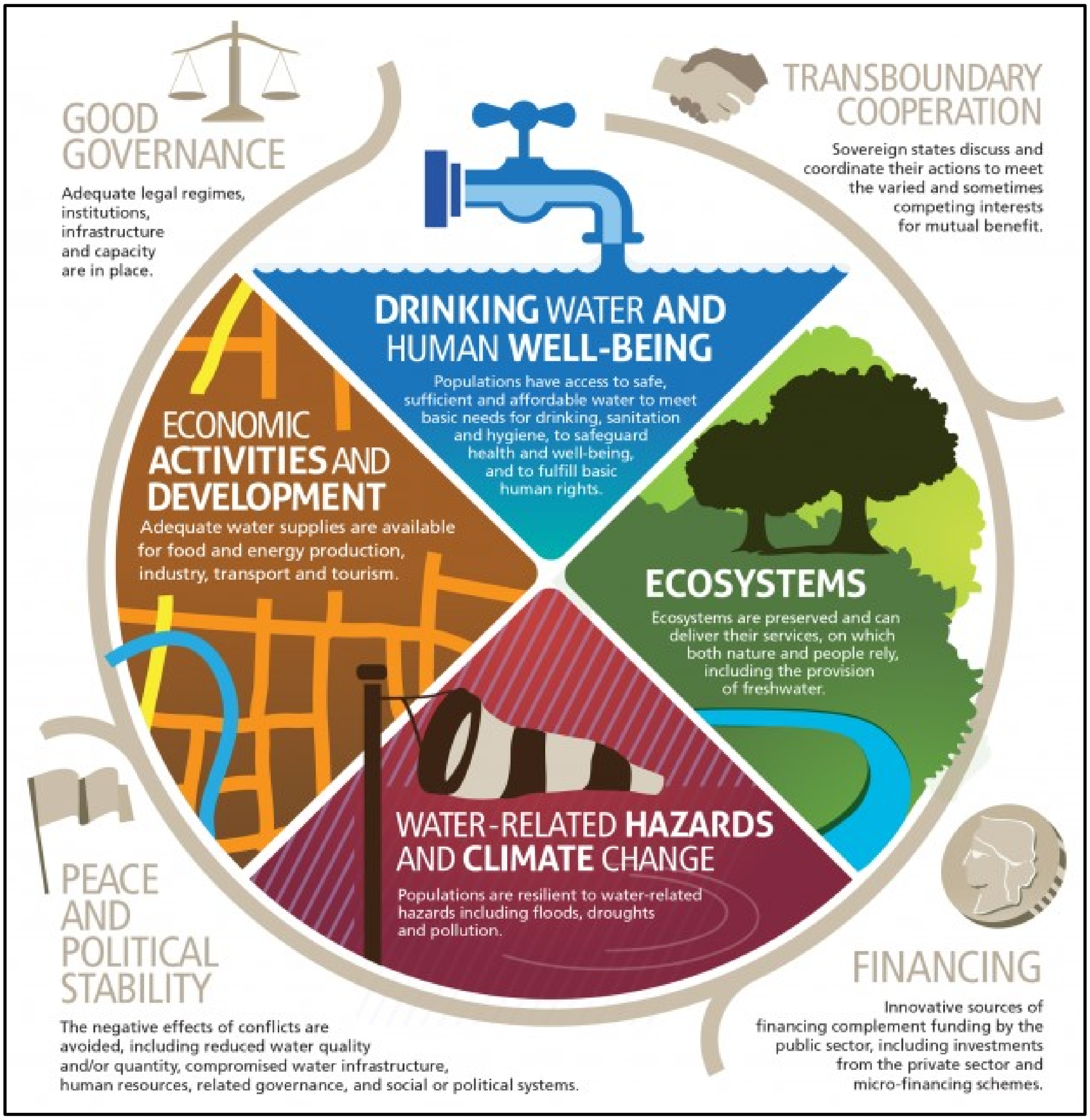

Figure 2.2: UN-Water diagram of water security (UN-Water, 2013).

The concept of water security has been growing in popularity within the realm of academic literature in the last ten or so years. For example, a study by Cook and Bakker (2012) assessing the use of the term ‘water security’ in academic literature found that before the year 2000, hardly any literature referencing water security was published. Bakker (2012) notes that this increase in research “reflects the growing concerns over water-related human and ecosystem vulnerability” (p. 914). This general growth in concern is a direct result of threats to the drinking water supply systems, threats to economic growth and human livelihoods, threats from pollution of water resources, and increased hydrologic variability as a result of climate change (Bakker, 2012). Themes within the literature can be broken down into four main categories: water security assessment; water-related hazards; water as a human need; and, sustainability of water resources (Cook & Bakker, 2012). The issue of water security has also been growing in popularity within the realm of politics. However, as Falkenmark and Lundqvist (1998) note, discussion of water-related problems at the political level is still mostly limited to the technical issues, such as water supply, irrigation, dams and infrastructure development.

Research addressing water security faces several challenges. These include the fact that there are multiple definitions of water security that are used by academics and practitioners, the fact that analyzing socio-environmental implications of changes requires interdisciplinary and collaborative research, and the fact that researchers in different disciplines tend to conduct water security research at different scales (Bakker, 2012). Making water security even more difficult to assess is the fact that water is a highly variable resource that is increasing in demand, both in rural and urban settings and in the global north and south (Rogers, 2006).

It may be appropriate at this point to question why, in Canada, would a study related to water security be necessary? Despite the large volume of water in Canada, water resources are less secure than many believe (Cook & Bakker, 2012). As Schindler and Smol (2006) explain, the amount of water that can be sustainably used in Canada is only about 7-9% of the global total, making Canada's ratio of water to land similar to that of the United Sates. It is true that a large amount of this water is found in Canada's northern regions. However, this is only made possible by the depressions left behind by retreating glaciers. Coupled with lower precipitation rates due to colder temperatures, most of the larger lakes in northern Canada have a water renewal time of 100 years or more, making them technically 'fossil water' (Schindler & Smol, 2006). This implies that the natural rate of replenishment is longer than the human lifespan, similar to other fossil resources, such as oil and gas. Since northern water is replenished at such a low rate, removal of any significant amount of water from these sources would not be sustainable over the long term.

Accessibility of water and the integrity of sources, core components of water security based on the earlier description, are directly linked to human actions. As Gregory *et al*. (2009) explain, "water resources are powerfully shaped by human actions, including the reduction of the Earth's storage capacity through the development of the built environment; degradation of water quality through pollution; and the overuse and mismanagement of water resources that makes them scarce" (p. 807). These same human actions can be seen in Canada's northern regions today as the population in several communities continues to rise, resource development in northern Inuit communities continues to increase, and reports of contamination become more common (Schindler & Smol, 2006). Large developments outside of communities and in adjacent lands, such as mining and oil and gas sites, also have great impacts on water across the region (Pearce *et al*., 2010a).

Arctic residents rely on surface water for a variety of reasons, including: domestic needs, such as drinking, cooking and cleaning; industrial needs, such as the construction of ice roads and infrastructure maintenance; and subsistence needs (White *et al*., 2007). Other water is also important for cultural reasons. For example, the use of sea ice and waterways for travel and access to country foods (White *et al*., 2007). In many Inuit communities across Canada, traditional sources of water are often used in lieu of community water supplies because community members are either distrustful of the water sources provided or believe it to smell/taste unpleasant or different (Moquin, 2005). Traditional sources of water are untreated or raw water sources, such as that from lakes, rivers, ponds, melting ice or melting snow in winter or spring, and are often stored in household tanks or plastic containers (Martin, 2005). The fact that several communities and/or community members are choosing to use (or in some cases are provided no other option but to use) alternative sources calls into question the notion of water security. Adding to this, policy documents in Canada have generally lacked a focus on water management which has resulted in poorly defined rights to water and confusion over the implementation of water conservation and management (Jackson, Storrs & Morrison, 2005).

Effects of climate change are also having an impact on the security of water in northern regions. For example, changes in the cryosphere have important implications for infrastructure maintenance and design (Furgal & Prowse, 2008). Downing and Cuerrier (2011) explain that "the shifting permafrost, rising-sea-levels and spring run-off have accelerated soil erosion decreasing the structural integrity of community infrastructure" (p. 59). This includes structures such as homes, roads, airports and water treatment facilities, which can have a significant impact on the quality and availability of water (Downing & Cuerrier, 2011; White *et al*., 2007). Having access to a good quality of water also has important implications for health. Falkenmark and Lundqvist (1998) compare the function of freshwater in the body to that of blood: "pollution of water systems, on which humanity depends, can be seen as analogous to blood poisoning" (p. 38). If we accept this to be true, ensuring water security in Canada's northern region should be of the utmost importance.

A study by Norman *et al.* (2011), in which water managers across Canada were interviewed, identified several drivers of water insecurity (Table 2.1) and many key themes required for water security in Canada (Table 2.2).

Table 2.1 Drivers of water insecurity, as seen in Norman *et al*. (2011), Table 2, p. 58.

Drivers of Water Insecurity	Percent Reported
Water quality issues	43
Governance (government/planning and regulatory issues	36
Quantity/supply issues (availability)	38
Infrastructure	23
Groundwater	17
Access/source protection "security"	17
Insufficient data/lack of knowledge	14
Climate change	13
Funding	10
Industry	6

Many of the drivers of insecurity and themes identified as necessary to water security are connected. For example, while insufficient data/lack of knowledge was identified as a driver of water insecurity in Canada, ongoing monitoring of ecological systems was identified as necessary for water security. In general, many of the solutions to water insecurity suggested by the water managers in the study were related to water governance and management.

Table 2.2 Key themes of water security. These were identified by interviewees and workshop participants as needs to achieve water security (listed in order of frequency reported), as seen in Norman *et al*. (2011), Table 2, p. 60.

Coordination of datasets
Increased funding for local and regional level stewardship projects
Better coordination of water management between political jurisdictions
A more holistic approach to water governance (including ecological, health, economic and cultural aspects)
Wider adoption of a watershed approach
Better coordination of groundwater and surface water systems
Ongoing monitoring of ecological systems (both spatially and temporally)
Better communication between academic research, policy decisions, and community (in particular between rural and First Nations communities)
Increased involvement/re-engagement of federal level governmental officials.

This study provided important insight into the perspectives of water managers across Canada at the national level. It also provides a good starting point for assessing water security in the ISR. As demonstrated in this chapter, there are several unique properties to the ISR, and northern Canada in general, that may or may not be reflected within priorities expressed by water managers from Norman *et al.'s* (2011) national-level study. An explanation of how these tables will be drawn upon to assess water security is addressed in the following chapter.

CHAPTER 3: METHODS

3.1 THEORETICAL PERSPECTIVE

In a very simplified form, political ecology (PE) is described as "the study of the relationship between policies, nature and society" (Gregory *et al*., 2009, p. 380). In PE, the main focus is on human-environment relationships, with importance being placed on the recognition that this relationship is present at all scales and inextricably intertwined with larger economic and political forces (Knox *et al*., 2010). The PE approach begins with the assumption that "what can be known is prefigured in part by social, political, and historical conditions" (Turner & Robbins, 2008, p. 301). Working from this assumption, it addresses the uneven characteristics of the human sub-system, such as social, cultural and economic power and the unempowered, marginalized and less entitled sectors of society, and frames these problems in terms of their human consequences and system interactions while also considering ecosystem processes (Turner & Robbins, 2008). It explores the "linkages between political struggles over natural resources, cultural meanings attached to the environment and the ecological dynamics of environmental change" (p. 770) by fusing analyses of "ecological conditions, sociopolitical relations, and cultural practices in order to understand the complex dialectics between nature and society" (Nygren & Rikoon, 2008, p. 768).

Academically, PE has a longer history than the term itself, one that is rooted back to human and cultural ecology and anthropology and geography from the 1940s and 1950s (Gregory *et al*., 2009). It was first defined by Blaikie and Brookfield in *Land Degradation and Society*:

> "The phrase 'political ecology' combines the concerns of ecology and a broadly defined political economy. Together this encompasses the constantly shifting

> dialectic between society and land-based resources, and also within classes and groups within society itself." (Blaikie & Brookfield, 1987, p. 17).

Based on this definition, PE is meant to combine concerns about the environment with concerns about the role of the state, or the relationship between political and economic processes. The colonial model of framing environmental problems was related to "the epochs political environment, in which the socially constructed role of the colonists was that of frontier breakers who converted the "untamed" forests for the agricultural development of the country" (Nygren & Rikoon, 2008, pp. 773-774). Blaikie and Brookfield's approach in *Land Degradation and Society* moved away from this. Instead, it focused on the land manager, specifically households, while rejecting the colonial model framing the environmental problem of land erosion, which focused on environmental constraints, mismanagement, overpopulation and market failure (Gregory *et al*., 2009). In the process, they addressed the role of the state in the marginalization of sectors of society through the reinforcement and tendency of the state to lend its power to dominant groups and classes through actions such as taxation, land tenure policy and the allocation of resources (Blaikie & Brookfield, 1987). Since then, many PE studies have addressed the role of politics on access and control over natural resources, focusing in particular on patterns of resistance and struggle (Gregory *et al*., 2009; Nygren & Rikoon, 2008). In the 1990s, researchers became increasingly interested in the linkages between knowledge, power, and representation as a central focus for analysis. Increased attention was paid to "social relations at different scales of environmental negotiation which opened the door to sophisticated analyses of the role of politics and power in mediating resource access and control" (Nygren & Rikoon, 2008, p. 770).

Important to the concept of PE was the acceptance of the multicausality of land degradation. The recognition that land degradation is social in origin, it is both a result and cause of social marginalization, and allowed for new types of questions to be asked (Nygren & Rikoon, 2009; Gregory *et al*., 2009). Blaikie and Brookfield (1987) demonstrated that poverty and environmental degradation can be mutually causal in that the impoverished would destroy their own environment to postpone their own destruction, leading to poor land management which can result in environmental degradation that can further deepen poverty (Gregory *et al*., 2009). To address this, the PE approach follows a chain of explanation that links regional and/or spatial accounts of environmental degradation, beginning with the relation of land managers to land, groups in wider society, and eventually to the state and global economy (Blaikie & Brookfield, 1987; Gregory *et al*., 2009). It works on the premise that local factors of environmental change that can be linked to land managers are influenced by external structures, such as the state, and distant sociopolitical and economic factors and decisions (Gregory *et al*., 2009; Turner & Robbins, 2008).

Also of importance to the concept of PE is the recognition that nature plays an active role in shaping human-environment interactions. PE directs attention to the role of environmental processes in land-use and social change, or the human subsystem, focusing on themes of access, knowledge and control (Turner & Robbins, 2008). It is assumed that "physical and ecological processes have an active role in shaping the sociopolitical relations and cultural conceptions related to the environment, while the multifaceted relations of politics and power, and the cultural constructions of the environment, shape the control and use of natural resources, and consequently the course of environmental change" (Nygren & Rikoon, 2008, p. 778).

To assess these relationships, PE studies begin with an environmental problem and attempt to examine the drivers of this problem through understanding the actions of people or land managers by contextualizing them within broader political and economic constraints (Robbins & Bishop, 2008). In so doing, they relate environmental changes to state policies, interstate relations and global capitalism (Bryant, 1992). Bryant (1992) cautions that addressing the diverse influences on socio-economic groups and political processes that environmental change may affect should "not be confused with environmental determinism, but should focus on the contextual sources of environmental change and conflict over access" (p. 14).

Relating these processes together can become further complicated by our understanding of the environment. As Nygren and Rikoon (2008) point out, "recent efforts in political ecology to better relate the cultural meanings of environment to overlapping ecological processes reveal the inherent difficulty of conceptualizing the "environment"" (p. 775). Many political ecologists take the position that "physical world entities exist independently of human attempts to describe them, and ecological processes may maintain or change their functions independently of human consciousness" (Blaikie, 2008, p. 771). It has been noted that the "boundaries between environment and politics and nature and society, are blurred and in many respects artificial" (Nygren & Rikoon, 2008, pp. 768-769). Cohen and Bakker (2014) also note how even the 'natural' boundaries of the ecological scale are at least somewhat socially constructed in that the boundary of a watershed is often defined by the management and/or policy decision-makers. This thesis acknowledges the ability of ecological processes to exist outside of human consciousness. It also recognizes the active role of nature in shaping society.

Another important aspect addressed through PE is the issue of scale. Environmental zoning often reflects the interests of the social group controlling this political process (Boschet & Rambonilaza, 2015). One suggestion for addressing this is through the use of rescaling, such as a shift from provincial to watershed-based management systems. However, as Cohen and Bakker (2014) point out, while rescaling of environmental governance is frequently viewed as being a progressive solution to addressing environmental challenges, it can entrench the previous patterns of resource use that contributed to the original issues they were intended to resolve. A main concern of political ecologists should be to what degree the rescaling of water management weakens the state's control over local actors (Cohen & Bakker, 2014). For example, policies contain various conflicting goals and objectives and may reflect the desire of the politically empowered to assert control over individuals and groups with lower socio-economic status and less political power (Bryant, 1992).

Some downfalls to using PE have been noted over time. For example, PE takes a diffuse pathway towards questions about the environment and development so can seem less concentrated (Turner & Robbins, 2008). When the approach was first gaining in popularity, it was dubbed 'the everything pill' because it was seen as a theory and method that insisted on including everything (Robbins & Bishop, 2008). As such, studies could quickly become overwhelming. Because it was such an all-encompassing approach, over time PE became contested amongst the many communities using the approach (Turner & Robbins, 2008). Despite criticism, the conceptualization of PE "was and remains expansive, eclectic and inclusive" (Blaikie, 2008, p. 765). It has a high degree of adaptability in terms of subject matter, can be applied at different scales, and appreciate both local and global perspectives.

The analysis of water security in the ISR found in this thesis draws on some core concepts from PE. Chiefly, it draws on the acceptance of the multicausality of land degradation and applies this understanding to the concept of water security in the ISR. In so doing, it recognizes the complex and interconnected nature of political decisions, socio-cultural actions and ecological dynamics. To assess the interconnected nature of governance, environmental and socio-cultural challenges, PE studies fuse analyses of environmental conditions, cultural practices and political decisions. This thesis combined analyses of the ecological conditions, socio-cultural practices, economic and governance decisions in the ISR with regards to water, based on the existing literature. From these assessments, links between the core thematic analyses were drawn to contribute to the development of a more tailored understanding of water security in the ISR.

3.2 LITERATURE SELECTION

Literature was collected from a wide variety of online sources, including academic publication databases, government websites and other relevant websites to the NWT and ISR. The literature search included publications from the establishment of the IFA in 1984 up to date of devolution transfer date (April 1st, 2014). The literature search completion coincided with the transfer date, and thus was chosen as an appropriate end point based on thesis time constraints. Considering the pre-devolution situation also enables future comparison of water security between pre- and post-devolution in the ISR. All literature considered relevant to inland freshwater in the NWT, and the ISR specifically, was collected. The literature collected came from a variety of sources including peer-reviewed and grey literature, such as policy documents, management plans, legal documents, and reports from government bodies, land claim organizations, and consulting groups. In total, five academic databases were queried for relevant sources. Science, social science, Arctic-specific and more general databases were included in the search (Table 3.1). The rationale for using such a variety of databases was to obtain as wide a variety of documents as possible.

Table 3.1: Literature search terms and websites

<table>
<tr><th>Databases</th><th colspan="3">Searches</th></tr>
<tr><td rowspan="4">ASTIS
Geobase/Georef
Scopus
Social Sciences Full Text
Web of Science</td><td>“Northwest Territories”</td><td rowspan="2">AND</td><td rowspan="2">“drinking water”
“freshwater”
“groundwater”
“municipal water”
“potable water”
“surface water”
“water”
“water management”
“water policy”
“water resources”</td></tr>
<tr><td>“Inuvialuit”</td></tr>
<tr><td>“water”</td><td>AND</td><td>“Inuit”
“Inuit Knowledge”
“Traditional Knowledge”
“Inuit Traditional Knowledge”
“Inuit culture”</td></tr>
<tr><td>“water use”</td><td>AND</td><td>“Inuit”</td></tr>
<tr><th>Websites</th><th></th><th></th><th></th></tr>
<tr><td colspan="4">Aboriginal Affairs and Northern Development Canada (AANDC)
Canadian Council of Ministers of the Environment (CCME)
Environment and Climate Change Canada (ECCC)
Parks Canada (PC)
Fisheries and Oceans Canada (DFO)
Health Canada (HC)
Government of the Northwest Territories (GNWT)
Access Research NWT (ARNWT)
Inuvialuit Regional Corporation (IRC)
Inuit Tapiriit Kanatami (ITK)
Town of Inuvik</td></tr>
</table>

Within the databases, 26 queries were performed using a variety of combinations of search terms (Table 3.1). The same 26 queries were repeated across each of the databases in order to maintain consistency throughout the search and collection of documents. Two types of searches were performed. The first type of search used terminology focused on the geographic region of interest for the study, Northwest Territories and Inuvialuit, and different water terminology. The terminology chosen focused heavily on water sources and management because the purpose of the project was to obtain as much information about freshwater in the ISR and NWT as possible. In total, 20 queries were performed and repeated across the five databases during the search using the geographic terminology.

A second, more general, search focused more broadly on literature discussing Inuit and water/water use. The goal of including a broader search on Inuit and water/water use was to ensure that Inuit perspectives and issues were reflected as much as possible in the analysis and to ensure that literature relevant to the ISR but not tagged by geographic location would not be left out. It was also hoped that more general literature would help to provide added context for the project. Documents from the general searches were ultimately chosen for analysis if they were determined to be relevant to the ISR. Relevance was determined based on whether the document mentioned the NWT, Inuvialuit, water legislation, regulations and/or policies applicable to the ISR.

In addition to the databases, eleven websites were also combed for relevant sources, most of them government or land claim/Inuit organizations' websites (Table 3.1). This search included websites from all levels of government, from municipal to federal, to ensure that all potential jurisdictional duties and responsibilities would be reflected in the analysis. Relevant legislation, policies, regulations, management plans and agreements were collected from these sites for inclusion in the analysis.

In the end, all of the documents selected for analysis were based on relevance, which was assessed by their abstracts and/or their introductions and conclusions. Documents were considered to be relevant if they addressed freshwater-related issues in the ISR and Inuvialuit specifically and/or if they addressed water management, policies, programs, legislation and regulations applicable to the ISR. This included those directly applicable to the ISR as well as those relevant at broader scales, such as territorial or federal policies on water management. Literature addressing Inuit relationships with water, water use or water management was also included if it included the ISR or specific Inuvialuit communities. In total, 116 documents were selected for thematic content analysis.

Some limitations to the literature review include that it relies on previously published research and other publicly available documents. As a result, the academic literature collected was limited by what could be found in the databases used in the search. Hence, the rationale behind using several types of databases (science, social science, etc.) to search for literature. The collection of other documents, such as policy documents, management plans, guidelines and reports, was also limited by what has been made publicly available on government websites. Particularly for smaller communities, not all relevant information and reports are made readily available online; some may only be available in hard copy. Therefore, access to these documents was limited. Despite some limitations, the use of a literature review to assess water security provided several benefits, including: characterizing the current state of northern water research; identifying gaps in the literature; and, providing a foundation for future research directions that could be pursued by scientists, northern governments and Inuit organizations.

3.3 CODING

A preliminary review of the literature collected helped to generate the codes that were used to analyze the literature. This was done by first reading the abstracts, introductions and conclusions, or some combination of these, to gain a general idea of the content of the documents. Information about the documents was then inserted into a list in an excel spreadsheet along with general themes that emerged from the initial review (Appendix A). From this preliminary review, six general themes were identified: economy, society, culture, environment, governance and health.

Overall, the literature was heavily focused on the challenges associated with governance and the environment in the ISR, placing less emphasis on health, social and cultural connections with water (Figure 3.1). The main focus of the literature was also shown to differ based on the type of document. In general, academic-source documents focused heavily on environmental concerns, issues with governance, and cultural connections to/uses of water. By contrast, the government-source documents focused heavily on issues related to governance and the economy (Figure 3.1).

After the initial review of the documents, a coding scheme, based on the six general themes, was developed (Table 3.2). Sub-themes under each of the six main themes were added to the coding scheme based on topics that emerged from the initial review of the documents. Once the coding scheme was finalized, all of the documents were uploaded to NVivo 10, a qualitative analysis software program. All of the different themes and sub-themes were added under the project and provided their own “node” or folder. Each document was opened and read from beginning to end, with the exception of books and some policy or management planning documents, where only the relevant chapters or sections were read. As the documents were read, any information referring to any of the themes or sub-themes was highlighted and assigned to the relevant node. This same process was repeated for each of the documents.

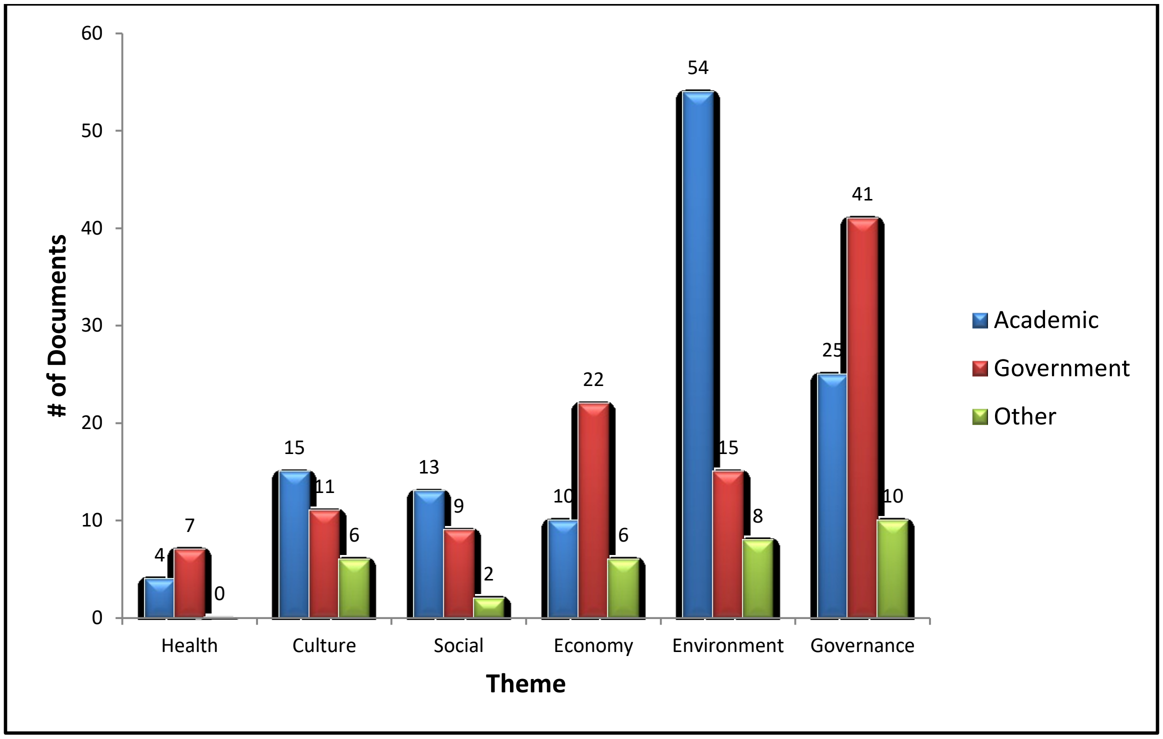

Figure 3.1: Number of documents with content in the six themes of water security. This is further broken down by the type of document from which the content came: academic (blue), government (red) and other (green).

In some instances, a sentence or paragraph was relevant to more than one theme or sub-theme. In those cases, the sentence or paragraph was coded to both themes and/or sub-themes. Although this created an overlap of information in some of the nodes, it was seen as necessary in order to analyze all relevant content under each appropriate theme/sub-theme. While this created more work at the analysis phase because there was more content to review, it also made it easier to see which themes overlapped with each other in the literature. Therefore, some degree of overlap was seen as appropriate and necessary for understanding thematic relationships. Overall, the environment and governance themes had the greatest volume of coded content while the social and health themes contained the smallest volume of content (Figure 3.2).

Table 3.2: Coding scheme. The scheme was developed based on an initial review of the documents and was used to systematically analyze of all collected documents.

GOVERNANCE	ECONOMICS	HEALTH
➢ Water Management o Federal o Territorial o Municipal o Local o Land Claim o Regional ➢ Water Policy o Federal o Territorial o Municipal o Local o Land Claim o Regional ➢ Water Distribution o Federal o Territorial o Municipal o Local o Land Claim o Regional ➢ Water Treatment o Federal o Territorial o Municipal o Local o Land Claim o Regional	➢ Development o Infrastructure o Planning o Maintenance ➢ Cost o Budget o Funding o Subsidization o Operations and Maintenance ➢ Impact on Economy o Supply o Demand ➢ Infrastructure	➢ Physical o Water Quality o Contaminants o Disease o Dental Health ➢ Mental o Depression o Anxiety ➢ Health Care
ENVIRONMENT	**SOCIAL**	**CULTURAL**
➢ Water Quality o Assessment o Contamination ▪ Mercury ▪ Mine water o Remediation o Climate Change o Wastewater ➢ Water Quantity o Climate Change ➢ Accessibility	➢ Water Use ➢ Perceptions o Water Quality ▪ Taste o Water Quantity o Accessibility	➢ Traditional Knowledge o Water Sources o Water Quality ➢ Inuit Perspectives ➢ Traditional Water Use o Historical o Current o Accessibility o Reliability ➢ Spiritual Well-Being

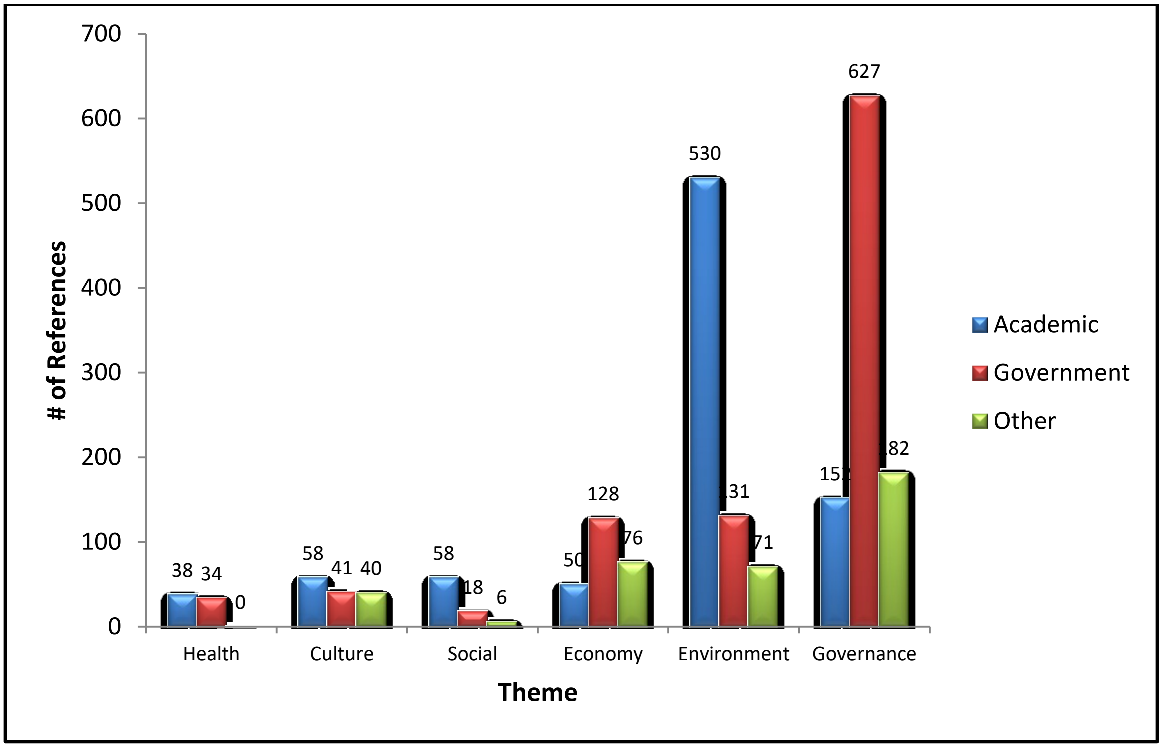

Figure 3.2: Volume of content in the six water security themes. For clarification, NVivo terminology refers to coded text as a "reference". This is further divided by the volume of content from different types of sources: academic (blue), government (red), and other (green).

Throughout this coding process, a few sub-themes emerged that were not included in the original coding scheme. In these cases, a new sub-theme was added to the coding scheme if the topic was relevant and not already included. Other reasons for adding a sub-theme included whether a topic arose that was deemed to be very relevant to the project but not yet included in the coding and/or there was a strong possibility the topic would also be found in documents not yet coded. As these sub-themes emerged, they were added to the coding scheme in NVivo and all subsequent documents were coded according to the updated coding scheme. Previously coded documents were scanned again in case there was any content relevant to the newly created nodes.

3.4 THEMATIC ANALYSIS

Thematic analysis was used to address the multicausality of water security (Section 3.1). Once all of the documents were coded, the information was then prepared for analysis by running a query. This enabled the creation of a report for each theme and sub-theme detailing all relevant content from the coded documents. During this process, it was discovered that there were some sub-themes that contained very little to no content. In these cases, sub-themes with limited content were either combined with the larger sub-themes or themes. For example, under the main theme of health, there is a physical health sub-theme. This sub-theme is further divided by water quality, contaminants, disease and dental health. When the reports were generated, it was discovered that there was a very limited amount of content in the water quality report and no content in the disease report. In this case, the small amount of content in the water quality report was combined with the contaminants report as the two are very closely related.

After the reports were prepared for analysis, the content in each theme and sub-theme was examined. Analysis of the content for each report was done by first grouping together the content based on the similarity of the topics. The content from each report was then iteratively analyzed for common topics of discussion. This iterative analysis was used to organize the thematic content results and to create conceptual diagrams.

This same process of evaluation was used for each of the six themes. However, the content for the governance theme was prepared differently from the other main themes due to the nature of the content. When analyzing the content in the governance theme, it quickly became apparent that proceeding in the same way would result in a great deal of overlap in the sub-themes because there were federal, territorial, municipal, local and regional reports for each of the sub-themes. This was particularly troublesome because of the high volume of content coded to the governance theme. Because one of the core goals of the thesis was to determine the structure of governance, it was decided that reports and their content would instead be grouped by the level of governance rather than by the original sub-themes (Table 3.2). Therefore, reports for each level of governance from the four original sub-themes were combined for analysis so that all content relevant to federal governance was analyzed together, all content relevant to territorial governance was analyzed together, all content relevant to land claim organizations was analyzed together, etc. This did not require the coding scheme to be restructured. Instead, the reports were generated differently to support the analytical process.

After being reorganized into this new structure, analysis was done using the same iterative process as the other five main themes. Done this way, there was still a degree of overlap in the content found in the reports because some of the content was relevant to more than one level of government and therefore coded to more than one sub-theme. However, through analyzing by level of government, these overlaps helped to highlight different areas of connection between the different levels of government. Because of the differences between the governance theme and five other themes, and the important context that the governance structure provides for understanding core issues across the other themes, the governance results are presented first in the results chapter.

3.5 CONCEPTUAL DIAGRAMS

Conceptual diagrams were developed for each of the six themes to succinctly summarize the core ideas and concepts to emerge from the themes. This representation allows the reader to visualize the connections between the sub-themes as well as make comparisons between the main themes. Each diagram centers around one of the main themes, moving outwards based on the connected and more specific relationships to emerge from the analysis. The different levels were then colour-coded for ease of visualization. This same process was used for each of the main themes, with the exception of the governance theme. As with the preparation for analysis, the nature of the content in the governance theme did not lend well to this type of visual representation. There were far too many governing bodies, pieces of legislation, regulations, policies and management plans to succinctly and neatly place into this type of conceptual diagram. For this reason, a different type of conceptual diagram was created.

Because there were several governing bodies at each level of governance and many formats through which water is governed (i.e. legislation, regulation, policies, management plans), the diagram focused on the connections between the governing bodies and their related legislation. Legislation was chosen because the requirements are legally binding whereas policies and management plans are not necessarily legally binding. Therefore, they were seen as holding more weight and higher consequences for non-compliance. While regulations are also legally binding, they were left out unless they were combined with legislation. The rationale for leaving out the regulations was that the regulations are developed as a result of the existing legislation and would add unnecessary bulk and complexity to the diagram.

The governing bodies were first divided by level of government: federal, territorial, land claim and co-management and their respective pieces of legislation related to water. Connections were then drawn between governing bodies and all relevant pieces of legislation. Connections were made whenever a piece of legislation was either produced by the governing body or assigned specific responsibilities related to water to the governing body. Similar to the other conceptual diagrams, the levels of governance and connections were colour-coded for ease of visualization.

3.6 WATER SECURITY ANALYSIS

Once the analyses of the different themes associated with water security were done, and the links between the core themes were drawn, they were then compared to the key drivers of water insecurity and key themes identified as necessary for water security in Canada, identified by Norman *et al*. (2011) (Table 2.1 and Table 2.2). Comparison of the interconnected relationships identified in the literature to those identified by water managers at the national level provided insight to the unique aspects of water security in the ISR, and the Canadian Arctic more broadly.

However, there were some limitations to using only this one study for comparison. For example, the study focused primarily on the opinions of those involved in water management and policy in Canada and as such, is a reflection of those in a position of power, although it did include some grassroots organizers. By focusing primarily on water managers and policy-makers, it is possible that the perspectives of other key stakeholders, such as scientists conducting water research and Indigenous organizations, are not well reflected. It also recognized that, although there were respondents from all provinces and territories, a large number were from British Columbia. As a result, there may be a heavier emphasis on the key issues and concerns in British Columbia. Furthermore, little explanation was provided about the how the individual drivers and themes were defined.

Despite these limitations, the study by Norman *et al.* (2011) was the most recent and comprehensive study on the perspectives of water security in a Canadian context. It reflects the perspectives of a broad range of individuals engaged in water management and water policy implementation at all levels of government, with representation from all provinces and territories in Canada. As such, it provided important insight about water security in a Canadian context and proved to be a useful source for comparison. The comparison to how water security is understood at a national level in Canada also helped to identify key considerations for northern water security to better reflect the unique conditions of the ISR (Chapter 6).

CHAPTER 4: RESULTS AND ANALYSIS

"We don't manage our water, we can only manage human activities and developments"
– Richard Binder, Inuvialuit Aboriginal Steering Committee (Gordon Foundation, 2011, p. 14)

4.1 GOVERNANCE

There are several government departments and agencies across multiple jurisdictions that maintain important roles and responsibilities associated with water in the NWT (GNWT ENR & INAC, 2010; MacLeod Institute, 2002; INAC, 2010b; Pearce *et al*., 2011). The following section begins with an overall description of the core government bodies responsible, in some way, for water management in the Inuvialuit Settlement Region (ISR). This includes governing bodies at all levels of government, as well as co-management boards. The sections that follow outline the various management plans, some for the NWT and others more specific to the ISR, which cover freshwater in some capacity. In the latter section, results from the analysis of the content, including critiques of government (in)action, management plans, policies and regulations are described. This also includes suggestions for moving forward and general comments about the current state of water management.

4.1.1 Governance Structure, Roles and Responsibilities

Analysis of the documents identified 36 key water management agencies, including: 8 federal departments and agencies; 5 territorial departments; 15 land claim organizations; and 8 co-management boards (Table 4.1). The following section outlines the roles and responsibilities of the different government departments and agencies, Inuvialuit organizations and co-management boards as laid out in the appropriate legislation, regulations and policies.

Table 4.1: Government bodies and co-management boards. This includes all those that maintain responsibilities in the management of onshore waters in the ISR, NWT, Canada.

Federal	Territorial	Land Claim	Co-Management Boards
➢ Aboriginal Affairs and Northern Development Canada ➢ Health Canada ➢ Environment Canada ➢ Transport Canada ➢ Parks Canada ➢ Department of Fisheries and Oceans ➢ National Energy Board ➢ Canadian Environmental Assessment Agency	➢ Environment and Natural Resources, ➢ Aboriginal Affairs and Intergovernmental Relations, ➢ Municipal and Community Affairs ➢ Health and Social Services ➢ Public Works and Services	➢ Inuvialuit Regional Corporation ➢ Inuvialuit Community Corporations (6) ➢ Inuvialuit Land Administration ➢ Inuvialuit Game Council ➢ Inuvialuit Hunters and Trappers Committees (6)	➢ Mackenzie Valley Land and Water Board ➢ Mackenzie Valley Environmental Impact Review Board ➢ Inuvialuit Water Board ➢ Environmental Impact Screening Committee ➢ Environmental Impact Review Board ➢ Fisheries Joint Management Committee ➢ Wildlife Management Advisory Council (NWT) ➢ Wildlife Management Advisory Council (Yukon)

The roles and responsibilities of the government bodies and co-management boards are laid out in various pieces of legislation and regulations across all levels of jurisdiction. Associated with those are a number of policies, management plans and guidelines produced by the various governing bodies. These plans are sometimes produced by a single governing body, but are more often produced through collaboration between multiple government departments and at multiple levels of government. As a result, the relationship between governing bodies, legislation, regulations, guidelines, policies and management plans is a complex web of interactions (Figure 4.1).

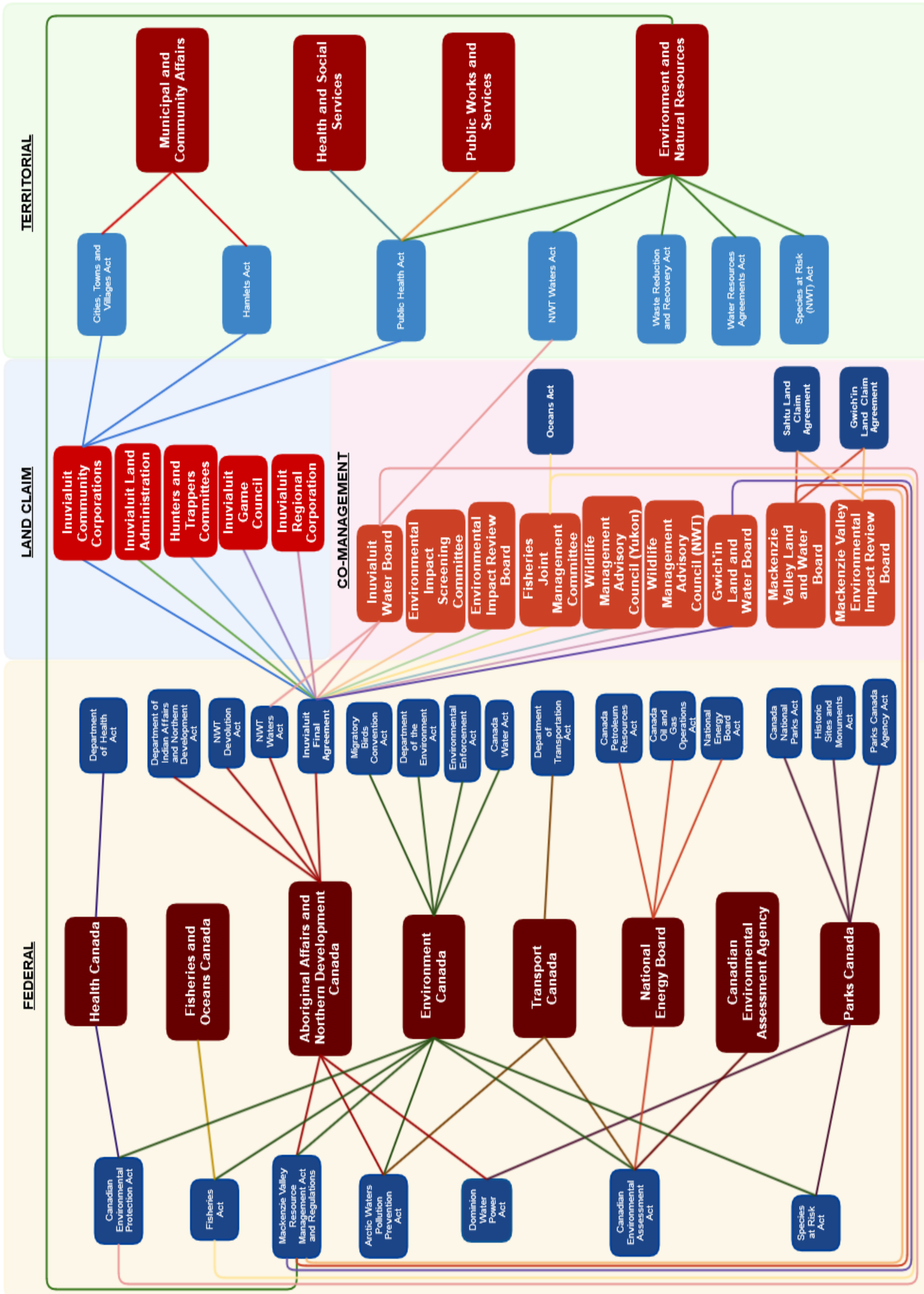

Figure 4.1: Relationship between governing bodies and legislation.

The bulk of legislation governing water quality and use has been produced at the federal level (Figure 4.1). The greatest relationship between the levels of governments is that between the federal government and various co-management boards, followed by the federal government and land claim bodies. The high level of interaction between the federal government, Inuvialuit land claim organizations and co-management boards is mostly a result of the IFA (Figure 4.1). However, there are also several pieces of federal legislation that address co-management boards to some degree. The two levels of government with the least interaction are the federal and territorial governments. Figure 4.1 reveals that the territorial government has the least amount of interaction with all other levels of government relevant in the ISR. The territorial governments greatest relationship to other governing bodies is its relationship with the Inuvialuit Community Corporations (ICCs) at the land claim level of governance.

Figure 4.1 helps to demonstrate the complexity of water management in the region. Not only are there multiple government departments and organizations at all levels of jurisdiction, there are also multiple accompanying pieces of legislation from all levels of jurisdiction, which are also often linked to one or more governing bodies. For example, the responsibilities of Environment Canada (EC) related to water and water management are addressed in 10 pieces of federal legislation. Some of this legislation is also linked to other governing bodies. The Fisheries Act is relevant to EC and Fisheries and Oceans Canada (DFO) at the federal level, as well as the Fisheries Joint Management Committee (FJMC), a co-management board. Similarly, the responsibilities of Aboriginal Affairs and Northern Development Canada (AANDC) are addressed in seven pieces of federal legislation. One of these, the Mackenzie Valley Resource Management Act

(MVRMA), is relevant to: AANDC and EC at the federal level; Environment and Natural Resources (ENR) at the territorial level; and, the Gwich'in Land and Water Board (GLWB), Mackenzie Valley Land and Water Board (MVLWB) and Mackenzie Valley Environmental Impact Review Board (MVEIRB), all co-management boards.

While Figure 4.1 demonstrates the relationship between the governing bodies and legislation, it does not convey the specific roles and responsibilities of the governing bodies laid out in the legislation and associated regulations, nor does it communicate the policies, guidelines and management plans through which these governing bodies operate. The roles and responsibilities are laid out below in a hierarchal manner, beginning with the federal government and working down to the co-management boards. This is not meant to be a comment on the level of importance of each level of governance in the ISR, but rather a way of organizing the various water responsibilities of the governing bodies from the most broadly geographically applicable to the most geographically specific.

4.1.1.1 Federal Government

Table 4.1 indicates eight federal bodies that hold distinct roles and responsibilities associated with water in the ISR. These are directly associated with the jurisdictional powers that the federal government maintains (INAC, 1998b). Table 4.2 outlines the roles and responsibilities of each of the different federal departments and agencies with respect to water.

The Canadian constitution does not define water ownership and there are no special provisions in the Inuvialuit Final Agreement (IFA) about federal land ownership or water use on federal lands in the ISR (Gordon Foundation, 2011; INAC, 1998b; IFA,

Table 4.2: Responsibilities of the federal departments and agencies with respect to water in the ISR.

Governing Body	Responsibilities
Aboriginal Affairs and Northern Development Canada	- administration, control and ownership of water (until full devolution) - development, implementation and interpretation of water management legislation and policy - coordination of monitoring programs, technical support, allocation of funding - inspection of water, wastewater and solid waste facilities - expertise and funds to assist with water and wastewater services - water licence compliance, advise on water quality and protection - coordinating environmental research, monitoring and water data collection - developing guidelines and codes of practice for water resource management and monitoring
Canadian Environmental Assessment Agency	- support sustainable development - administer Canadian Environmental Assessment Act - administrative and advisory support for review boards - promotion of strategic environmental assessments - encouraging public participation and research and development
Environment Canada	- water quality and quantity monitoring - developing regulations, national policies and standards - evaluating water quality protection measures, reducing pollution at the source - enforcement of water legislation and issuance of water licences by the IWB - enforcement and permitting for pollution and use of toxic substances - support inter-jurisdictional water management agreements and promote ecosystem approaches, investing in water research - oil spills in National Parks and some federal facilities and migratory bird protection
Fisheries and Oceans Canada	- safe waters, productive ecosystems and winter water withdrawal from lakes - develops policies and programs related to fisheries management - maintains service standards, safety, environmental protection, conservation and sustainable resource use - develops plans, policies and programs with the aim of protecting fisheries, freshwater environments and understanding aquatic resources
National Energy Board	- independent federal agency - makes recommendations of terms and conditions for permits - determines projects that are of public interest and level of environmental assessment required for proposed development projects. - conducts environmental assessments for proposed projects, ensures proper level of environmental assessment is completed, and ensures environment is protected in planning, construction, operation and abandonment of projects within jurisdiction - regulates oil, gas and electric utility industries, pipelines, development and trade - responsible for oil spills on land and water at oil and gas production sites
Parks Canada	- administers and manages PC water resources -protection of natural resources and natural processes - manage and maintain National Parks for current and future generations - ensure appropriate application of environmental assessment processes for proposed projects within National Parks and Historic Sites - provide technical expertise, manage and implement research and monitoring programs in/on Parks and Historic Sites - issuance of research and collection permits and enforcement of regulations - pollution prevention, public health and determining appropriate use and activities in Parks
Transport Canada	- transportation and safety legislation, transportation systems, oil spills on roads - conduct environmental assessments for proposed projects - ensure appropriate application of TC mandate in Canadian and northern environmental assessments - development of policies, regulations and programs

1984). However, water in the NWT, including water in the ISR, is under the ownership of the federal government (Gordon Foundation, 2011; IFA, 1984; Rosenberg Forum, 2009; Wootton *et al*., 2008). Furthermore, the federal government maintains the right to control water, waterways, river beds, lakes and other water bodies for the management of:

- Wildlife, such as fish, migratory game, non-game and insectivorous birds (IFA, 1984; INAC, 1998b);
- Government functions related to navigation, transportation, flood control, etc., such as dredging operations for transportation on navigable waters (IFA, 1984; INAC, 1998b); and
- Water resources management on Crown land, including water data collection, water research, habitat and freshwater environments (GNWT ENR & INAC, 2010).

As laid out in the IFA, the federal government may access Inuvialuit lands for the purpose of carrying out these activities and the Inuvialuit cannot interfere or impede with any of these federal rights (IFA, 1984). A similar agreement of access by the federal government to waters in the NWT can be found in the NWT Land and Resources Devolution Agreement, where the federal government has the right to access public lands and water to fulfill its responsibilities, including on settlement lands (INAC *et al*., 2013).

Because of the responsibilities and rights to access for the purpose of fulfilling their responsibilities, the federal government holds important powers directly related to water that can complicate water management initiatives in the region (GNWT DAAIR, 2007; Gordon Foundation, 2011). While the federal government maintains jurisdiction and ownership of ISR waters, consent from Indigenous organizations, such as the Inuvialuit land claim organizations, would most likely be sought before approval of a proposed project would be given (GNWT DAAIR, 2007; Gordon Foundation, 2011).

As seen in Table 4.2, many of the federal departments hold distinct responsibilities for water in the ISR. However, there are cases were these responsibilities overlap. For example, most of the costs associated with environmental remediation in northern Canada are reverted to the federal government. These responsibilities are divided among different federal departments, depending on the location of the required remediation. For example, when dealing with spills:

- AANDC is the lead agency responsible at authorized facilities, on sections of territorial highways on ice surfaces, spills on water and territorial (Crown) lands and waters in the NWT;
- the National Energy Board (NEB) is responsible for spills on land and water at oil and gas exploration and production facilities;
- EC is responsible for dealing with spills in National Parks and at other federal facilities authorized under federal legislation;
- the Canadian Coast Guard is tasked with ensuring that spills from ships and barges and mystery spills on water are addressed;
- Transport Canada (TC) is designated as the lead investigating agency for all ship source spills; and,
- the Inuvialuit Land Administration (ILA) is responsible for spills on Inuvialuit lands (GNWT ENR, 2012c).

The applicable legislation includes: IFA, Northwest Territories Waters Act, Fisheries Act, Canada Water Act, Canadian Environmental Protection Act, Canadian Environmental Assessment Act, and Arctic Waters Pollution Act at the federal level; the Northwest Territories Public Health Act, Hamlets Act, and the Cities, Towns and Villages Act at the territorial level; and, municipal bylaws at the municipal level (Wootton *et al*., 2008). As evidenced by this example, the structure of water governance in the ISR is both complex and requires the coordination and cooperation between appropriate departments and agencies. This example only demonstrates the legislation and agencies responsible for water treatment, but there are many more aspects of water management than just treatment.

4.1.1.2 Territorial Government

A growing area of concern for the GNWT is the management of the quantity and quality of water resources in the NWT in order to maintain their integrity (GNWT ENR & INAC, 2008; Ritter, 2007). The GNWT's water responsibilities are shared among several departments (Table 4.3) whose duties are coordinated through the Interdepartmental Water and Wastewater Management Committee (GNWT HSS, 2011; GNWT, 2012a). The Department of Aboriginal Affairs and Intergovernmental Relations (DAAIR) also has limited water-related responsibilities.

Table 4.3: Responsibilities of the territorial government with respect to water in the ISR.

Governing Body	Roles/Responsibilities
Aboriginal Affairs and Intergovernmental Relations	- Renewable resource development and activities on commissioners land
Environment and Natural Resources	- ENR policy should not prejudice IFA - sustainability of water resources - transboundary agreement negotiations - conserving environment for social and economic benefit - wildlife and forestry management
Health and Social Services	- Environmental Health or Medical Officer issues boil water advisories - regulate drinking water safety - inspect water treatment plants - monitor water sampling and testing
Municipal and Community Affairs	- administration and management of waters in the ISR - conducts research, provides funding and aids with policy development for water and wastewater - enables communities to provide water services through legislation - providing education opportunities for community officials and training for water operators - aiding communities develop infrastructure and operations and maintenance plans
Public Works and Services	- provides technical expertise - provides training and operational assistance for water supply infrastructure

All NWT residents are entitled to use water and to dispose of waste (GNWT, 2004). This entitlement, however, does not come without responsibilities. The GNWT holds a number of water-related responsibilities, including:

- the regulation of public water supply systems;
- providing certification, training and support for water treatment operators;
- inspecting water treatment plants;
- assisting communities with operations and maintenance tasks;
- construction of public infrastructure;
- ensuring sanitation services; and,
- reviewing community water quality data to ensure that water is safe for use (Table 4.3) (GNWT ENR & INAC, 2010; GNWT HSS, 2007; GNWT HSS, 2011; Ritter, 2007).

The Northwest Territories Waters Act and Northwest Territories Waters Regulations both play important roles in water management at the territorial level. They dictate how inland waters can be used, disposal of waste into inland waters and any acceptable changes to inland water bodies (GNWT, 2014c; Wootton *et al*., 2008). The Waters Act also dictates roles and responsibilities, such as: who, and under what circumstances, there are exemptions from water licences; who has authority to make regulations about water (Commissioner); and, requirements for water use and water licences (GNWT, 2014b).

4.1.1.3 Land Claim Organizations

The IFA governs the arrangements in the ISR (IFA, 1984; MacLeod Institute, 2002). Settlement claims, such as the IFA, outline water quality and quantity parameters that carry federal force (IFA, 1984; Rosenberg Forum, 2009). Within the agreement, the roles and responsibilities of the land claim organizations with respect to waters are established (Table 4.4). The MVRMA and NWT Waters Act, along with the IFA and other land claim agreements in the NWT that touch in the Mackenzie Valley, lay out the legislative framework for environmental assessment and regulatory approvals for the ISR and Mackenzie Valley (GNWT ENR & INAC, 2010).

Indigenous organizations in the NWT, such as the IRC, have some surface and sub-surface land holdings, as per their agreements (EISC, 2004; IFA, 1984; MacLeod Institute, 2002; Pearce *et al*., 2011; INAC, 1998a). This ownership extends to the beds of rivers, lakes and other water bodies in parts of the region, but not to the water contained within (IFA, 1984). It also does not give the Inuvialuit exclusive rights to harvest fish in these areas (IFA, 1984). In other words, the IRC owns land beneath many water bodies within the ISR, and some sub-surface resources, but does not own the water or the resources within the water bodies.

Table 4.4: Responsibilities of the land claim organizations in the ISR.

Governing Body	Responsibilities
Inuvialuit Land Administration	- administration of Inuvialuit lands - grants permits for access to Inuvialuit lands - spills on Inuvialuit land, based on the IFA
Inuvialuit Regional Corporation	- administering Inuvialuit lands - ensuring water quality, quantity and rates of flow are unaltered - federal and territorial obligations in the ISR are being met - review licence applications and make recommendations to regulatory boards - nominate regulatory board members - public consultation participation - development and participation in land and water programs, policies and strategies - made up by the six Community Corporations - funded through subsidiary corporations and businesses
Inuvialuit Game Council	- comprised of the six Hunters and Trappers Committees - supported entirely by implementation funding
Inuvialuit Community Corporations	- bylaw-making authority in communities - bylaws relating to wastewater systems - control of development activities in nearby Inuvialuit private lands - raw water testing
Hunter and Trappers Committees	- concerned primarily with all matters concerning wildlife, including water quality, quantity and changes to the environment that may have an impact on wildlife
Land Use Planning Group	- land use planning in the ISR - partake in territorial land use planning commissions

With these rights comes some responsibility for management. The Inuvialuit received \$152 million in capital transfer payments from the federal government in 1997 as part of the IFA to help with the establishment of the economic and political bodies in each of the Inuvialuit communities (Pearce *et al*., 2011). Because of this responsibility, the land claim organizations, and their associated rights with regards to waters, need to be recognized, considered and respected in watershed management decisions (GNWT ENR & INAC, 2008; GNWT, 2012a).

4.1.1.4 Co-Management Boards

There are several co-management boards that deal with water to some degree in the ISR (Table 4.5). Co-management boards were created from the settlement of various

Table 4.5: Responsibilities of the co-management boards in the ISR with respect to water.

Governing Body	Roles/Responsibilities
Mackenzie Valley Land and Water Board	- recommendations of terms and conditions for permits - determine projects that are of public interest - regulation of water and water resources in the Mackenzie Valley - issuing land use permits and water licences in the Mackenzie Valley - assessing transboundary land and water use applications - ensuring consistent legislation across the Mackenzie Valley - conduct preliminary screenings for development proposals - determine whether assessment and review is necessary
Mackenzie Valley Environmental Impact Review Board	- co-management board - conduct quality environmental impact assessments that protect the Mackenzie Valley - guidelines for screening projects - must present findings to AANDC and NEB - does not make final decisions
Gwich'in Land and Water Board	- responsible for water licencing in Inuvik
*Inuvialuit Water Board**	- established by the NWTWA to grant licences - responsible for water licencing in IFA communities (except Inuvik)
Environmental Impact Screening Committee	- environmental screening for proposed development activities - annual review of mineral activities in the ISR
Environmental Impact Review Board	- makes recommendations for development projects - supports EISC and IWB with public reviews of development projects in the ISR
Fisheries Joint Management Committee	- monitoring fish and marine mammals - developing fisheries management plan for rivers west of the Mackenzie to the Yukon/Alaska border
Wildlife Management Advisory Council – NWT	- terrestrial and avian wildlife in the NWT
Wildlife Management Advisory Council – Yukon	- terrestrial and avian wildlife in the Yukon Territory

** Previously the NWT Water Board.*

land claims in the NWT and generally have a number of functions, including land use planning, environmental assessment, land and water management (McLeod Institute, 2002; Pearce *et al*., 2011). Co-management boards also facilitate communication between various levels of government (Pearce *et al*., 2010).

Regulatory boards play an important role in the management of water resources as they are responsible for evaluating development proposals, determining whether there would be significant impacts to land or water as a result of development, and determining whether a monitoring program will be necessary (INAC, 2010b). The co-management structures in the ISR and Gwich'in Settlement Area have the same general goals, both incorporating the principle of conservation (Ayles & Snow, 2002). The land and water boards from both regions provide an opportunity for the Inuvialuit to participate in resource management decisions (Gordon Foundation, 2011). While the Inuvialuit have this opportunity to participate in decision-making through the co-management boards, the federal government still has the final say in the majority of decisions (Gordon Foundation, 2011). However, the federal government maintains that they would be unlikely to proceed with projects without the approval of Indigenous governments and organizations.

4.1.2 Management Plans

There are several management plans addressing water-related issues in the ISR, and the NWT more broadly (Table 4.6). The GNWT describes water management as "guiding water and land uses so that residents of the NWT will enjoy the greatest net benefits over the short and long term (GNWT ENR & INAC, 2008, p. 9). Within the management plans, the GNWT acknowledged a number of key water management issues that need to be addressed in a water resources management strategy, including:

- changes in streamflow, groundwater and lake levels;
- contaminant transport from upstream industrial development;
- changes in water quantity, quality and ecosystem structures associated with climate change;
- the relationship between chemical and physical changes and ecological and biological effects;

- resulting changes on subsistence harvesting and cultural practices;
- coordinated research and reporting on water science issues;
- effective communication and consultation between water resource managers and residents; and,
- information exchange with other jurisdictions (GNWT ENR & INAC, 2008).

While water management plans were recognized for their importance, a number of challenges in the development and implementation of management plans emerged from the literature. For example, two issues facing water managers in the development and implementation of programs in the NWT are a lack of baseline data and an imperfect understanding of complex natural ecosystems (MacLeod Institute, 2002). Baseline data is critical as it helps with the monitoring and assessment of cumulative impacts on the environmental, setting thresholds and developing mitigation strategies for water management (INAC, 2010b). Other general management challenges for the NWT mentioned in the literature were: knowing ahead of time what types of activities would net the best results in the long run for the economy environment and society and, managing water over a larger area, such as the watershed scale. The MacLeod Institute (2002) recognizes that industrial and commercial activities are valued for economic benefits and can have negative environmental and social impacts, but believe that the management of resource development can ensure that no lasting ecological or social damages are done. Median flow guidelines are one way of addressing this; when incorporated into water resources planning and management, they act as a way to protect and conserve aquatic biota (Baki, Zhu, Hulsman, Lunn & Tonn, 2012). The challenge with managing water at a larger scale is that there are a greater number of variables to be considered, which could lead to less precise and less reliable management decisions (MacLeod Institute, 2002).

Table 4.6: Management plans addressing water in the ISR.

MANAGEMENT PLAN	PRODUCED BY…	DESCRIPTION
	NATIONAL	
Strategy for the Management of Municipal Wastewater Effluent	➢ *CCME*	Canada-wide strategy to manage discharge of municipal wastewater and to protect human and environmental health. A Northern Working Group is focused on solutions for northern environments.
	TERRITORIAL	
NWT Water Strategy: Northern Voices, Northern Waters	➢ *GNWT* ➢ *Aboriginal Steering Committee* ➢ *INAC*	Ecosystem-based approach to water management that uses the watershed unit. Considers the quantity, quality, flow and chemical/physical changes of surface and groundwaters within the watershed, including those associated with climatic change. It also aims to include all water uses across the watershed, including subsistence practices, harvesting and cultural practices.
Northwest Territories Source Water Assessment and Protection (SWAP)	➢ *GNWT ENR*	Multi-barrier approach to management. Aimed at reducing and preventing drinking water contamination in the Northwest Territories.
Northwest Territories Cumulative Impact Monitoring Program (CIMP)	➢ *Gwich'in Tribal Council* ➢ *Tlicho Government* ➢ *Inuvialuit Game Council* ➢ *North Slave Métis Alliance* ➢ *Sahtu Secretariat Incorporated* ➢ *Dehcho First Nations* ➢ *NWT Métis Nation* ➢ *GNWT* ➢ *AANDC*	Community-based approach to management that addresses the environmental impacts of land and water uses. Focuses on the cumulative impacts of land and water uses.
Guidelines for Designing and Implementing Aquatic Effects Monitoring Programs (AEMP) for Development Projects in the Northwest Territories	➢ *INAC Water Resources Division* ➢ *Zajdlik & Associates Inc.* ➢ *MacDonald Environmental Sciences Ltd.*	AEMPs measure the impacts of development projects and are the responsibility of the developer. They are often a requirement for water licences and involve monitoring water quality, quantity and flow. The Guidelines provide guidance on establishing AEMPs.
Land Use and Sustainability Framework (LUSF)	➢ *GNWT*	Intended to guide decisions about land use and development. Main priorities include the promotion of sustainable development to protect water quality, quantity, flow and health of NWT residents.
Managing Drinking Water Quality in the NWT: A Preventative Framework and Strategy	➢ *GNWT* ➢ *Whiteworks: Policy, Planning & Evaluation* ➢ *Jennifer Luckay Creative Communications*	Multi-barrier approach to protecting drinking water that includes keeping NWT water clean, making drinking water safe and proving drinking water is safe. Goal is to use preventative measures to protect NWT drinking water, which will ultimately contribute to the health of NWT residents.
	ISR/COMMUNITY	
Integrated Community Sustainability Program – Inuvik (Inuvik-ICSP)	*Prepared for the Town of Inuvik by:* ➢ *Kavik-AXYS* ➢ *Stantec Consulting Ltd.*	Goal is to integrate social, cultural, economic and environmental issues into community planning dimensions.
Inuvik Inuvialuit Community Conservation Plan	➢ *Community of Inuvik* ➢ *Wildlife Management Advisory Council* ➢ *Joint Secretariat*	Provides conservation and resource management guidelines. Goals include: identifying important wildlife habitat and seasonal harvesting areas; describing a community process for land use decisions; managing cumulative impacts; describing a system for wildlife management; enhancing the local economy; and, identifying educational initiatives that promote conservation, understanding and appreciation.

In general, water management plans, legislation and policies, particularly those aimed at the NWT and ISR, are shaped by northern environmental, economic and socio-cultural conditions. Many of these conditions relate to water uses and water security challenges in the region. This includes the abundance of water, the assumption of pristine water sources, natural peak and minimum water flow timing, limited financial base and cultural preservation, to name a few. Determining which challenges to address in management planning is important to the success of the management plan. This includes determining which challenges are high priorities for local residents and for economic stability. Some type of strategy for defining high priority issues is needed.

4.1.3 Water Management as a Collaborative Process

"The long-term sustainability and health of our water is a shared responsibility."
– GNWT ENR & INAC (2010, p. 11), GNWT ENR, 2011c.

One of the core themes among the management plans was the need for collaboration and cooperation to manage land and water resources. The impact of water use on the resource as a whole depends on the level of impact of the water use and the compounding impacts with other water uses in the same region. Therefore, to protect water for any of the purposes of the current management plans, consideration of all water uses is necessary. It was acknowledged that interdisciplinary research and the inclusion of local knowledge are important for understanding Arctic environmental changes (Kokelj *et al*., 2012). The Council of Federations, a council consisting of the 13 Premiers across Canada, developed a Water Charter in which they recognized that partnerships, working collaboratively, increasing monitoring efforts, sharing information and cooperation are the keys to successful water management and conservation for Canada (Council of the Federations, 2010). In relation to these acknowledgements, it was recommended that an Arctic wastewater management framework be developed through collaboration with northern stakeholders, including Inuit (Wootton *et al.,* 2008).

Even though the management plans were created at different scales and with different objectives in mind, the need for collaboration and cooperation between agencies is present at all levels, although emphasized to varying degrees. Federally, the Canadian Council of Ministers of the Environment's (CCME) Strategy for the Management of Municipal Wastewater Effluent has established a northern working group consisting of the governments of the NWT, Nunavut, Quebec, Newfoundland and Labrador and federal agencies. These governments are expected to work collaboratively to develop an approach to wastewater management in the far north assessing environmental risk, considering economic implications, developing requirements for compliance, monitoring and reporting, and developing northern standards for performance (CCME, 2009).

At the territorial level, the Aquatic Effects Monitoring Program (AEMP) recognized the need for cooperation and data sharing for the purposes of monitoring environmental impacts (Zajdlik, MacDonald & INAC Water Resources, 2009). Without the collaboration and cooperation of those collecting data, there is a risk that research efforts may be duplicated and that larger scale changes to the environment may not be visible. Other management plans incorporated cooperation and collaboration as core components of building the management plan itself. Collaborating with as many stakeholders as possible was one of the main goals of the NWT Source Water Assessment and Protection (SWAP) Plan (GNWT, 2010a). In Managing Drinking Water Quality in the NWT, better cooperation between agencies was mentioned as a goal of drinking water quality management for the NWT (GNWT, 2005a).

For other management plans, collaboration and cooperation played an even larger role. For example, the NWT Water Strategy (NWTWS) strongly encouraged and reiterated the necessity for water managers and partners to work in a collaborative manner to: practice water stewardship; define water problems and find acceptable solutions; address capacity issues; appropriately incorporate Indigenous peoples and Traditional Knowledge to initiatives; and, monitoring of environmental changes (GNWT ENR & INAC, 2010). The Strategy recognized that "stewardship requires the cooperation and coordinated effort of individuals, governments, boards, organizations, communities, industry and others to be successful" (GNWT ENR & INAC, 2010, p. 11). Similarly, the NWT Land Use and Sustainability Framework (LUSF) (2012) recognized that collaboration with regional organizations, communities, the federal government, the GNWT, regulators, co-management boards, industry and ENGOs operating in the NWT, as well as the neighbouring jurisdictions of Alberta, Yukon, Saskatchewan, British Columbia and Nunavut, was necessary for making water management decisions, addressing the effects of climate change, the promotion of tourism, developing wildlife management plans and resource development plans. In particular, it noted that devolution requires cooperation and collaboration with all land use and land management partners, including the federal government, which maintains authority and responsibility for some public lands and resources, such as National Parks (GNWT, 2012a). The NWT Cumulative Impact Monitoring Program (CIMP) also placed a heavy emphasis on the need for collaboration, assigning the goal of facilitating governance and partnerships to "align, coordinate and integrate environmental monitoring" (p. 5) at the top of their list of activities (AANDC, 2013).

Collaboration and cooperation was also emphasized in local management plans. The Inuvik Inuvialuit Community Conservation Plan (ICCP) recognized that interjurisdictional and international cooperation for the coordinated management of wildlife and habitat, renewable resource management and decision-making, review of development proposals, and the management of migratory species is necessary to enhance the local economy, resource conservation and environmental and wildlife protection (Community of Inuvik, Wildlife Management Advisory Council (NWT) & Joint Secretariat, 2008). The Inuvik Integrated Community Sustainability Plan (Kavik-AXYS & Stantec Consulting Ltd., 2010) concluded that "collaboration on decision-making and actions of all government and local groups, ensure that people's well-being – culture, health, recreation, education and opportunities – expand personal and professional goals, and overall basic needs" (p. 9).

From reviewing the ways that collaboration and cooperation between governments, communities, Indigenous groups, ENGOs, etc. are incorporated into the management plans, it is clear that working together to better manage water in the north is a common goal of water management at all scales. The management plans may have different purposes, but they all have one related goal: to protect water for current and future generations, for whatever use they are designed to protect. By collaborating with the different groups of water users, they can ensure a better outcome.

4.1.4 Summary

From the analysis of governance structures and mechanisms related to water in the ISR, there is clearly a complex relationship between the various governing bodies that control and manage water resources. There were a number of important results that emerged from the governance literature:

1. There are 36 governing bodies that play a role in the management of freshwater in the ISR: 8 federal bodies, 5 territorial bodies, 15 land claim bodies and 8 co-management boards.
2. The governing structure is an intricate web of interconnections between multiple levels of government. The greatest interaction between the various levels of government is found between the federal government and the co-management boards, followed by the federal government and the land claim bodies. The least amount of interaction was found between the federal and territorial governments.
3. There are several management plans designed to address water in some capacity within the ISR. These plans range in scale from national initiatives to community level plans. In total, there are eight management plans, two frameworks and two management models.
4. Environmental changes can have significant impacts on water management planning and implementation.
5. The need for a collaborative approach to management and the inclusion of Indigenous governments was a core theme across the literature.

4.2 ENVIRONMENT

Water is considered to be one of the defining features of the environment in the NWT (GNWT ENR & INAC, 2010). Despite their importance, arctic freshwater ecosystems and their hydrology are some of the least understood environments (Baki *et al*., 2012; Gantner, 2014). Indigenous knowledge is often the only long-term information available since baseline data on water across the region is sparse (Gantner, 2014). The primary emphasis to emerge from the literature characterizing environmental conditions related to water were water quantity and quality, and the impacts of climate change on both (Figure 4.2).

4.2.1 Water Quantity

The Canadian Arctic has some of the world's largest rivers, several large lakes, numerous permanent and semi-permanent streams, rivers, lakes and ponds, large areas of wetlands and peatlands and river delta habitats (Burn, 1995; Wrona *et al*., 2006). The Mackenzie River Basin drains approximately one-fifth of the land area of Canada, or 1.8 million km^2, stretches 15 degrees of latitude, and has the largest flow of freshwater into the North American Arctic (9700 m^3/s) (Ayles & Snow, 2002; Beaulieu *et al*., 2011; Fassnacht, 2000; Graydon, Emmerton, Lesack & Kelley, 2009; Goulding *et al*., 2009; Millot *et al*., 2003; Szeto *et al*., 2008; Woo & Thorne, 2003). There are three deltas within the Mackenzie Basin: the Peace-Athabasca, Slave and Mackenzie Deltas (Fassnacht, 2000) (Figure 4.3). The Mackenzie River Delta is the largest in Canada,

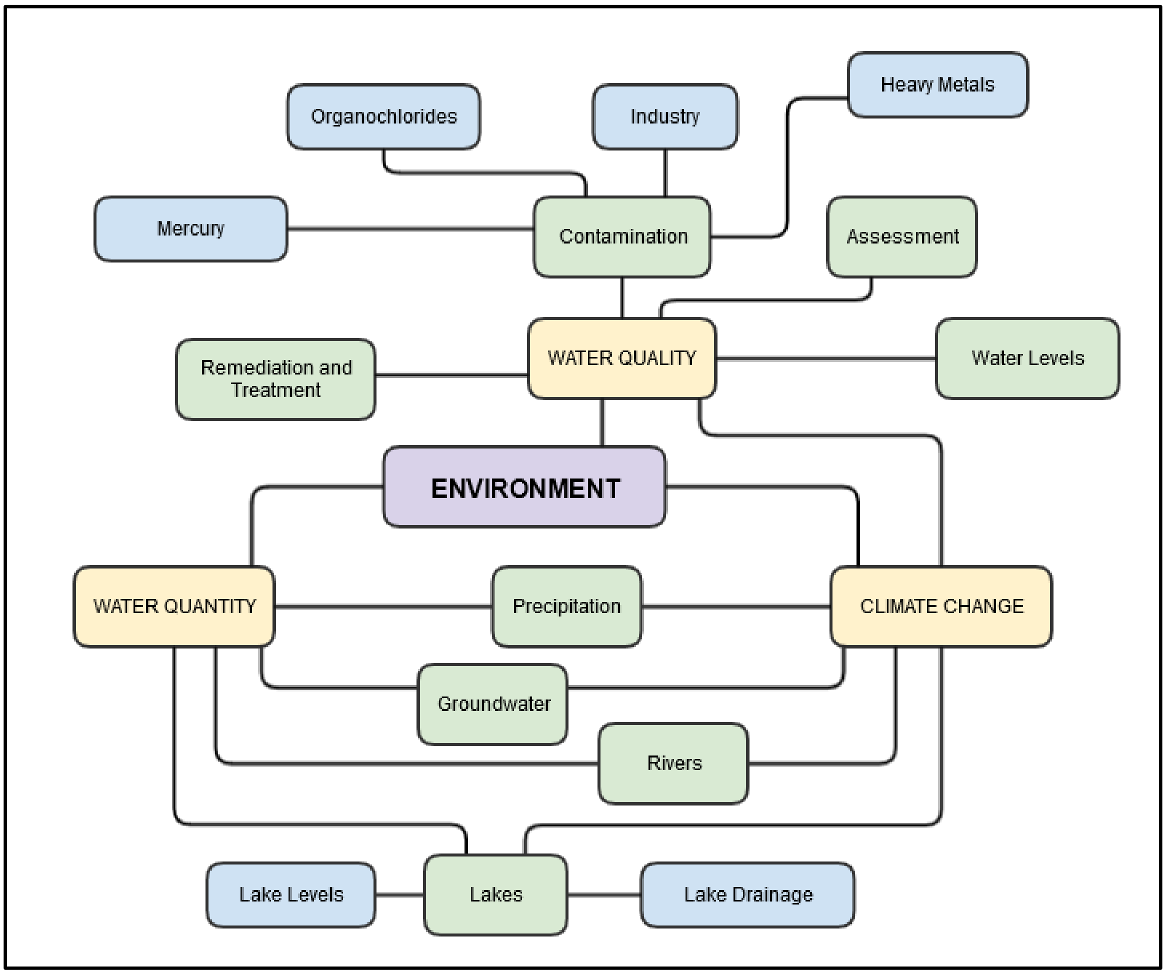

Figure 4.2: Environment considerations for water in the ISR

measuring 200 km long and 65 km wide, and contains more than 45,000 lakes of varying sizes (AMEC, 2005; Emmerton, Lesack & Marsh, 2007; Ensom, Burn & Kokelj, 2012; Lesack & Marsh, 2010; Lesack, Marsh, Hicks & Forbes, 2014; Prowse *et al.*, 2009). The Mackenzie River is the longest river in Canada, measuring 1802 km in length (INAC, 2010b). The ISR communities are at the outlet of the Mackenzie River and concentrated within the Delta, with the exception of two communities on islands in the Arctic Archipelago (Figure 4.3). The abundance of water resources in this landscape occupies

Figure 4.3: Map of the Mackenzie Basin (University of Saskatchewan, n.d.).

up to 30% of the land and is generally present as chains of lakes connected by outlet streams (Baki *et al*., 2012). The Tuktoyaktuk Coastlands, which lie between the Mackenzie Delta and the Amundsen Gulf, is characterized by thick, unconsolidated sediments, massive ice, retrogressive thaw slides and lake coverage of up to 30% (AMEC, 2005). Up to 20% of Canada's wetland is found in the Arctic (Prowse *et al*., 2009).

4.2.1.1 Lakes

The average size of lakes within the Mackenzie Delta increases seaward, with smaller lakes found in the upper delta and larger lakes found in the lower delta (Emmerton *et al*., 2007). The percent of lake cover also changes, with 15-30% in the southern delta, 30-50% in the middle delta and <30% in the northern delta (Ensom *et al*., 2012). The large number of lakes in the Delta is due to the large number of small, but nonetheless, significant water bodies (Emmerton *et al*., 2007; Lesack & Marsh, 2010). It is predicted that 60% of the delta lakes maintain through-taliks, unfrozen ground within permafrost, a number that is more likely to be overestimated than underestimated (Ensom *et al*., 2012). The abundance of lakes was also found to be higher in permafrost regions of the NWT. It was said that permafrost could promote the occurrence of lakes in several ways, including the thawing of ice rich permafrost (Marsh, Russell, Pohl, Haywood & Onclin, 2009). Lakes found in the floodplains of the Delta are generally small, shallow and originate from thermokarst, or thawing of ice-rich permafrost (Emmerton *et al*., 2007).

Ice-jams created during spring ice break-up along the Mackenzie River result in flooding, and are the main source of recharge for lakes in the highest elevation in the

Delta and produce water levels that are much greater than could be achieved under open-water conditions (Goulding *et al*., 2009; Marsh & Hey, 1994). Variation in the water level of the main channel plays a crucial role in the hydrology of lakes across the Mackenzie Delta (Marsh & Hey, 1994). Up to 85% of the Delta lakes always flood in the spring, when flow is at its highest, with 60% continuing to exchange water with the channels and 25% being closed off after this peak period (Graydon *et al*., 2009). This relationship is seeing some changes. River-to-lake connection time in lower elevation lakes has increased over the last 30+ years as a result of rising sea levels while connection times in the highest elevation lakes have decreased, likely as a result of decreased ice-jamming during spring river ice breakup (Lesack & Marsh, 2010; Marsh & Hey, 1994). Some research into the impact of sediment infilling of lakes during the period they are connected to channels has been done. In the end, it was noted that the rate of sedimentation infilling is relatively minor (>4.4 mm/yr) to the overall depth of the lakes (Lesack & Marsh, 2010). Although lake levels vary, Pohl *et al*. (2009) found no obvious trends in the timing or volume of peak lake levels in an upland tundra lake (50 km northeast of Inuvik).

4.2.1.2 Lake Drainage

Thousands of thaw lakes in the Mackenzie Delta have been lost from the landscape as a result of rapid lake drainage, a process where lakes are completely or partially drained within hours (Pohl *et al*., 2009). It has been estimated an average of two lakes per year have been lost to this process in the Tuktoyaktuk Peninsula over the last few thousand years (Pohl *et al*., 2009). The rate of rapid lake drainage has varied over the last 50 years, likely as a result of the complex relationship between hydrologic processes and climate (Marsh *et al*., 2009). Marsh *et al*. (2009) identified 175 drained, or partially drained, lake basins from aerial photographs of the region taken in 2000 and later confirmed through field observations in 2005 that 74 of 75 basins identified were drained lake basins. There are sequences of drained thaw lake basins which suggest that drainage of an upstream lake can result in the drainage of downstream lakes (Marsh *et al*., 2009).

Other research suggests that thermal ice wedge cracking during the winter and high lake water levels are likely the key contributing factors to rapid lake drainage (Pohl *et al*., 2009). Up to 15% of water bodies in the western Arctic have shoreline retrogressive thaw slumps (French *et al*., 2014).

4.2.1.3 Rivers

Major flow periods in Arctic rivers generally coincide with spring melt which starts in late May and peaks in June, but pulses of high water can occur after rainstorms due to the low storage capacity of the underlying permafrost and tundra (Ayles & Snow, 2002; Newton, Prowse & Bonsal, 2014b; Woo & Thorne, 2003). For example, the peak water level in spring of the East Channel of the Mackenzie River at Inuvik generally exceeds the late summer water level by more than four meters (Ensom *et al*., 2012). However, high flow in some rivers remains over the course of the summer months (Newton *et al*., 2014b). For example, while peak flow of the Mackenzie River is in June, discharge throughout the year remains relatively high as a result of the fact that its headwaters are much farther south (Ayles & Snow, 2002).

4.2.1.4 Groundwater

Although groundwater is important to Arctic lake systems, it is often overlooked due to the difficulty in measuring discharge (Dugan *et al*., 2012). Permafrost controls the distribution and quality of groundwater across the region by controlling the recharge to underlying aquifers and the discharge to surface water systems (Prowse *et al*., 2009). Despite the abundance of water bodies and channels, over 90% of the Delta is underlain by continuous permafrost (Ensom *et al*., 2012). Even with the presence of permafrost, there is perennial flow of groundwater through karst carbonate and evaporate bedrock (GNWT ENR, 2011a; Utting *et al*., 2013). Utting *et al*. (2013) demonstrated that non-thermal groundwaters have a circulation time between two and three decades, indicating that groundwater systems have significant storage and flow paths across the region.

4.2.1.5 Precipitation

The Mackenzie Delta is characterized by low annual precipitation as a result of the rain-shadow effect off the Cordillera, with annual precipitation of approximately 250 mm at Inuvik and decreasing northeastwards with approximately 125 mm at Tuktoyaktuk (AMEC, 2005; Goulding *et al*., 2009; Szeto *et al*., 2008). The greatest amount of rainfall in Inuvik occurs in July while snowfall is greatest in the fall (AMEC, 2005). While no consistent trends in precipitation were found in the Delta, in recent years a decrease in fall and winter precipitation and increase in spring precipitation have been noted (Goulding *et al*., 2009). Precipitation and runoff play a relatively small role in the water balance of lakes with long connection times (duration of connectivity between lakes and rivers) with rivers but can play a more significant role in the water balance of lakes with short connection times because it would act as the main source of replenishment (Lesack & Marsh, 2010).

Snowfall is the major form of precipitation in the Mackenzie Basin (Woo & Thorne, 2003). Seasonal variations of snow cover timing, duration, thickness and distribution have significant impacts on groundwater recharge, surface runoff and streamflow (White *et al*., 2007). Snow cover also has an impact on winter water storage and year-round runoff (White *et al*., 2007). It is recognized that the total amount of snowfall is generally underestimated (Woo & Thorne, 2003).

Surface evaporation is weak in the winter because of cold temperatures and limited sunlight but there is a considerable amount of moisture recycling during the summer months (Szeto *et al*., 2008). Evapotranspiration is more important to the overall water balance in the north as a result of low precipitation and sublimation (Prowse *et al*., 2009). As a result, evapotranspiration governs the water cycle in the region.

4.2.1.6 Ice

There was a limited amount of information about ice in the Delta in the literature. However, it was noted that segregated ice, found in ice-rich zones at the top of permafrost in non-bedrock zones, could be important hydrological reservoirs (Kokelj & Burn, 2003).

4.2.2 Water Quality

The quality of a water source is a function of the chemical, physical and biological properties of the source and tells us how suitable the water is for drinking and for plants and fish to live in (GNWT ENR, 2012b; INAC, 2010b). There are a number of other reasons why water quality is measured, including: to contribute to existing knowledge; to address community concerns about contaminants; and, to support transboundary water agreements (INAC, 2010b). NWT residents identified access to safe drinking water as a basic human right, and in 2007 the GNWT agreed and passed a motion that recognized this right (Gordon Foundation, 2011).

There were a number of potential issues with physical access to water that emerged from literature. For example, there are several threats to built municipal and transportation infrastructure, such as the thawing of permafrost, coastal erosion, flooding and early spring melt/late freeze-up, that can all have an impact on the ability of a community and community members to safely access water resources (Pearce *et al*., 2011). Much of the water in the NWT may already be committed for future human use, which could have an impact on access to water resources in the future (Plummer *et al*., 2012). Northern communities that lie within the discontinuous permafrost zone are able to more easily access groundwater supplies; access decreases as permafrost becomes more widespread (Prowse *et al*., 2009). Meanwhile, access to water in the Arctic Islands is limited by the concentration of permafrost and limited precipitation levels (Prowse *et al.*, 2009). One of the goals of the Northern Waters Strategy is to ensure that local residents have access to safe and clean drinking water at all times (GNWT ENR & INAC, 2010).

Greater access to information about water monitoring will help inform local residents about potential issues and lead to better decision-making abilities (GNWT, 2013). Information about water quality can be found in the NWT portion of the National Hydrometric Network, produced jointly by EC and AANDC, and the GNWT Municipal and Community Affairs (MACA) water quality database (INAC, 2010b). There is also a Northern Aquatic Food Chain Contamination Database that provides and overview of contaminants in the region and is a useful tool for researching and understanding the impact of contaminants in the Arctic (Careau & Dewailly, 1995).

Descriptions of general surface water quality across the region were found in the literature. For example, the majority of surface waters in the Mackenzie River Basin are oversaturated with calcite and the rivers are predominantly alkaline (Millot, Gaillardet, Dupre & Allegre, 2003). In 2012, the GNWT found water across the NWT had a pH range of 7.5 to 8.9, with an average of 8.3, which is on the high end of the normal range for surface waters (GNWT ENR, 2012b). High concentration of dissolved organic content is another major characteristic of Mackenzie Basin rivers (Millot *et al*., 2003). The concentration of organic matter in Arctic rivers is drawn from carbon-rich drainage areas that contain up to half of the world's organic carbon stored in soil (Frey & McClelland, 2009). Dissolved organic content, the dominant food source for bacteria, was found to be highest in July near Aklavik and Inuvik, coinciding with the period when highest summer water temperatures have been observed (Droppo, Jeffries, Jaskot & Bakus, 1998; GNWT ENR, 2012b). The transport of dissolved organic matter is expected to decrease with an increase in thawing permafrost as a result of increased adsorption through newly exposed mineral soils (Frey & McClelland, 2009).

Turbidity can also have an impact on the quality of a water source. Turbidity is described as the cloudiness of water resulting from small particles, where high turbidity raises the amount of hiding space for bacteria, viruses and protozoa, increasing the health risk of the water while decreasing the effectiveness of disinfectants (GNWT HSS, 2007). Several rivers in the NWT have naturally high turbidity (GNWT ENR, 2012b). The major constituents of lake water between Inuvik and Richards Island was found to be Ca, Mg and sulfate (Kokelj, Jenkins, Milburn, Burn & Snow, 2005).

The importance of groundwater and its characteristics were also discussed. Understanding groundwater flow in permafrost terrain was said to be important for mining development and for understanding potential environmental impacts (Utting *et al*., 2013). Groundwater can have an impact on infrastructure and surface water sources by affecting pipeline and roadway stability and influencing nutrient transport and the chemical signatures of surface water bodies (Dugan, Gleeson, Lamoureux & Novakowski, 2012; Prowse *et al*., 2006). Like surface water, groundwaters in the Mackenzie Basin are often supersaturated in calcite due to recharge through organic-rich soils that overlay fractured carbonate bedrock (Utting *et al*., 2013). The interaction between groundwater and surface water is expected to become more important as permafrost continues to thaw (White *et al*., 2007). In the end, Millot *et al*. (2003) found that although there are small variations, the water quality of the Mackenzie River has remained relatively stable over the last half century.

4.2.2.1 Water Quality Assessment

There are several tests that can be done to assess the quality of water sources, including:

- water temperature, which affects the amount of oxygen in the water and can have an impact the plants, bugs and fish that live in river or lake;
- pH, which is a measure of the acidity of water and can impact the uptake potential of certain metals;
- turbidity, which describes the cloudiness of water indicating the amount of particles in water to which contaminants can attach;
- changes in conductivity as a result of human waste and salinity, that can have an impact on plants, bugs and fish; and,
- chlorophyll-a, which is a human and industrial waste that can increase nutrients resulting in higher amounts of algae that eventually die and decay, decreasing dissolved oxygen in the process and making it more difficult for fish to breathe (AMEC, 2005; GNWT ENR, 2012b).

Three tools for measuring water quality were mentioned: YSI sondes, Polyethylene Membrane Devices (PMDs) and Diffusion Gradients in Thin Films (DGTs). YSI sondes can measure basic water quality parameters, such as pH, turbidity and conductivity, from a single point over long periods of time; PMDs measure oil and gas related chemicals (hydrocarbons) dissolved in water; and DGTs measure the concentration of dissolved metals in water (GNWT ENR, 2012b). Grab water samples, single rather than continuous samples, taken in the NWT are sent to the Taiga Environmental Laboratory in Yellowknife where they are analyzed for 75 parameters (GNWT ENR, 2012b).

Biomonitors can also be useful for testing the quality of a water source. Plankton have been shown to be good biomonitors of PCBs and pesticides in lakes; fish have been shown to be good biomonitors of contaminants in lakes and rivers; and, mink have also been shown to be good biomonitors as they are uniquely susceptible to contaminants in fish (Braune *et al*., 1999). The ENR has committed to providing training for those involved in community-based monitoring by partnering with the University of Alberta and University of New Brunswick to teach water quality sampling and fish monitoring techniques (GNWT ENR, 2011c).

Currently, there are no Canadian guidelines for dissolved metals, such as aluminum, iron and manganese, and dissolved hydrocarbons in water, but there are some guidelines for water quality, such as the CCME Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME, 2009). While these guidelines provide a target with which water samples can be compared, they are not specific to northern rivers, which sometimes have naturally high concentrations of some metals (GNWT ENR, 2012b). AANDC took water samples from 23 NWT community water supplies. Results showed levels higher than guidelines for a number of parameters, such as pH, fecal coliforms, nitrite, arsenic, and lead (INAC, 2010b). As a result, AANDC (2010) recommended that these parameters be monitored on a site-specific basis to determine the reason that some parameters are exceeding comparative guideline levels. There are many ways in which the quality of water can be altered, both natural and human-induced impacts are provided in the following sections.

4.2.2.2 Water Levels

Change in water levels, whether it is natural or artificial, can have an impact on the composition and quality of water. For example, damming can result in numerous impacts, such as altering the light penetration into aquatic systems, changing the concentration of dissolved organic carbon which can have an impact on biogeochemical processes and can act as nutrient sinks that either deprive downstream habitats from essential nutrients or release nutrients in pulses that are useless or harmful to downstream environments (Cott *et al*., 2008).

Natural changes in water level, such as those experienced during river ice break-up, can also have an impact on water quality. For example, the increase in river water flow during spring break-up impacts nutrient fluxes to the Beaufort Sea (Emmerton *et al.*, 2007). Biological uptake and sedimentation are enhanced in lakes compared to turbulent and light-limited rivers and as a result, river floodwater entering lakes can cause significant changes in nutrients and chemistry (Emmerton *et al*., 2007). Seasonal snowmelt also releases 8-9 months of chemical deposition within a relatively short period of time which can strongly influence the chemical input of small and medium sized catchments, such as an increase in organic acids (Quinton & Pomeroy, 2006). Fire was also found to have an impact on the chemistry of water in small lakes (Kokelj *et al*., 2005).

4.2.2.3 Water Contamination

NWT waters have low levels of contaminants and pollution compared to other parts of the world, and are often considered to be pristine when compared to southern locations in Canada (Braune *et al*., 1999; GNWT ENR, 2011a). However, there is evidence that contaminants are bioaccumulating in humans and that the Arctic is not as pristine as originally thought (Braune *et al*., 1999; Leitch *et al*., 2007). Anthropogenic disturbances to Arctic freshwater environments are expected to grow with increased exploration and development (Kokelj *et al*., 2012). Anthropogenic sources of pollution come in two forms: point source (fixed from a single point) and non-point source (various points) (GNWT ENR, 2012b). Examples of point sources of pollution include effluent pipes, sewage lagoon outfall and fuel tanks while examples of non-point sources of pollution include spring melt, road salts, streambank erosion and landslides (GNWT ENR, 2013).

4.2.2.4 Industry

Human activities, such as mining, petroleum exploration, hydroelectricity and municipal water use have direct impacts on water quality that are expected to increase as population and economic activities grow (INAC, 2010b). Industry and associated activities, such as the development of infrastructure, exploration and production act as stressors for freshwater environments and can be widespread (Thienpont *et al*., 2013). Increased contaminant input as a result of increased industrialization is of particular concern (Prowse *et al*., 2006). Mining has the potential to have serious consequences to aquatic ecosystems through acid mine drainage, metal contamination and chemical pollution (Gordon Foundation, 2011). Polycyclic aromatic hydrocarbons (PAHs) are produced during oil and gas activities and are toxic to the environment (Thienpont *et al*., 2013). An increase in hydrocarbon exploration and development activities in the Arctic will increase the potential for widespread contamination of freshwater lakes (Thienpont *et al*., 2013). Long range atmospheric transport of mercury to the Arctic has increased as a result of increasing industrialization and has had an impact on Arctic ecosystems, inhabitants and wildlife (Graydon *et al*., 2009). More information on mercury and its effects on freshwater ecosystems and humans can be found in the mercury section.

4.2.2.5 Organochlorines

Organochlorines are toxic in some forms, such as insecticides and DDT, and were first determined to be present in Arctic freshwater and fish in the 1970s (Braune *et al*., 1999). Persistent organic pollutants (POPs), such as PCBs, have physiochemical properties that make them resistant to degradation, making it easier for them to bioaccumulate (Carrizo & Gustafsson, 2011). Toxaphene, a major organochlorine contaminant found in fish, can co-occur with mercury, but is not dependent on its presence (Braune *et al*., 1999). It was noted that organochlorine concentrations in lakes are generally low, the higher concentrations of PCBs in Arctic lakes was attributed to increased snow melt and runoff (Braune *et al*., 1999).

In general, PCB and toxaphene levels are higher in eastern Arctic lakes than in western Arctic lakes (Braune *et al*., 1999). An increase in PCBs, toxaphene and DDT, despite global banning and restricted usage through the late 20th century, has been observed since the 1990s (Carrie *et al*., 2010). These increasing trends go against the observed decrease in atmospheric contaminants leading to the conclusion that other mechanisms of transport than the atmosphere should be considered (Carrie *et al*., 2010). Some types of PCBs are more readily available than others. For example, trichlorinated and tetrachlorinated congeners are abundant in the Mackenzie, making up approximately 75% (Carrizo & Gustafsson, 2011). Spatial distribution is also variable. For example, Braune *et al*. (1999), found concentrations of PCBs and toxaphene in broad whitefish in lakes within the ISR to be 2-10 times higher than nearby Horseshoe Bend. The highest levels of organochlorines, PCBs and DDT, were found in birds in upper trophic levels, piscivores and molluscivores, however many of the birds pick up contaminants in their southern wintering grounds (Braune *et al*., 1999).

Net plankton is a useful biomonitor for PCBs and organochlorines (Braune *et al*., 1999). Burbot are also useful for determining the spatial distribution of organochlorines because they are relatively sedentary and they are readily available along the Mackenzie River (Braune *et al*., 1999). Mink are also extremely sensitive to PCB contaminants, experiencing adverse effects to reproductive systems with small quantities, which makes them good biomonitors for PCBs (Braune *et al*., 1999). Evidence for declining organochlorine concentrations in Arctic freshwaters is limited and there is not a large margin of safety for Arctic freshwater piscivores (animals that eat fish) (Braune *et al*., 1999).

4.2.2.6 Hydrocarbons

An increase in hydrocarbons also emerged as a concern in the literature. Natural sources of hydrocarbons include forest fires and natural oil and gas deposits while human sources are related to oil and gas development (GNWT ENR, 2012b). Hydrocarbons can either be dissolved in water or attached to dirt in water, therefore, rivers that carry more dirt also often carry more hydrocarbons (GNWT ENR, 2012b). Hydrocarbons dissolved in water are more capable of getting into plants, and fish than those attached to dirt because those attached to dirt generally stay attached unless there is a change in pH or temperature (GNWT ENR, 2012b). Hydrocarbons are important to monitor because humans and fish can experience adverse effects if high enough levels are consumed (GNWT ENR, 2012b).

4.2.2.7 Heavy Metals

Heavy metals in Arctic biota are a result of both anthropogenic and natural sources (Braune *et al*., 1999; GNWT ENR, 2012b). Braune *et al*. (1999) note two areas of concern that need to be addressed: the relative contributions of metals from different natural and geological sources and the biological implications of metals from different sources. Plants absorb metals, such as cadmium, which are then passed on to grazers (Braune *et al*., 1999). The accumulation of cadmium in plants used as winter forage for caribou and naturally high cadmium concentrations in soils are likely the cause of high cadmium concentrations in some caribou herds (Braune *et al*., 1999). Birds that generally eat prey associated with bottom feeders are also more likely to have higher concentrations of cadmium (Braune *et al*., 1999). The concentration of metals is generally higher during spring melt runoff (GNWT ENR, 2012b).

Another contaminant mentioned was arsenic. There are both natural and anthropogenic sources of arsenic in the NWT. The natural source of arsenic comes from the underlying bedrock while anthropogenic sources include the use of arsenic in the milling process and increased weathering of bedrock due to climate warming that exposes fresh surfaces to the elements (GNWT ENR, 2011a). Some grab samples in the NWT in 2012 showed arsenic levels above the guideline for total arsenic, although the majority of the arsenic was attached to dirt and therefore less readily available to plants, bugs and fish (GNWT ENR, 2012b). Long-term data from the Mackenzie River has also shown that exceedances from the guideline levels have occurred in the past (GNWT ENR, 2012b).

4.2.2.7.1 Mercury

Mercury was said to be one of the most troubling contaminants that can be found in the Arctic because its concentration has been rapidly increasing while environmental processes in the Arctic are still poorly understood (Leitch *et al*., 2007). Increased levels in fish have resulted in Public Health Advisories for some lakes in the NWT (GNWT ENR, 2011a). River discharge, terrestrial input from melted permafrost, forest cover and forest fires are said to have a role in the spatial distribution of mercury in Arctic ecosystems and lakes (Leitch *et al*., 2007). While forest cover can reduce mercury runoff, forest fires will likely increase mercury runoff to the Mackenzie River (Leitch *et al*., 2007). The Northern Contaminants Program is compiling data about mercury to help support international policy discussions (GNWT ENR, 2011a). This program is important for long-term monitoring and for its collaboration with Indigenous communities.

There are natural sources of mercury, as it is a constituent of rocks, but also anthropogenic sources of mercury, such as atmospheric input, which has increased significantly since preindustrial times and has resulted in deposition on land and water surfaces across the Arctic (Braune *et al*., 1999; French *et al*., 2014). While there is limited data on the temporal trends of mercury in the NWT, some research has found an increase in mercury and PCBs in Mackenzie River burbot, a predatory fish that is a staple food source for some northern communities (Braune *et al*., 1999; Carrie *et al*., 2010; GNWT ENR, 2011a). Carrie *et al*. (2010) attributed this to be a result of reduced ice cover and increasing temperatures, which were said to increase exposure to contaminants. The NWT has several lakes with fish populations that exceed the guidelines for mercury, although there is significant variation from lake to lake (Braune *et al*., 1999; GNWT ENR, 2011a). Increased levels of mercury are generally found in older and larger fish which have had a longer time for mercury to bioaccumulate (Braune *et al*., 1999; GNWT ENR, 2011a). Relatively little research has been done on the forms of mercury found in Arctic fish (Braune *et al*., 1999). However, studies have found a 2- to 3-fold increase in mercury deposition since preindustrial times, although there is some debate about whether these numbers are accurate (Carrie *et al*., 2010).

Different levels of mercury have been found in different sources of freshwater, with the total level of mercury varying by the type of water source (e.g. river, lake, pond) and the time of year (Graydon *et al*., 2009). The concentration of mercury in the Mackenzie River and regional lakes was observed to be higher during the spring peak flow period, when transport of suspended sediments is also higher, than later in the summer (declining over 60% from June to August), suggesting that increasing surface runoff facilitates the mobilization of mercury, which forms strong bonds with organic matter (Fassnacht, 2000; Graydon *et al*., 2009; Leitch *et al*., 2007). Research also demonstrates that levels of mercury are increasing at greater rates in smaller lakes compared to larger bodies of water, partly as a result of higher water temperatures (GNWT ENR, 2011a; Graydon *et al*., 2009). Dissolved organic content was shown to both promote and inhibit the bioaccumulation of mercury in tundra lakes and plays a critical role in determining the bioavailability of mercury (French *et al*., 2014). Results suggest that there is a 2- to 3-fold increase in mercury bioaccumulation as lakes reach their dissolved organic content thresholds (French *et al*., 2014).

4.2.2.8 Treatment and Remediation

Wastewater contains dissolved or suspended matter from a home, community or industry; municipal wastewater is one of the largest sources of pollution to surface water sources in Canada (INAC, 2010b). Suspended sediment particles can act as a transport medium for contaminants so understanding the transport of suspended sediments is important for understanding the fate of contaminants (Fassnacht, 2000; Mouchot, Alfodi, De Lisle & McCullough, 1991).

The concern with wastewater effluent is focused on potential environmental degradation as a result of the toxic components of the waste (AMEC, 2005).One of the GNWT's goals is to ensure that wastewater from economic activities is treated to the extent that it does not adversely affect water values and uses (GNWT ENR & INAC, 2008). The level of treatment required has an impact on the cost required to treat the water to this standard as well as influencing the level of risk to downstream water users (GNWT ENR & INAC, 2008). The CCME has developed a Canada-Wide Strategy for the Management of Municipal Wastewater Effluent with the goal of developing discharge objectives, monitoring programs and achieving secondary level treatment for wastewater effluent (INAC, 2010b). The Northern Research Working Group of the CCME is evaluating the wastewater treatment needs of northern communities to determine which treatment solutions should be implemented (INAC, 2010b).

The disposal of waste drilling fluids (waste muds, altered drilling muds, organic bactericides, organic and inorganic compounds, detergents, waste cements, biocides, etc.) in the ISR has historically included containment in on-site sumps that are backfilled after the completion of a well, a method that has assumed drilling wastes will be contained permanently by the permafrost environment as fluids are expected to freeze in situ before being capped (AMEC, 2005; Thienpont *et al*., 2013). Over 150 drilling sumps have been constructed in the Delta over the last 60 years, with about 1800 sumps in total across the Canadian Arctic (AMEC, 2005; Thienpont *et al*., 2013). However, flooding in the Mackenzie Delta has increased concern over the potential for contact between flood and sump waters (AMEC, 2005). Thienpont *et al.* (2013) have also found that permafrost has not performed as well as expected when used as a containment medium. For example, 74% of the sites assessed by Thienpont *et al*. (2013) had ponding which suggests there has a been a significant thaw of the sump materials which increases the potential of surrounding ground and surface waters becoming contaminated with drilling muds. AMEC (2005) also found salt crystallization, ponding, eroded ground cracking and slumping. There is evidence that these ponds are being used by wildlife; bear and moose tracks and eggshells, feathers, tracks and droppings were observed along the edges of the caps (AMEC, 2005). AMEC (2005) linked the success of permafrost as a containment medium to the construction, site operations and abandonment practices at each site. Ensuring proper containment of these fluids is essential as they have been shown to be toxic to freshwater organisms (Thienpont *et al*., 2013).

Treatment of waste fluids, such as flocculation, dilution, pH adjustments and controlled removal of hydrocarbons, can be used to reduce the toxicity of wastewater

(AMEC, 2005). Flocculation is a process where smaller, water-soluble soil particles aggregate to form larger particles, is driven by physical, chemical and biological mechanisms, and ultimately leads to changes in the chemical and biological behavior of sediment during interactions with contaminants and the biological community (Droppo *et al*., 1998). Bioremediation is another type of treatment mentioned in the literature. It was noted that bioremediation is a common choice for cleaning hydrocarbon-contaminated sites but that relatively little is known about its use in northern latitudes where cold temperatures and remote locations pose challenges (Yeung *et al*., 2013). A study by Yeung *et al*. (2013) found evidence to support the claim that bioremediation of dissolved hydrocarbons is happening within fractured rock in cold regions within Canada, which is in line with similar studies in other cold regions around the world. Wootton *et al*. (2008) also note that although there has been limited scientific, peer-reviewed research on the performance of lagoons and wetlands, particularly across seasons, some monitoring and compliance results suggest that they can treat effluent to desirable levels. While the reuse of wastewater has been employed in other regions, it is typically not done in the Arctic because most operations occur in the winter months so the fluids freeze shortly after being placed in the sumps (AMEC, 2005).

Some incongruities were also mentioned. For example, despite the fact that monitoring effluent is a requirement of water licenses issued by the IWB and the GLWB, it was noted that most municipalities in the ISR rely on compliance monitoring for signaling treatment problems rather than monitoring effluent quality (Wootton *et al*., 2008). Some future recommendations identified in the literature include more research on the impacts of wastewater effluent in the ISR, particularly at drilling waste disposal sumps, with a focus on their impacts on humans and wildlife, and setting research priorities based on consultation with the Inuvialuit (AMEC, 2005; Wootton *et al*., 2008).

4.2.3 Climate Change

There is growing evidence that climate warming is having an impact on northern water resources (Quinton *et al*., 2011). Wrona *et al*. (2006) noted that the most significant challenge to understanding how freshwater systems will be impacted by future climate change is the limited understanding of the relationship between the climate system and the aquatic ecosystems and its processes. The impact of climate change on Arctic freshwater systems is complex with variables such as precipitation, river discharge and societal responses remaining relatively uncertain (White *et al*., 2007). For example, warming air temperatures will enhance the degradation of permafrost which could lead to the drainage of Arctic lakes, but warming could also enhance the thermokarst deepening of existing lakes or aid with the creation of new lakes through subsidence of ice-rich soils (Emmerton *et al*., 2007). Sea level rise in the Tuktoyaktuk region has been noted and is expected to continue, which could likely result in the inundation of coastal lakes (Emmerton *et al*., 2007). Despite the uncertainty, it is noted that anthropogenic disturbances can result in extreme water level fluctuations (Cott *et al*., 2008). Other impacts being noticed include later ice freeze-up, thawing permafrost, ground slumping and increased sedimentation in rivers (Pearce *et al*., 2011). Fire and climate-induced active layer deepening of ice-rich permafrost can also add significant amounts of water to the active layer (Kokelj & Burn, 2003). The degradation of permafrost can also redistribute moisture and solutes deeper into the soil (Kokelj &Burn, 2003). Prowse *et al*.

(2006) explain that even small changes to the climate can result in large impacts to the freshwater environment and that these effects can be either gradual or very abrupt.

4.2.3.1 Rivers

It was noted in the literature that changes to the climate will result in changes to river flow. For example, warmer temperatures in the late winter and early spring result in earlier snowmelt which could be responsible for decreased water flow over the summer months (Abdul-Aziz & Burn, 2006; Baki *et al*., 2012; Emmerton *et al*., 2007; Lesack *et al*., 2014; Newton, Prowse & Bonsal, 2014a; Prowse *et al*., 2006). The Mackenzie River Basin in general was observed to have increased streamflow in the winter months, decreasing flow in the late spring, summer and fall months, and earlier onset of peak flow in the spring (Abdul-Aziz & Burn, 2006; GNWT ENR, 2011a; Newton *et al*., 2014b). While the GNWT (2011) attributed increased winter flow to increased fall temperatures and rain, Lesack *et al*. (2014) found that earlier ice break-up was more a function of local spring warming. Overall, Emmerton *et al*. (2007) and Lesack *et al*. (2014) came to the conclusion that there will be an increase in water flow to the ocean and a reduction in channel storage within the delta.

Temperature increases are also expected to lead to less severe river ice breakups and flooding in the spring (Prowse *et al*., 2006). Reduced river flow and changes in salinity are considered by Inuvialuit elders and fishers as contributing factors in the reduction of the char population to a critical stage in the Big Fish River (Papik *et al*., 2003). This is already being observed in the region. According to White *et al*. (2007), one of the best ways to detect large-scale changes in the terrestrial hydrological cycle is through river discharge as it integrates precipitation, evapotranspiration and changes in water storage upstream from the gauging station. While it incorporates all of these elements naturally, it doesn't really tell us about how these specific functions of the water cycle are changing individually. Dam regulation of water discharge can complicate the impacts of river discharge as well (White *et al*., 2007).

4.2.3.2 Lakes

Thaw lakes are sensitive to climate change and can be altered by a number of processes associated with climate change including lake level change, increased ground flow from thawing permafrost and increased thawing and erosion along the shoreline by thermokarst processes (Marsh *et al*., 2009). Because of earlier snowmelt and peak streamflow periods, the annual flood pulse that supplies lakes in the Delta may arrive earlier (Emmerton *et al*., 2007). Small inland lakes were said to be particularly vulnerable to climate changes (Cott *et al*., 2008).

Concern about the reduction of lake levels as a result of climate change came up frequently in the literature. For example, Baki *et al*. (2012) attributed lower lake levels to continuous summer evaporation and additional loss to groundwater as a result of permafrost thaw. Cott *et al*. (2008) mention that 11% of lakes in areas of discontinuous permafrost have become shallower or disappeared in the last 30 years, suspecting that initiated permafrost thaw influenced local water tables. Elsewhere, reduced ice-jamming during spring ice break-up was said to reduce the amount of water supplied to lakes in the Delta during the annual flood pulse which could result in a reduction in river water replenishment and reduction of lake levels (Emmerton *et al*., 2007; Lesack *et al*., 2014). Some work has already shown a reduction in river-to-lake connection times in the upper delta over the last 50 years (Goulding *et al*., 2009; Lesack & Marsh, 2010). The terrestrial portion of the Delta near Inuvik does not flood annually and even when it does, it is a small amount of water for a short period of time (Marsh &Hey, 1994). Another cause is increased evapotranspiration as a result of increasing temperatures, which can exacerbate droughts, impact precipitation recycling and reduce water levels (Newton *et al*., 2014b; Pohl *et al*., 2009; White *et al*., 2007). Increased evaporation and evapotranspiration, along with increased permafrost thaw, is expected to decrease surface water levels and coverage (Prowse *et al*., 2006).

Lake sizes are also expected to be impacted by climate changes. Initiation, development and disappearance of lakes are natural processes in areas underlain by permafrost that can be impacted by changes in climate, which has been shown to result in both decreases and increases of lake areas (Brisco *et al*., 2009; White *et al*., 2007). Climate warming could result in the creation of melt-water ponds as permafrost begins to degrade (Brisco *et al*., 2009; White *et al*., 2007). AMEC (2005) describe moisture contents of 1000% or more by volume, due to the presence of excess ice, as being common in the lower Mackenzie Delta which if thawed, could result in ponding, the creation of new lakes and/or the expansion of existing lakes. A deeper active layer will increase water storage capacity and result in ponding in some places (GNWT ENR, 2011a; White *et al*., 2007). When ice-rich permafrost thaws, the soil is disturbed and ponds can form in depressions (Prowse *et al*., 2006). Lakes could appear and grow in areas of continuous permafrost (White *et al*., 2007). Connection times in the lower Delta have increased, which has mainly been attributed to increased sea levels, but has also led to the drainage of lakes in the outer portion of the Mackenzie Delta (Emmerton *et al*., 2007; Lesack *et al*., 2014; Prowse *et al*., 2006).

While some processes will increase the number and size of lakes, others may lead to the disappearance of lakes. Lakes may shrink or disappear in areas with more degraded permafrost and deeper active layers, which could allow water from lakes to drain easier to groundwater (AMEC, 2005; Brisco *et al*., 2009; Prowse *et al*., 2006; White *et al*., 2007). Lakes may also drain catastrophically when lake barriers are breached by channels; a process known as rapid lake drainage (Marsh *et al*., 2009; White *et al*., 2007). Catastrophic drainage can happen in a period of less than 24 hours and has often been associated with ice wedges, ice wedge cracks and high lake levels (Marsh *et al*., 2009). Apart from high lake levels, other research has attributed other factors such as retrogressive thaw slumps, deeper active layers leading to growth in thaw lake size and increased precipitation leading to increased bank erosion (Marsh *et al*., 2009; Pohl *et al*., 2009). Other processes predicted to occur as a result of climate change that may act to reduce the occurrence of catastrophic lake drainage include: lower lake water levels, increased evaporation as a result of longer ice-free periods in the summer months, and a reduction in ice wedge thermal cracking as a result of warmer winters (Pohl *et al*., 2009).

Lake drainage can also have an impact on rivers in the region. Marsh *et al*. (2009) and Prowse *et al*. (2006) mention that peak discharge from lake drainage in the Tuktoyaktuk Coastlands area can be many times larger than rain and snowfall peak discharge and that approximately 1-2 lakes per year drained in this way over the last few hundred years. However, Marsh *et al*. (2009) note that this rate has been dropping over the last 50+ years.

4.2.3.3 Precipitation

Changes in precipitation as a result of climate change were also noted in the literature. An increase in atmospheric temperature, poleward transport of moisture and increased open water as a result of decreased sea ice extent will increase the amount of precipitable water resulting in an increase in net precipitation in the Arctic (Prowse *et al*., 2006; White *et al*., 2007). Climate warming and increased snow cover could have implications for aquatic ecosystems and terrestrial mammals, such as: reduced ability to access underlying vegetation; increased shelter for small, borrowing animals; reduction in lake ice thickness and cover; and, a reduction in the survivability of overwintering fish (White *et al*., 2007).

Abdul-Aziz and Burn (2006) found a positive correlation between annual precipitation (rain and snow) and annual mean flow of rivers. An increase in precipitation could also lead to an increase in streamflow, bank erosion and cause rapid thaw lake drainage if barriers between thaw lakes and river channels are breached (Pearce *et al*., 2011; Pohl *et al*., 2009). Despite the prediction about snowfall, later studies found that there has been a reduction of the snowpack, a shorter accumulation season, and decreasing snowfall on land (Newton *et al*., 2014b). Sachs Harbour is the one exception; it has seen an increase in snowfall (Pearce *et al*., 2011). Changes in the seasonality and river levels will also have social, cultural and economic implications by impacting travel typically done on the river (White *et al*., 2007).

4.2.3.4 Groundwater

Climate change is also expected to have an impact on groundwater. For example, as permafrost thaws, groundwater outflow should increase (Marsh *et al*., 2009). It was also mentioned that one of the consequences of future permafrost thaw is that the Arctic freshwater system could transition from a surface water to a groundwater dominated system (Frey & McClelland, 2009). Lastly, it was recognized in the literature that the significance of groundwater as a contributor to streamflow should not be underestimated and that glacial melt, which was not often mentioned in the literature, should also be considered (Stadnyk *et al*., 2005).

4.2.3.5 Water Quality

There are many expected changes to the quality of water as a result of changes to the climate that can have adverse impacts on humans, such as: the chemical composition of surface runoff and groundwater flows; changes in flood frequencies; increase in runoff in northern latitudes; rising sea levels; longer open water seasons; ground subsidence; and, the magnitude and frequency of storm surges (Abdul-Aziz & Burn, 2006; INAC, 2010b; Kokelj *et al*., 2012; Prowse *et al*., 2006; White *et al*., 2007). Landscape changes within freshwater catchments are expected to have an impact on the transportation and transformation of contaminants; contaminant transport is expected to increase and these can either be stored in sediments or biomagnified through the food web (Prowse *et al*., 2006). Reduced ice cover and enhancement of mixing processes in lakes is expected to increase the potential for northern lakes to become contaminant sinks (Prowse *et al*., 2006). Increase in summer water flow has implications on channel erosion and water quality (Marsh *et al*., 2009). The impact of these changes on Arctic freshwater ecosystems is poorly understood but is expected to be varied and significant (Braune *et al*., 1999; White *et al.*, 2007; Wrona *et al*., 2006). Reducing water consumption, protecting water quality and adapting for future climate changes are priorities of the GNWT (Council of the Federations, 2010).

Most changes in water quality found in the literature were linked to physical changes to the environment. These changes are expected to impact water quality used by biota, which are then used for human consumption (White *et al*., 2007). For example, increased thawing of ground ice could lead to ground subsidence, increasing silt deposition in water bodies and significantly impacting the quality of water found in these lakes (AMEC, 2005; Kokelj *et al*., 2005; Quinton *et al*., 2011). There is some concern about the impact of climate change on organic matter in Arctic rivers, which have some of the highest concentrations globally (Frey and McClelland, 2009). Warming in the Mackenzie Basin is expected to have a significant impact on mercury cycling (Leitch *et al*., 2007). Algal productivity associated with climate change was suggested to increase mercury accumulation (Carrie *et al*., 2010). Climate change was also said to enhance bioaccumulation and increase the level of mercury in predatory fish (GNWT ENR, 2011a). Increased water discharge from additional surface runoff and bank erosion was related to an increased mercury concentration in the Mackenzie River (Leitch *et al*., 2007). Increased temperatures can also increase the occurrence of forest fires and release or partial release of contaminant mercury stored in snow and soils (Leitch *et al*., 2007). An increase in river flow could have an impact on temperature, sedimentation and nutrient transport which could have subsequent implications for habitat and breeding conditions of anadromous fish (fish born in freshwater that spend most of their lives in the sea, returning to freshwater only to breed) (Emmerton *et al*., 2007; Prowse *et al*., 2006; White *et al*., 2007).

Other physical changes include thaw slumps and sea level rise. It was found that thaw slumps and thermokarst disturbance can impact the chemical composition of lakes for several decades, long after the slumps become inactive (Kokelj *et al*., 2005). For example, Kokelj *et al.* (2005) found that up to one-tenth of the lakes in the Mackenzie River Delta have elevated ionic concentrations associated with thaw slumping, that the concentration of dissolved organic content was lower in lakes affected by thaw slumping, and that water in lakes disturbed by thaw slumping were clearer than water in undisturbed lakes. Apparently, the impact of permafrost degradation on the biogeochemistry of rivers is dependent on watershed characteristics as well as the current permafrost conditions, the sensitivity to thawing and the type of permafrost degradation (Frey & McClelland, 2009). The concentrations of major ions are expected to increase considerably as a result of permafrost degradation, as are the concentrations of phosphate and silicate in river waters (Frey & McClelland, 2009). Permafrost thaw slumps have also resulted in wide pH and dissolved organic carbon gradients in tundra lakes, two variables that regulate mercury bioaccumulation (French *et al*., 2014). Some contaminants from thawing permafrost have already leached into community water sources making them undrinkable (Rosenberg Forum, 2009).

It was mentioned in the literature that expected sea level rise will increase the frequency of storms and therefore the number of saline intrusions from storm surges (Kokelj *et al*., 2012). In other words, there is an expected increase in the salinity of some waters along the edges of the Delta. For example, a storm surge in the Mackenzie Delta in 1999 was observed by Inuvialuit to change the salinity of channels within 20 km of Aklavik and lakes across the alluvial plane from fresh to brackish water (Kokelj *et al*., 2012; Thienpont *et al*., 2012). Scientific research done a decade later found that no recovery had occurred in the disturbed systems; salt concentrations remained elevated in the outer delta soils and the presence of brackish diatoms remained the same or increased over the time period (Kokelj *et al*., 2012; Thienpont *et al*., 2012). Increased evaporation associated with climate warming is also expected to reduce water levels, further increasing the concentration of salt in lakes (Thienpont *et al*., 2013).

Other changes are associated with human activities. For example, changes in contaminant concentrations in Arctic biota have been attributed to global contaminant uses, emissions and long-range atmospheric transport (Carrie *et al*., 2010). The impact of climate change on sumps is expected to be exacerbated by thawing in adjacent areas and increasing active layer depth associated with shrub growth (Thienpont *et al*., 2013).

Changes in water quality are already being observed by some in the ISR. For example, some Inuvialuit Elders and fishers noticed that there have been changes in salinity of Big Fish River, a popular fishing location which has also seen a significant decline in water levels and a significant reduction in the char population (Papik *et al*., 2003).

4.2.4 Summary

Adequate water quantity and acceptable water quality are important for human and ecosystem health in the Arctic. As this section demonstrated, there are many processes that can impact the quantity and quality of water in the ISR. Many of the processes and impacts are associated with climate change, are highly variable, and remain poorly understood. Still, several important conclusions can be made:

1. Water resources are widely distributed across the region and include both surface and sub-surface sources. Resources can be found in lakes, rivers, permafrost, precipitation, ground ice, glaciers, snowpacks and groundwater.
2. Water quality is important for freshwater ecosystems, wildlife and humans. Changes to water quality can be a result of natural processes, human related activities or a combination of both. Water levels, water flow, storm surges, thaw slumping, ground subsidence, sea level rise, increased runoff, forest fires, rising atmospheric and water temperatures, flooding, atmospheric transport, industry development and human uses of water are among the many processes that have an impact on water quality.
3. Contamination of water resources have widespread and varied consequences for water quality, which are compounded by the limited amount of information on their impacts in remote, northern regions.
4. Mercury is a contaminant of particular concern due to its rising levels, its ability to bioaccumulate, and its adverse health effects on fish, bugs, wildlife and humans.
5. Persistent organic pollutants, such as PCBs and DDT, are also of great concern for their potential to bioaccumulate and their implications for human and ecosystem health.
6. Climate change will have a variety of impacts on the distribution of water across the region. This has implications for the availability and accessibility of water sources in the future. Some of these changes are already being observed.

4.3 ECONOMY

Emerging from the literature analysis were three main themes relating to economic influences on water in the ISR, including: development, cost and impact of the economy on water (Figure, 4.4). The following section describes these relationships.

4.3.1 Development

Water is an important aspect of economic development in the ISR and across the Arctic. A number of development goals, many related to freshwater, were referred to within the literature. These development goals demonstrate that the GNWT is aware of the relationship between industry, economic development, freshwater and health, and recognizes that this needs to be monitored and addressed. They included:

- developing major infrastructure (e.g. pipelines and highways);
- investing revenue from resource development into a heritage fund;

- providing an adequate quantity and quality of water to fulfill current and future economic needs;
- reinforcing the importance of water conservation in the development process;
- reducing water consumption while increasing water efficiency; and,
- enhancing source water protection efforts to improve conservation and water quality (Council of the Federations, 2010; GNWT ENR & INAC, 2008; GNWT ENR & INAC, 2010).

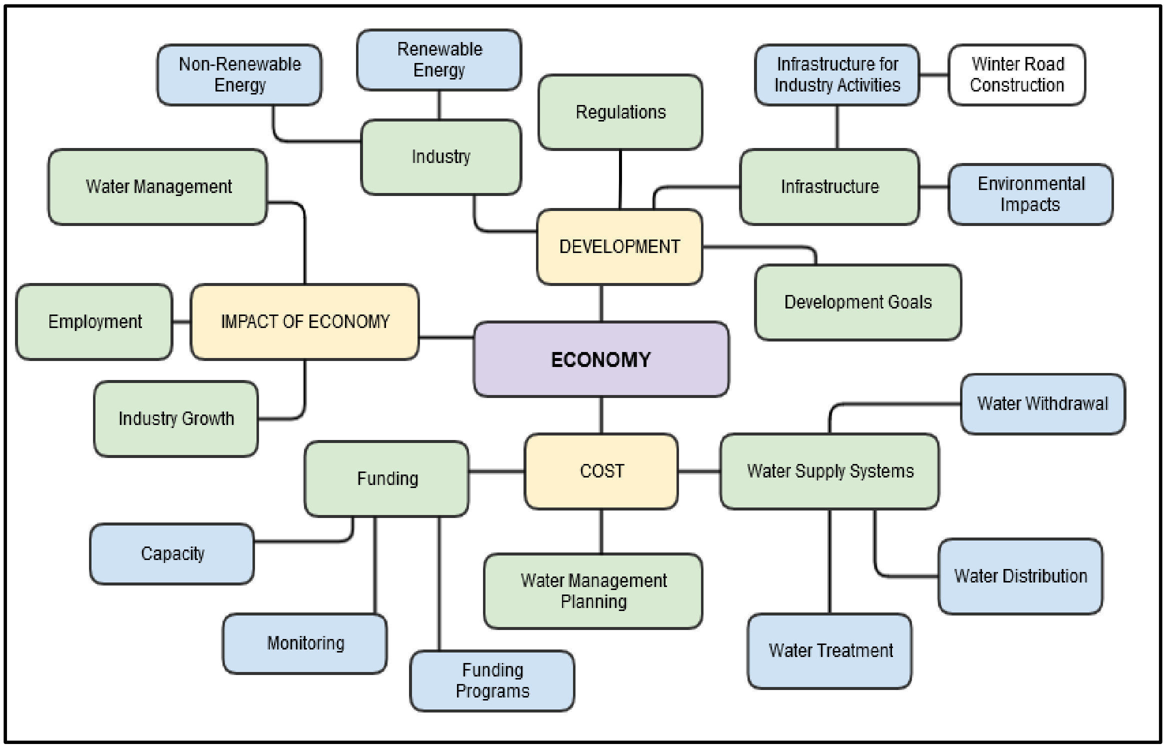

Figure 4.4: Economic considerations for water in the ISR

In terms of development activities, mining and oil and gas were referred to the most in the literature. Oil and gas developments were described as key components of the NWT economy (GNWT ENR & INAC, 2010). According to a 2005 report, 15 different companies owned a total of 310 wells in the ISR (AMEC, 2005). However, just a few years later, the GNWT reported that oil and gas developments in the NWT and the number of wells declined (GNWT ENR, 2011a). Pipelines, such as the Mackenzie Valley pipeline that would transport northern gas to southern markets, were then expressed as being the key to achieving a healthy and sustainable economy as they would create jobs and revenue for NWT residents (GNWT DAAIR, 2011a). It was also recognized that this could lead to negative environmental impacts. For example, water is required for downhole injection so increased development could increase demand for water (GNWT ENR & INAC, 2010). There is also the concern for watercourse crossings and upstream developments (GNWT ENR & INAC, 2010). Detailed knowledge of the hydrologic conditions along the transportation corridors over time would be one way to deal with the potentially negative impacts associated with pipelines (Mouchot *et al*., 1991).

Mining continues to be the largest industry in the NWT, with diamond mining accounting for over 50% of the economic base (GNWT, 2012a; GNWT ENR & INAC, 2010). Mining requires a great amount of water for processing and other purposes associated with development, and can result in negative impacts to water environments (GNWT ENR & INAC, 2010; INAC, 2010b). Population growth and development activities are expected to increase the potential for negative impacts to aquatic ecosystems in the NWT (INAC, 2010b). Although recognized by the GNWT, the clear commitment and desire to increase development in the NWT appears to outweigh the importance of maintaining the health of aquatic ecosystems.

The need to explore renewable energy options, such as hydroelectricity, also arose within the literature. At the Rosenberg Forum (2009), it was recommended that the NWT explore sustainable economic activities outside of extractive activities. Similarly, the NWTWS highlighted to need to diversify the non-renewable resource-based economy and indicated that this would likely include hydroelectric development in the future (GNWT ENR & INAC, 2010). At present, only roughly seven percent of the energy used comes from renewable resources, and while this is mainly in the form of hydroelectricity and biomass, hydroelectricity generation has declined (GNWT ENR, 2011a). The general sentiment towards hydro development in the literature was positive as it was seen as a way to displace imported fossil fuels, create employment and increase economic development (GNWT ENR & INAC, 2010; GNWT DAAIR, 2011a). The NWT Hydro Strategy was developed to promote the hydro potential of the territory (GNWT ENR & INAC, 2010). The Strategy recognizes the link between hydro development and the health of water resources and is working to obtain baseline data and traditional knowledge which would help manage water flows and ensure effective power production (GNWT ENR & INAC, 2010; INAC, 2010b).

Before and throughout the duration of most industry development projects, such as the Mackenzie Valley Pipeline and Highway, a certain degree of infrastructure must be in place (GNWT DAAIR, 2011a). What is distinct to the North is the use of water for infrastructure, such as winter roads, ice drilling pads, ice landing strips, exploratory drilling, ice crossing construction, hydrostatic testing of pipelines and camp use, which are essential for northern resource exploration and extraction (Cott *et al*., 2005; Cott *et al*., 2008; Council of the Federations, 2010; GNWT ENR & INAC, 2008; Hirose *et al*., 2008). Winter road construction is the greatest industrial demand for water, with ice roads requiring the highest amount of water (1.3 to 3.5 million l/km) (Cott *et al*., 2008). Winter roads are constructed across frozen ground, lakes and rivers using compacted snow, applied ice caps and ice aggregates, and are therefore limited to the winter season (Stephenson, Smith & Agnew, 2011). The timing of ice road usability varies, but the typical period is November-December to March-April (Prowse *et al*., 2009).

In the NWT, there are a limited amount of permanent roads, therefore the ice roads are relied on to transport supplies to communities and development sites (Cott *et* *al*., 2005; Cott *et al*., 2008). For example, the Tibbitt to Contwoy Winter Road, which operates in the NWT and Nunavut, is 600 km long, much of which is located over frozen lakes (495 km), and is the main supply road for a number of mines, including: the Ekati and Diavik diamond mines, the Lupin gold mine, the Snap Lake and Jericho mines, and multiple exploration sites (Hall, 2013; Pearce *et al*., 2010; Prowse *et al*., 2009). As a result, development projects are often carried out over the winter months when snow and ice are readily available for road, runway and drilling pad construction, and temperatures are stable enough to prevent thawing (Cott *et al*., 2005; Pearce *et al*., 2010). Resupply of resources to existing mines, such as materials, heavy equipment and fuel, is also generally limited to winter months due to the operating season of ice roads (Prowse *et al*., 2009). Winter roads are also relied on to transport supplies to communities and to access regional centers (Cott *et al*., 2008). In terms of infrastructure in the ISR, there is a gravel highway that links Inuvik to Fort McPherson and Tsiigehtchic, winter ice roads connecting Inuvik to Tuktoyaktuk and Aklavik, and no road access to Ulukhaktok, Paulatuk and Sachs Harbour (Wootton *et al*., 2008).

The construction of winter roads is generally considered to have less negative consequences for terrestrial ecosystems. However, there are still some potential consequences for aquatic ecosystems that need to be considered. For example, construction of winter roads and other infrastructure requiring water is typically done by withdrawing water from small, nearby lakes which reduces oxygen and water levels and impacts over-wintering fish (Cott *et al*., 2008). This potentially negative impact on over-wintering fish was recognized by the DFO and drove them to create a protocol for winter water withdrawal in small lakes (Section 4.1) (Cott *et al*., 2005).

While infrastructure, such as ice roads, can result in negative impacts on the environment, environmental changes can also impact infrastructure. For example, warming temperatures are thawing permafrost which reduces the load-bearing strength and can result in the movement of the foundation of infrastructure, such as buildings, roads and airport runways (AMEC, 2005; Andrachuck & Pearce, 2010; Gordon Foundation, 2011). The potential threat of damage to infrastructure as a result of warming temperatures is not equal across the ISR. For example, the infrastructure in Ulukhaktok is situated on stable land with low ice concentrations reducing the threat of thawing permafrost while the infrastructure in Tuktoyaktuk has an increased sensitivity to permafrost degradation and coastal erosion due to its location on low-lying land (Andrachuck &Pearce, 2010). Even though the probability of damage in Ulukhaktok is lower, damage to building foundations as a result of permafrost degradation has been observed (Andrachuck & Pearce, 2010).

One last consideration is the potential impact of rapid lake drainage on industrial and resource development infrastructure. While rapid lake drainage has had a minimal impact on towns or industrial infrastructure to date, infrastructure for new and expanding development projects (or towns) could be under threat if climate changes increase the rate of lake drainage (Marsh *et al*., 2009).

A number of regulations related to development in the NWT are aimed at securing the harmony between water protection and development activities. These include: DFO's Protocol for Winter Water Withdrawal in the Northwest Territories, Water Supply Systems Regulations, Municipal Lands and Water License Regulations (Section 4.1). All of these regulations address how water can and should be used in the development process. For example, the DFO Protocol for Winter Water Withdrawal addresses the withdrawal of water from lakes in the NWT for the creation of ice roads for industry use (Cott *et al*., 2005). In essence, it provides guidelines for use to prevent irreversible damages to aquatic systems from development. Meanwhile, Water License and Water Supply Systems Regulations address how water can be used and provide guidelines for use (Cott *et al*., 2005; Cott *et al*., 2008; GNWT HSS, 2011).

Finally, the roles that technological innovations could play in the development process were also addressed. The potential for new technology to advance water conservation and protection and aid with adaptation to climate changes were alluded to. For example, the Council of the Federations (2010) posited that technological innovation could help improve water efficiency across Canada. Other technologies, such as thermo-siphons and rip-rap barriers, were suggested as strategic, technology-based responses to changing environmental conditions (Pearce *et al*., 2011). Despite the techno-engineering fixes that have already been applied in the NWT, there is still a need for more research into new technologies (Wootton *et al*., 2008).

4.3.2 Cost

Another area of focus in the literature was cost. In general, there were two areas of concentration: the costs associated with water management and funding sources. Having adequate funding to deal with the various costs that may arise throughout the water management process is essential to the success of a given program (Rosenberg Forum, 2009). Many aspects of water management require money, including the development of management plans, water withdrawal, water treatment, water distribution, and operations and maintenance. The GNWT recognized that watershed management planning can be costly and suggested that these costs be shared across multiple levels of jurisdiction to reduce the burden of costs to stakeholders (GNWT ENR, 2012a). In terms of drinking water, once a management plan is place, the following step would be to determine suitable water sources. Several costs associated with water withdrawal for drinking water were emphasized in the literature, including: bathymetric surveys to determine the suitability of a site; water license applications for the right to remove/use water; setting up infrastructure for access or transporting equipment to a site; and, transportation of personnel to the site (Cott *et al*., 2005; GNWT HSS, 2011; GNWT, 1998b).

Once a system for water withdrawal is in place, some system for water treatment would have to be developed and implemented. Two categories of water treatment that were mentioned in the literature were raw water treatment for drinking water and wastewater treatment. The costs associated with the treatment of wastewater depend on the type of treatment required, which must take into account human health and the potential for damages downstream (GNWT ENR & INAC, 2008). The decision about the level of wastewater treatment and the treatment types used are some of most critical decisions managers must make (GNWT ENR & INAC, 2008).

Raw water usually comes from surface water or groundwater wells, has no previous treatment and is not considered safe for drinking or hygiene (GNWT HSS, 2011). As such, it also needs to be treated before it is distributed to water users across communities. Similar to wastewater treatment, the costs associated with the treatment of raw water will vary depending on the quality of the source water and the type of treatment required. The costs of water treatment for drinking water can be quite high

(GNWT ENR & INAC, 2008). For example, the town of Inuvik uses a combination of chlorine, hydrofluosilicic acid and acti-zyme to treat their water, for which the total estimated cost for chemical consumption for the year of 2006 was $20,900 (EarthTech, 2008). Filtration systems are also used in the water treatment process. The GNWT recognizes that filtration systems can be expensive to operate and have made the decision to permit an exclusion from the filtration process if the source water is clean enough and there are two disinfectants used in the treatment process (GNWT HSS, 2011). Because of this exception, it becomes cheaper to maintain the integrity of the source water than to use costly engineering solutions (Rosenberg Forum, 2009). Also of note is the use of raw water reservoirs in the NWT to store water when the quality is best or for communities that do not have year-round access to a water source (GNWT HSS, 2011).

There are also costs associated with water distribution that should be considered. Even though there is an abundance of water in the NWT, providing water for municipal and other uses can be an expensive undertaking that varies considerably due to socio-economic and geographic factors (GNWT ENR & INAC, 2008). Three types of costs emerged from the analysis, including:

- the economic rate, which refers to the direct and indirect costs associated with the delivery of trucked or piped water and sewer services;
- the volume-dependent costs, which are the costs that vary as a result of the quantity of water treated and delivered and sewage collected and treated; and,
- the non-volume dependent costs, which include the fixed costs associated with treatment and delivery systems that remain the same no matter the volume treated and/or delivered (GNWT, 2012b).

After withdrawal, treatment and distribution are dealt with, there are operations and maintenance costs to consider (Table 4.7). The total standard costs are the total costs necessary to adequately operate and maintain a water treatment, delivery and sewage system, and are measured by adding the total non volume-dependent costs to the total volume-dependent costs and multiplying by a standard 9% administration fee (GNWT, 2012b).

Table 4.7: Standard operational costs (adapted from Earth Tech, 2008).

Type of Cost	Examples
Direct operational costs	Chemicals for water treatment, fuel to warm water and prevent utilidors from freezing, power and fuel to run the water and sewage facilities.
Direct maintenance costs	Spare parts, supplies, repair contracts
Staff costs	Salaries, wages, benefits
Office and shop costs	Building and yard leases, hardware, tools, insurance
Capital replacement costs	Replacement of old or obsolete facilities

These operations and maintenance costs are generally higher in the North (Wootton *et al*., 2008). For example, the total estimated annual cost for utility staff in Inuvik was $415,000 in 2006 (Earth Tech, 2008). While some of the total operations costs in Inuvik vary based on water demand, the majority are fixed (Earth Tech, 2008). In the NWT, there are 30 independent community supply systems with various challenges to operations and maintenance, including remote locations, limited resources and limited certified operators (GNWT HSS, 2011). Some communities struggle with a backlog of maintenance duties as a result of the high costs and limited qualified personnel (Pearce *et al*., 2012). Research also revealed that necessary maintenance for sewage treatment systems, as well as operations and maintenance manuals, were not complete for all ISR communities (Wootton *et al*., 2008).

A further consideration is the total cost of adapting building foundations to reduce the impact of climate changes, which has been estimated to be greater than $126 million (CAD) in the ISR (Pearce *et al*., 2011). The New Deal for NWT Community Governments, which was implemented in 2007, saw community governments assume full authority for community public infrastructure planning, development, maintenance and replacement (Wootton *et al*., 2008). This is a significant burden on the communities as infrastructure degrades faster in the Arctic climate, they are already struggling to afford existing maintenance, the cost of construction materials is higher and the building season is short (Earth Tech, 2008; Pearce *et al*., 2011; Wootton *et al*., 2008).

Securing an adequate amount of funding to develop and implement water management strategies is highlighted by residents as one of the main barriers to water stewardship strategies in the NWT (GNWT ENR, 2013; Rosenberg Forum, 2009). In a 2006 client survey conducted by MACA, 35.5% of respondents felt that inadequate funding was the biggest challenge that NWT communities face, while another 23.1% felt that a lack of qualified personnel was the greatest challenge in NWT communities (Wootton *et al*., 2008). Lack of qualified personnel was said to be a result of limited resources and capacity (GNWT ENR & INAC, 2010; Wootton *et al*., 2008). Therefore, the greatest challenges to water management, according to local residents, are either inadequate funding or a symptom of inadequate funding. Similarly, a panel at the Rosenberg Forum (2009) on water management in the NWT acknowledged that inadequate funding poses a serious threat to the success of water management strategies in the NWT, and usually results in higher costs to governments than initial funding would have. One interesting resulting suggestion is to develop a system whereby those putting stress on water systems pay into support programs funding the implementation of the water management programs (Rosenberg, Forum, 2009). A solution to inadequate funding presented in the NWTWS was to use collaborative strategic planning to develop coordinated funding arrangements to lessen the impact of limited capacity (financial and qualified personnel) (GNWT ENR & INAC, 2010).

There are some funding resources available to deal with the costs associated with water management in the ISR. For example, MACA provides funding through their Community Government Funding Policy for some of the operations and maintenance costs for municipalities and, in 2008-2009 funded almost $2 million in water and sewer operations and maintenance costs for ISR communities (Wootton *et al*., 2008). Funding under this policy was intended to aid with operational costs of water services and is only available to community governments that have enacted a bylaw that calculates economic rates that should be charged to the various categories of users within the community (GNWT, 2012b). The NWT CIMP coordinates and helps fund monitoring initiatives across the NWT and in 2011/2012, provided approximately $2.5 million to various projects, including those focusing on water (AANDC, 2013). Another program worth noting is the Federal Building Canada Fund, which has contributed significantly to the construction of water treatment plants in each ISR community (GNWT HSS, 2011).

Despite this funding, the Rosenberg Forum (2009) found that cuts to monitoring programs have taken place over the last 20 years in the NWT and questioned the effectiveness of current monitoring programs to determine whether upstream activities are having negative impacts on water quality and flow. Although several funding sources for different phases of water management emerged from the literature, it is clear that the amount of funding currently provided to communities is not enough.

4.3.3 Impact of the Economy

The impact of the economy on water and people also emerged within the literature. Within this discussion, the main concern was the issue of employment. In general, the costs of living in Inuvialuit communities are very high when compared to the costs of living in southern Canada (Pearce *et al*., 2012). The GNWT LUSF (2012) notes that the economy of the NWT maintains a diversity of interests related to land-based activities. It postures that the diversity of land-based activities that contribute to the economy supports the quality of life of local residents and leads to economic prosperity (GNWT GNWT, 2012a). While this could be the case in some NWT communities, others have found that there are a limited number of wage-based jobs in Inuvialuit communities, such as Paulatuk, and very few community members that hold the necessary qualifications for these jobs (Pearce *et al*., 2012). The result is a higher unemployment rate and a greater dependency on social services (Pearce *et al*., 2012).

While water, snow and ice are often used for travel, the unpredictability of weather and associated hazardous travelling conditions are also having an economic impact on communities. In general, this is leading to a reduction in the participation in subsistence activities among community members and an increase in the dependence on wage-based employment (Pearce *et al*., 2012).

These findings demonstrate how the economy and shifts in environmental conditions are both impacted by, and are having an impact on, the amount of time spent on the land participating in subsistence activities. Shifts in environmental conditions driven by changes associated with water in various states, such as the timing of ice break-up and predictability of weather patterns, are reducing the ability of community members to spend time participating in subsistence-based activities (Pearce *et al*., 2012). Without the ability to gather the necessary food required using traditional methods, community members are shifting to wage-based employment to gain access to food. This has led to a greater demand for employment and employment opportunities within communities.

However, the lack of proper training acts as a barrier to employment for many community members and is seen as an area of importance to local residents (Pearce *et al*., 2012). This makes it more difficult to secure full-time, long-term employment.

Other sub-topics to emerge were industry growth and the management of water. The impact of water management on the economy was mentioned in relation to its ability to aid potential issues that may arise and have an impact on the local economy, such as distributional issues, water supply and demand issues, bulk exports and water flows (GNWT ENR & INAC, 2008). Elsewhere, it was described as a tool that can be used to mitigate or prevent impacts on the economy associated with changes to the environment and water (Andrachuck & Pearce, 2010; Cott *et al*., 2008; INAC, 2010b). In general, changes to the environment have the potential to impact water in various states, such frozen water on lakes and rivers or in permafrost (Andrachuck & Pearce, 2010). These changes can result in damage to infrastructure leading to high costs of reconstruction which can be a burden on the local economy. Adapting existing management plans and creating new management plans with these potential changes in mind can help to minimize or reduce the negative impacts as a result of changing water conditions in the environment (Cott *et al*., 2008).

Finally, industry growth was also mentioned in the literature. The NWT economy was noted as being one of the fastest growing in Canada. The growth rate from 1999 to 2004 was measured at 79%, far surpassing the national average for the same time period, which was measured to be 16% (Cott *et al*., 2008). Mining continues to be the largest industry in the NWT, diamond mining in particular, which contributes approximately half of the economic base in the NWT, and there is interest from the GNWT and industry partners to continue building the mining industry into the future (GNWT, 2012a; GNWT ENR, 2011a). Also of interest is that while diamond mining currently dominates the economy of the NWT, oil and gas exploration and extraction is predicted to have a greater impact on the economy in the future (GNWT ENR, 2011a; GNWT ENR & INAC, 2010). This industry growth is expected to increase the future demand for water, particularly in the winter season (Cott *et al*., 2005). Technological innovations could help to improve water efficiency and reduce economic and environmental impacts related to industry growth (Council of the Federations, 2010).

4.3.4 Summary

The relationship between the economy and water is complex. Water is both impacted by and has an impact on the economy in various ways, and these relationships are not always obvious. Below is a summary of the most important links between water and the economy:

1. Development in the NWT is expected to continue to grow. There are several development goals that need to follow the related regulations associated with water use.
2. Mining and oil and gas are the greatest industries in the NWT, but hydroelectricity has the potential to play a greater role in the future.
3. Development in the NWT is affected by water while water is also impacted by development. Many of these relationships are unique to the northern environment, such as winter water withdrawal from lakes for ice road construction. The creation and use of innovative technologies could help to reduce these impacts.
4. There are several costs at every stage of water management, from the planning phase through ongoing operations and maintenance. These costs are higher in the Arctic due to several conditions distinct to the North, such as the remoteness of communities. Some funding programs are in place but ultimately, they remain inadequate for most communities.
5. Changes in the freshwater environment, among other factors, are leading to a decrease in the participation in subsistence-based activities, resulting in a greater dependency on wage-based employment. Lack of appropriate training remains a barrier to entering the wage-based employment system.

4.4 CULTURE

Six topics emerged within the literature on culture, including: water use, environmental change, identity, well-being, values, and Traditional Knowledge (Fig. 4.5).

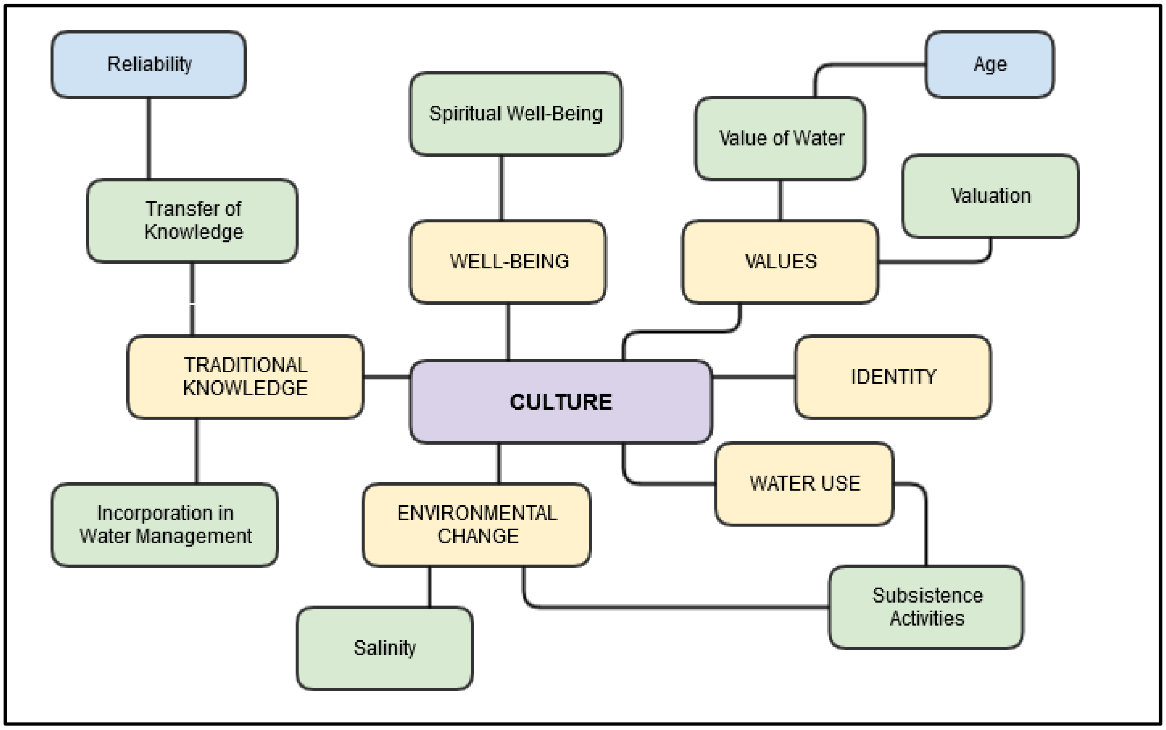

Figure 4.5: Cultural considerations for water in the ISR

4.4.1 Cultural Water Use and Environmental Change

The topic of water use and its importance to Inuvialuit culture came up frequently in the literature. The main water uses supporting cultural practices and values include subsistence hunting, trapping and fishing (Andrachuck & Pearce 2010; Careau & Dewailly 1995; Pearce *et al*., 2010; Prowse *et al*., 2009). There are several examples in the literature. Andrachuck and Pearce (2010) found that 57% of Tuktoyaktuk and 76% of Ulukhaktok community members participate in hunting and fishing activities while Pearce *et al.* (2010) found that 46% of households in Ulukhaktok received their primary source of meat from hunting, fishing and country foods. Prowse *et al.* (2009) found that

70% of northern Indigenous adults harvested natural resources through hunting and fishing, with 96% of those adults doing so for subsistence purposes. Subsistence practices in the ISR and other Arctic communities depend greatly on water; waterways are used for travel, lakes and rivers are used for fishing, and snow and ice are used for travel, drinking water, fishing and harvesting (AANDC, 2013; Careau & Dewailly, 1995; GNWT ENR & INAC, 2010; Kokelj *et al*., 2012; Papik *et al*., 2003).

Preferred harvesting sites are often chosen because they provide a preferred species for consumption, are a reliable source of food, and are easy to travel to. While water in rivers and lakes is used for subsistence practices, water in the form of snow and ice is also of significance in the ISR and across the Arctic. Use of, and travel across, snow and ice is a central aspect of cultural subsistence practices as they cover the land for a large portion of the year (Peace & Myers, 2012). For example, many people from the community of Sachs Harbour use inland lakes for ice fishing in May, travel to camps across coastal sea ice and frozen rivers by ski-doo or sled, and stay on snow-covered areas (Riedlinger, 2001). Among Inuvialuit communities, getting ice for drinking water is also an important cultural skill that is taught through land schooling (Pearce *et al*., 2011). This is an informal but significant use of water across the region. Gathering drinking water from the land is also important when travelling.

Several environmental changes that alter water resources in the region are being observed (Section 4.2). Environmental changes that impact water, snow and ice in the region also impact cultural subsistence practices (Rosenberg Forum, 2009). Changes to snowpack characteristics, lake ice thickness and duration, river flow, ice cover and river ice break-up all affect the ability to participate in subsistence-based activities (Collings, 2011; Nuttall *et al*., 2005). There are several examples of this in the literature. Access to caribou harvesting grounds in Prince Albert Sound from Ulukhaktok was prevented in the spring of 2005 when easterly winds that broke up the ice shifted to westerly winds and pushed the broken ice back into the community bays, preventing travel on sea ice by snow machine and travel by boat across the water (Pearce *et al*., 2006). The frequency of storms and storm surges has been observed to be changing, the results of which have been increased sediment build-up and slumping that have changed water depths and impacted navigation (Kokelj *et al*., 2012). Increasing winds along the coast have also been observed to be impacting the salinity of water; an increase north and west winds was observed to have resulted in an increase in the salinity of nearby river waters (Kokelj *et al*., 2012). In other areas further from the coast, salinity has either increased or decreased, in both cases straying from the norm and impacting the predictability of food sources. For example, the Big Fish River used to be very salty with a high Arctic Char population but the water there is now fresh enough to drink and the char are no longer being found there (Papik *et al.*, 2003).

This change in salinity has also corresponded with a change in water levels, which have dropped significantly (Papik *et al*., 2003). Lower water levels affect food sources, and thus impact subsistence activities (Fresque-Baxter, 2013). Lower water levels have led to difficulties in travel and fishing activities (Papik *et al*., 2003). They have also led to different types of fish being caught and changes to the landscape, which are making accessibility more difficult (Papik *et al*., 2003). This is also leading to a decrease in the safety of travel routes (Pearce *et al*., 2010), particularly as spring snowmelt is also observed to be occurring earlier in the year now than in the past (Prowse *et al*., 2006).

4.4.2 Identity, Values and Well-Being

Links between identity, well-being, values and water were identified in the literature. In general, it was noted that freshwater found in lakes, rivers, streams and ponds are of cultural importance beyond their use as a commodity (Alessa *et al*., 2010; GNWT ENR & INAC, 2010). NWT residents draw their cultural identity from the land, including its waters, which also shapes their values (GNWT, 2012a; Prowse *et al*., 2009; Rosenberg Forum, 2009). In other words, water has intrinsic cultural value because it provides life (GNWT ENR & INAC, 2010; INAC, 2010b). Water is also important for spiritual well-being. It was noted that while most individuals in the NWT see water as being important for biological purposes, many also view water as being important for the spiritual values it imparts on them (Alessa *et al*., 2010; GNWT ENR & INAC, 2010; Gordon Foundation, 2011). Because water is relied on for food, materials and habitation, and the spiritual and cultural values that it imparts, changes to water can and do have an effect on the identity of northerners by impacting traditional ways of life and well-being (Gordon Foundation, 2011; GNWT, 2012a). This was attributed to the idea that cultural sustainability is linked to lifestyle choices (Rosenberg Forum, 2009). In other words, in order to maintain cultural identity and well-being, lifestyle choices beyond the Western lifestyle, need to exist.

Some ISR residents fear that development will rob them of the spiritual and cultural values that they derive from water (Vaux Jr, 2010). It was noted that deterioration of cultural ties to land-based and subsistence activities through physical, economic and administrative changes is the most serious cause of decline in well-being for northern Indigenous peoples and is having long-lasting effects (Prowse *et al*., 2009).

This was linked to increased exposure to accidental death and injury that is likely associated with the high level of dependence on subsistence practices and the associated time spent on the land (Prowse *et al*., 2009). This is connected to environmental changes, such as weather, snow melt, ice break-up, etc. (Section 4.2.3).

The personal relationship with water also has an impact on how it is valued. In general, if there is little direct interaction with water, the value placed on water is reduced (Alessa *et al*., 2010). In the literature, it was argued that the value of water is central to northern life because life in the north revolves around water, some going so far as to compare the value of water to northern residents to that of desert inhabitants (Gordon Foundation, 2011; Rosenberg Forum, 2009). For desert inhabitants, life is shaped by the lack and constant need of water for survival. For northern residents, being physically surrounded by water in various forms (snow, ice, liquid), their lives are dependent on the characteristics of the water around them and can be greatly impacted by physical changes. For example, community members in Sachs Harbour noticed a shift from hard-packed to soft snow, which makes travel between communities and for subsistence purposes more difficult (Collings, 2011; Nuttall *et al*., 2005; Riedlinger, 2001). In both cases, daily activities are shaped around water, albeit for different purposes. Changes to water, in both cases, can have significant consequences for local communities.

Elsewhere in the literature, the importance of water to Indigenous peoples was compared to the importance of the heart, as the water gives life to the people, wildlife and plants (INAC, 2010b). It is also explained that water is valued for providing the option of living off of the land through hunting, fishing and trapping, which would not be possible if there were significant destruction of the habitat (Vaux Jr, 2010). Related to this is the perspective that sustainability in the north would not exist if the resources for subsistence, such as healthy freshwater ecosystems, are gone (Rosenberg Forum, 2009). Also mentioned was the cultural value of places on or near water. For example, Shingle Point, YT, was highlighted in one study as a place of value with cultural importance to Inuvialuit in the region (Papik *et al*., 2003). All of these references highlight the cultural value and significance of water to residents in the region. It is clear from these references that water holds a significant cultural value that should not be ignored in the assessment of water security or any other management or planning activity that could potentially have an adverse effect on freshwater ecosystems in the North.

Another topic that emerged from the literature was the relationship between age and how people tend to value water. Alessa *et al*. (2010) found that water was integral to the cultural identity of the older generation, which valued water primarily for subsistence, cultural and travel purposes whereas the younger generations valued water mostly for convenience values, such as washing and recreational activities. It was speculated that this difference in values is related to the fact that the younger generations tend to be more distanced from their water resources, through both physical distance and the use of technology, which reduces their intimacy with the resource (Alessa *et al*., 2010). This lead the authors to conclude that industrialization, technology and infrastructure have had an impact on the relationship that people have with water. While the older generation is maintaining its connection with freshwater resources through participation in subsistence activities, the younger generation is losing this connection to freshwater resources due to industrialization. In other words, the value placed on water is changing through a shift from subsistence-based to convenience-oriented lifestyles (Alessa *et al*., 2010).

Lastly, the difficulty in assigning a monetary worth to cultural values for the purpose of water management was addressed. In general, the literature agreed that it is difficult to place a monetary worth on the spiritual and cultural values that water imparts, even though cultural values may, in some ways, be seen as more valuable since they might not be replaceable (GNWT ENR & INAC, 2010). This task is made more difficult because there are many ways to assign worth and there are many different value systems. According to the Rosenberg Forum (2010), this is a result of the fact that religious, cultural and ethical values are not discussed in the same manner as economic worth. Despite the inherent difficulties, some strategies and management plans are making efforts to include worth of cultural and spiritual values, along with economic worth (Rosenberg Forum, 2010). In order for these traditional and cultural needs to be included, the spiritual, cultural and traditional uses of water need to first be characterized (GNWT ENR & INAC, 2008). This addition to management plans and strategies is important as it was found that many local residents are fearful that development may have an impact on the spiritual and cultural values that they have traditionally derived from natural resources (Vaux Jr, 2010). Since traditional ways of life, including water uses, are highly valued, they need to be respected and protected (GNWT ENR & INAC, 2010). While assigning monetary worth to cultural and spiritual values is difficult, and perhaps not a completely accurate representation of their importance, it at least allows these values to be represented in the planning and management processes (Rosenberg Forum, 2009). Without some form of representation, they run the risk of being completely ignored.

Based on the research, it is clear that cultural identity, well-being and values are closely linked with the land and resources in the region through land-based activities, such as hunting and fishing. As a result, changes to the environment would have an impact on the identity, well-being and values of northern residents. Much of these are linked to the opportunity to participate in traditional and subsistence-based activities, which take place on the land. If changes to the environment make participation in these activities more difficult or not possible, this could be damaging to the cultural identity of those who derive meaning through their connection to the land. Therefore, any impact on the ability to spend time on the land has the potential to negatively impact both the identity and well-being of northern Inuit communities.

4.4.3 Traditional Knowledge and Water Management

In the literature, it was noted that Traditional Knowledge (TK) is derived from a deep understanding of the environment (GNWT ENR & INAC, 2010) that comes from land-based education, where living and learning are the same thing (Pearce *et al*., 2010), and plays an important role in Inuvialuit culture (Papik *et al*., 2003). Inuvialuit TK is constantly being updated and evolving to help manage for climatic changes, which makes it a valuable tool for obtaining a more complete understanding of the environment (INAC, 2010b; Kokelj *et al.*, 2012; Pearce *et al*., 2010). An important topic to emerge from the literature was the transfer of TK. In general, it was explained that TK, important skills and spiritual teachings are often transferred through land-based learning (Alessa *et al*., 2010; Inuvik Region TK Newsletter, 2011; Kokelj *et al*., 2012; GNWT, 2005b). It can also be transferred through songs, stories, proverbs and dance (Alessa *et al*., 2010). It was also noted that the internet is now providing newer opportunities to transfer knowledge. For example, the GNWT and AANDC have created a discovery portal where knowledge can be communicated and transferred (GNWT ENR & AANDC, 2013).

The reliability and transfer of TK can be affected by the lack of involvement in subsistence activities by the younger generations (Andrachuck & Pearce, 2010; Pearce *et al*., 2012). There is concern among some ISR communities that youth are spending less time doing activities that would help them to accumulate necessary knowledge and skills needed for land-based activities. These missed opportunities to acquire knowledge increase risk when they do choose to participate, especially with changing climatic conditions (Section 4.2.3) (Pearce *et al*., 2011; Pearce *et al*., 2012). TK was noted as being important for adaptation to climatic changes (Andrachuck & Pearce, 2010), in part because it is locale-specific and sensitive to change (Alessa *et al.*, 2010). Yet, these same characteristics have caused its reliability to be questioned in some cases (Fresque-Baxter, 2013; White *et al*., 2007). TK provides important historical context that is important for understanding climatic change (INAC, 2010b). However, if environmental changes are happening at a faster rate than TK can be transferred, then the knowledge itself could be seen as less reliable.

The relationship between TK and water management also emerged from the literature. In general, it was agreed upon that TK, in combination with scientific knowledge, was important for responsible water use, policy development and management decisions (GNWT, 2011b; MacLeod Institute, 2002; GNWT ENR & INAC, 2008; GNWT DAAIR, 2011a; GNWT, 2012a; GNWT ENR & INAC, 2010; GNWT, 2005b). This opinion is supported by the GNWT who acknowledge through the Traditional Knowledge Policy (1997) that Indigenous peoples in the NWT have acquired an immense amount of knowledge about the land through their experience of living on the land. More recent documents, such as the GNWT Traditional Knowledge Policy

Implementation Framework and the GNWT ENR Traditional Knowledge Implementation Plan, highlight the need to incorporate TK in the planning and decision-making process (GNWT ENR, 2011a; GNWT, 2005b). The GNWT Traditional Knowledge Policy provides guidance on the use and incorporation of TK in management. It encourages a balance in the use of scientific and TK for decision-making and the development of programs and services (GNWT, 2012a). The NWT CIMP, which is laid out in land claims agreement and the MVRMA, also supports the use of TK and scientific knowledge in their program (INAC, 2010b).

The incorporation of TK into management plans was seen at all levels of government in the literature, with the exception of the CCME's Strategy for the Management of Municipal Wastewater Effluent, which did not include any references to TK. All water management plans for the NWT included TK to some degree. For example, the SWAP included the use of local and TK to inform management actions as one of its core objectives (GNWT, 2010a). The GNWT LUSF noted that TK should be recognized, valued and respected as an important source of information that can better inform management decisions about land, waters and resources (GNWT, 2012a). The NWTWS also acknowledged that "traditional knowledge comes from a deep understanding of the natural world" (p. 4), that it contains "cultural elements that stand alone because they cannot be clearly translated into western counterparts" (p. 18), and that "all types of knowledge, including traditional, local and western scientific, are an integral part of the Strategy and related initiatives" (GNWT ENR & INAC, 2010, p.4).

Monitoring for contaminants and mitigation were two areas of particular concern in the literature. Monitoring for contaminants was mentioned as being important to the

GNWT, who hope to increase monitoring efforts in the future (GNWT DAAIR, 2011a). Mitigation was also seen as being an important issue to Inuit that needs to be brought up in the management, planning and decision-making (Pearce *et al*, 2010). TK and related experiences are being used in community monitoring programs with the aim of providing Inuit with an opportunity to share their views about the environment (INAC, 2010b).

The contrast between Western and Indigenous cultures was also noted in the literature. The general consensus was that the differences between how Western society and Indigenous cultures conceptualize the world has implications for the way they approach water management. For example, Alessa *et al.* (2010) explain that Western perceptions include the belief of technological solutions to environmental problems and the individual pursuit of material well-being while the Indigenous perception focuses on the importance of TK, subsistence economies and holistic community well-being. Elsewhere, it was mentioned that the type of systematic planning that is common in Western tradition is a relatively new concept for Inuit (Pearce *et al*., 2012). Also noted was the difficulty in managing for the future due to the tendency in Inuit culture to deal with the immediate environmental conditions (Pearce *et al*., 2012). These differences can have impacts on the effectiveness of water management strategies, particularly when considering larger-scale, watershed-based plans that require the consideration of multiple types of knowledge.

Finally, the importance of self-governance to the ISR was also noted. The role of self-governance was identified as being a long-term goal that has always been held by the Inuvialuit (GNWT ISGA, N.D.). Self-governance would allow the Inuvialuit to manage their water resources in a way that is more closely related to their values and conception of the world. This could also allow for better representation in a larger-scale, watershed-based management strategy. Overall, it is clear that TK holds great value and should play an integral role in water management for the ISR.

4.4.4 Summary

In general, the literature demonstrated that the ability to connect with and spend time on the land is an integral part of the Inuvialuit culture. Several important conclusions can be drawn:

1. The most important cultural use of water is for subsistence activities, such as hunting, trapping and fishing. Participation in these activities is being affected by environmental changes.
2. The spiritual and cultural identity of people is drawn from the land and waters in the region. Changes to this environment have an impact on the lifestyle choices and identity of local residents.
3. Water holds a significant cultural value. This relationship is determined by the level of interaction with the land which is impacted by the use of technology, industrialization and physical distance from water sources.
4. Physical and spiritual well-being is closely connected to the amount of time spent on the land. If this intimate relationship is altered, it could have a negative impact on the general well-being of local residents.
5. The contrast between how Western and Indigenous cultures conceptualize the world leads to differences in how they approach water management and what they believe are best practices.
6. TK is important for adaptation to climatic changes and is constantly being updated. The rate at which climatic changes are being observed and the lack of participation in land-based activities by younger generations threatens the reliability and capability to transfer knowledge.
7. TK can and is used in management and monitoring plans. How this is done varies by region, leaving little uniformity and no guarantee as to the degree in which it will be respected and incorporated.

4.5 SOCIAL

When assessing the literature for social aspects of water, the main emergent themes included: water use, social change, social-environment relations, and water management (Fig. 4.6).

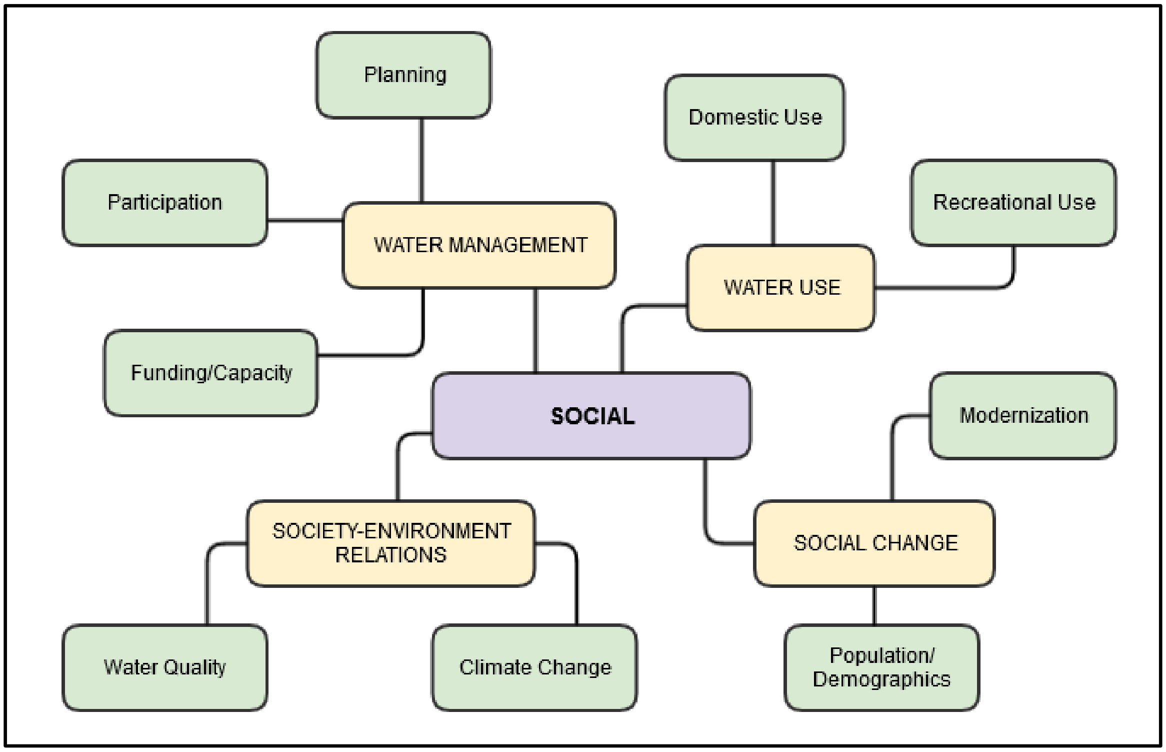

Figure 4.6: Social considerations for water in the ISR

4.5.1 Social Water Use

Two main types of water use were described in the literature: domestic and recreational. Like communities everywhere, domestic uses of water (e.g. cleaning, cooking, and bathing) are important to northern communities (Alessa *et al*., 2010). Most of these uses require the delivery of water to the household and are therefore tied to the municipal water supply. Municipal water supplies are local sources of water, delivered to households either by truck or piped delivery system. In the ISR, Inuvik operates on a piped delivery system while all other communities rely on trucked water. Outside of industrial water use, municipal consumption is the biggest use of water in the NWT

(INAC, 2010b). Meanwhile, the most important characteristic of domestic water supply was said to be access to an adequate amount of water for frequent hand and body hygiene (Ritter, 2007). This importance was recognized by the GNWT in the NWTWS where one of the core goals was to ensure that residents have access to a clean and abundant amount of drinking water (GNWT ENR & AANDC, 2013). Having a municipal water supply system in place would help to ensure that these needs are being met. That said, it has been shown that the installation of municipal water supplies in the NWT also increases the domestic use of freshwater (Alessa *et al*., 2010). In other words, the more water that is available, the more water is used.

Apart from domestic water use, the only other use mentioned was for recreational purposes. For example, some residents were said to place importance on water for recreational uses, such as swimming, boating, playing, etc. (Alessa *et al*., 2009). While travelling and recreational activities take place over land and surface water, snow and ice are also often used when participating in these activities. Access to water for domestic use is clearly recognized as important by both residents and the government (Alessa *et al*., 2009; GNWT ENR & AANDC, 2013; INAC, 2010b).

4.5.2 Social Change

Two aspects of social change discussed in the literature were population/demographics and modernization. Four characteristics were highlighted as being common to all NWT communities, albeit to differing degrees: small population, geographic isolation, historical culture and limited economic base (Ritter, 2007). Of these characteristics, the small population characteristic was mentioned the most frequently. It was noted that Arctic communities only make up a relatively small percentage of the population living in the North (Prowse *et al*., 2009). Furthermore, none of the Inuit communities in the NWT have populations exceeding 5000 people (Prowse *et al*., 2009). It was also mentioned that the demographics in the NWT are undergoing change. Indigenous peoples currently make up slightly over half of the population, but the non-Indigenous population is growing substantially (Prowse *et al*., 2009). With a growing population, there will be a growing demand for water resources.

Modernization was also mentioned in the literature. Many communities in the North are becoming increasingly modernized as the use of new technologies for water extraction, treatment and distribution are becoming more popular (Alessa *et al*., 2010). This is influencing a shift from freshwater subsistence to a reliance on municipal water supplies, which can affect knowledge about local water sources and reduce the amount of time spent on land (Alessa *et al*., 2010; Andrachuck & Pearce, 2010).

It is clear from the literature that there are some changes to the social construction of communities in the NWT and the Arctic. While the size of communities and proportion of the population in comparison to the rest of the country remains relatively small, changes in the make-up of communities are being observed. The most notable of these changes is the large increase in the non-Indigenous population (Prowse *et al*., 2009). Change in community characteristics, through modernization and a shift in population/demographics, have the potential to change the social dynamics of the communities.

4.5.3 Society-Environment Relations

Two main topics to emerge in relation to the environment were the concern for water quality and the potential impacts of climate change on northern communities. In general, NWT residents are dependent on surface water sources, which are limited due to the fact that it is a cold, dry desert impacted by the distribution of permafrost (Alessa *et al*., 2010). During the development of the NWTWS, many NWT residents brought up their concerns about the safety of drinking water, including the importance of watershed planning to protect their sources of drinking water (GNWT ENR, 2013). Community members who participated in the design of the community-based monitoring program raised several questions about water, including whether the water is healthy, whether the quality is changing, what stressors would impact water quality, whether the water is safe to drink, whether the water quality is having an impact on fish and wildlife, and whether there are cumulative impacts (GNWT ENR, 2012b).

Concerns about water do not rest solely on the minds of adult community members. For example, a participatory project done in nearby Fort Resolution, NWT captured stories about connections with water and the changing conditions of water. In the case study, Fresque-Baxter (2013) shows that young people in northern communities are aware of and concerned about how water is changing and what kinds of impacts this could have on their communities. Some examples of concerns expressed by young people in the community were: the impact of low water levels and fish abnormalities; water level changes and their impact on the ability to do activities on the land; and, the importance of water as a drinking source (Fresque-Baxter, 2013).

These concerns expressed by residents are validated by literature that demonstrates how physical and biological changes to the environment have an impact on the vulnerability of the occupancy and livelihood of local residents (Pearce *et al*., 2010). For example, changes to the environment, such as the timing of ice formation and river ice break-up, are having adverse effects on the convenience and safety of travel (Burn, 1995). In this case, the lack of predictability of natural, seasonal environmental processes increases the vulnerability of community members when participating in activities that require travel over land and water. For example, a shift in the timing of ice break-up could result in some travelers becoming stranded out on the land.

According to the literature, it is possible for communities to adapt to changing environmental conditions. Effective response to changes by communities and individuals rests in the ability to anticipate changes and their potential impacts (White *et al*., 2007). The adaptive capacity will rest on the communities' ability to cope with the stresses, hazards, risks and opportunities associated with changing conditions (Pearce *et al*., 2011). To deal with this, Pearce *et al*. (2012) suggest that community land-use plans should consider and incorporate expected changes related to future climate change. For example, they could include the impact of coastal erosion and permafrost degradation on community infrastructure (Pearce *et al*., 2010). Incorporating this type of anticipated environmental change could lead to the amendment of building codes to help communities cope with increasingly unstable permafrost (Pearce *et al*., 2012). The adaptive strategy of strengthening municipal infrastructure to help deal with changing climatic conditions is already being employed in some communities (Pearce *et al*., 2011). For example, Tuktoyaktuk has incorporated shoreline protection infrastructure to protect existing infrastructure from erosion (Pearce *et al*., 2010b). Adaptive strategies are also being employed by individuals across the ISR. Examples include: substituting store food for country food when an area or species is not accessible; using alternative modes of transportation and routes when travelling; changing to a different type of wildlife for harvesting when one species becomes less abundant; and, taking extra supplies when travelling (Pearce *et al*., 2010b).

From the results, it is clear that community members, both young and old, have concerns about changing environmental conditions associated with water and the potential impacts these could have on their communities. As seen in other sections, most of the concerns to emerge from the literature were related to land-based activities and the ability to safely spend time on the land. These concerns were validated by other research that demonstrates how changing environmental conditions are impacting the vulnerability of local residents.

4.5.4 Social Considerations in Water Management

Four main conclusions about water management were drawn from the literature: social well-being is important for water management; there are a number of opportunities where social characteristics can be applied throughout the management process; lack of funding and capacity are barriers to effective management; and, proper planning is an important component of water management. In general, it was noted that community members hold meaningful relationships with water and that these need to be considered throughout the decision-making process (Fresque-Baxter, 2013). This is particularly true seeing as social well-being, which encompasses all water uses and values associated with the diverse communities and cultures that draw from its water resources, is the ultimate goal of watershed management (GNWT ENR & INAC, 2008). Despite the meaningful relationships with water and the importance of social well-being to water management, it was said that little attention has been placed on the social characteristics in daily water management practices (Plummer *et al*., 2012). Instead, the literature has focused mainly on the wage economy (MacLeod Institute, 2002).

Aside from describing the importance of including social characteristics in the decision-making process, a number of recommendations for how this could be achieved were found. Firstly, it was recommended that local knowledge, a valuable source of information, should be used by decision-makers throughout the decision-making process (GNWT ENR & INAC, 2010). Having more baseline knowledge about water and the environment were also mentioned as being important to making better management decisions (GNWT ENR & AANDC, 2013). It was suggested that access to water quality monitoring information, such as contaminants, would increase local residents' knowledge about water-related issues, and subsequently lead to better decision-making at all levels (GNWT, 2013; GNWT DAAIR, 2011a). Other recommendations included developing a more robust framework that protects the land and water (GNWT DAAIR, 2011a) and including the perspectives of young people in the development of policy and management decisions about water (Fresque-Baxter, 2013).

Access to funding and capacity building were other issues to arise in the literature. Limited financial capacity was identified by NWT residents as one of the main barriers to implementing water stewardship initiatives, such as community-based monitoring and source water protection planning (GNWT ENR, 2013). For example, concerns about the community-based water quality monitoring programs were brought up by expert panelists at the Rosenberg Forum. There, it was mentioned that local participation in the monitoring program is voluntary but crucial to enhance trust and expand resources within a limited budget (Rosenberg Forum, 2009). Access to funding for training was said to influence the ability of individuals or families to secure consistent employment and consequently acted as a key determinant of the participation in subsistence activities, which can be expensive (Andrachuck & Pearce, 2010). Availability of funding was also said to affect the adaptive capacity of communities to deal with infrastructure risks and damages associated with environmental changes (Andrachuck & Pearce, 2010). Residents emphasized the need to diversify the local economy in order to deal with sensitivities related to climate change (Pearce *et al*., 2012).

Overall, the literature demonstrated that water is both meaningful to local residents and important for the social well-being of all water users in a watershed (Fresque-Baxter, 2013; GNWT ENR & INAC, 2008; Plummer *et al*., 2012). The literature suggested that having more baseline knowledge and including more local knowledge could help produce more robust management plans (GNWT ENR & INAC, 2010; GNWT ENR & AANDC, 2013). Two NWT-wide plans currently acknowledge the importance of local knowledge and involvement in the planning process: the NWTWS and the NWT SWAP (GNWT ENR & AANDC, 2013; GNWT ENR, 2013; Vaux Jr., 2010). Apart from the inclusion of local knowledge and involvement from local residents, funding and capacity were highlighted as main barriers to water management (Andrachuck & Pearce, 2010; GNWT ENR, 2013). Proper planning was said to enhance the adaptive capacity of communities in the wake of changing environmental conditions (Andrachuck & Pearce, 2010; White *et al*., 2007).

4.5.5 Summary

A number of important conclusions about the social relationship with water can be drawn from the literature. These include:

1. The two main social water uses are for domestic and recreational purposes.
2. Community members of all ages are concerned about environmental changes associated with water. Adaptive water management planning and management practices are one way of addressing associated challenges.
3. Small but changing populations/demographics and modernization are two aspects of social well-being observed in northern communities. These changes have the potential to impact the social dynamics of communities and in turn, water uses.
4. Proper water management is important for social well-being. The inclusion of more local knowledge and enhanced baseline knowledge would improve water planning and management.
5. Funding and capacity are main barriers to water management. One way of dealing with this is to enhance local participation in water management programs.

4.6 HEALTH

Water is connected to, and essential for, human health. Discussions in the literature centred on four main topics: dental health, water management, health care, and water quality (Fig. 4.7).

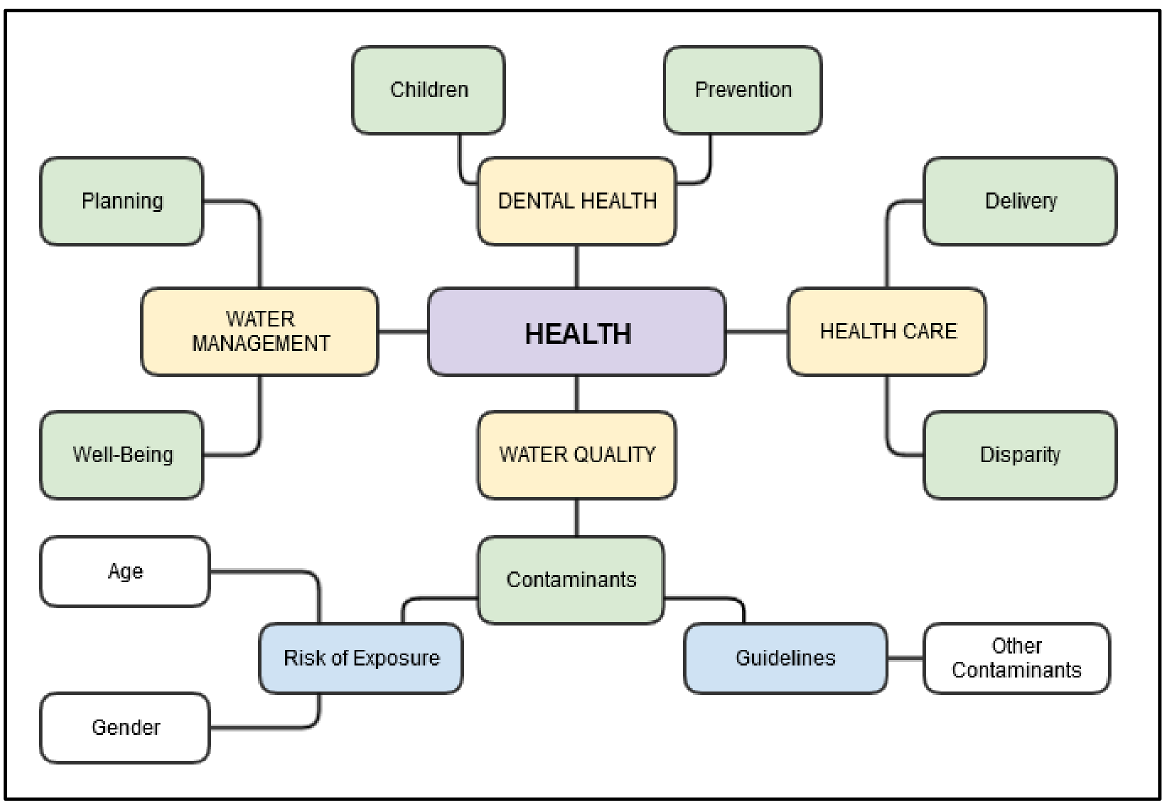

Fig. 4.7: Health considerations for water in the ISR

4.6.1 Dental Health

The discussion of dental health arose primarily from a study by Leake *et al*. (2008) on dental caries in Inuvik children and the prevention of oral disease. Early childhood tooth decay was noted as a major concern in communities with high Indigenous concentrations because of the high degree of prevalence. For example, 12% of Inuvik preschool children in the study needed urgent dental care (Leake *et al*., 2008). When compared to US children, it was uncovered that less than one third of US children had one or more cavities while two thirds of Inuvik children had three or more decayed or filled teeth (Leake *et al*., 2008). These results demonstrate that there is a significant disparity in the oral health of Inuvik children compared to other populations.

In addition to the high rate of dental caries, the prevention of dental caries was also discussed. Several factors for prevention were identified, including higher family income, community water fluoridation, breast-feeding, and drinking milk and fruit juice after beginning to walk (Leake *et al*., 2008). The factors identified in the Inuvik region were said to be consistent with other studies related to oral disease which have found that in general, higher incomes, access to fluorides and healthy diets resulted in better oral health (Leake *et al*., 2008). What should be noted here is the community water fluoridation factor as the benefits of fluoridation have apparently been well-documented; they have been found to reduce the number of cavities in children, adults and seniors alike (GNWT HSS, 2011).

Inuvik adds fluoride in the form of fluorisilicic acid to their drinking water (GNWT HSS, 2011; Leake *et al*., 2008). Despite this addition, the number of children with dental caries and severe dental disease is still significantly higher. This leads to the conclusion that fluoridation of drinking water is perhaps not the dominant factor in the prevention of oral disease. It also calls into question the state of oral health in the other ISR communities, which do not fluoridate their drinking water.

4.6.2 Water Management

A general theme across the literature was that proper water management is essential to the health and well-being of the residents of the NWT (GNWT, 2012a; Council of the Federations, 2010). The Council of the Federations (2010) also referred to fundamental components of water security, such as managing water so as to ensure an adequate quality and quantity for daily consumption, as being essential to human health.

Well-being, described as the collective well-being of all water users within a watershed, was noted as an ultimate goal of water management (GNWT ENR & INAC, 2008). This would include the consideration of: the water uses and values that a diverse population derives from all water resources within a system; the well-being of both the current and future generation of water users; and, the recognition of water as a fundamental human right (GNWT ENR & INAC, 2008). It was also stressed that having a well-established plan for dealing with water-related emergencies, such as the contamination of drinking water, is important for ensuring the health and well-being of NWT residents (Council of the Federations, 2010). These two topics can be seen as interconnected. Because of the relationship between water and health, the vulnerability of water resources is important and needs to be considered in the decision-making process (Plummer *et al*., 2012). If health and social well-being are to be achieved, planning and cooperation on a watershed scale is imperative.

4.6.3 Health Care

Health care was addressed in two ways. First, it was discussed in terms of the disparity of the health status between northern Indigenous peoples and the rest of Canada. For example, it was noted how the health status of northern residents is significantly lower than the national average (Prowse *et al*., 2009). Also of concern was the fact that even though Indigenous peoples make up the largest percentage of the population in the North, no environmental health positions are held by Indigenous peoples (Ritter, 2007).

Secondly, there was discussion about the delivery of health care. Water is important for the provision of health services. Health care clinics and hospitals require sanitary conditions to operate, which would not be possible without adequate amounts of clean water. The Inuvik Regional Hospital is the only hospital in the Beaufort-Delta Region and provides a number of services, such as acute care, laboratory, long-term care and surgeries (Town of Inuvik, 2015a). The GNWT currently provides insured health services across the territory, including the ISR (IRC, 2009). While there was no mention of the quality of health care, it was believed that an Inuvialuit Self-Government Agreement would allow the Inuvialuit to provide uninsured and Inuit-specific programs (IRC, 2009). Other research that could benefit the development, promotion and delivery of health care for children in the Inuvik region of the ISR is being done (Leake *et al*., 2008). This suggests that there are barriers that need to be addressed.

Even though there are barriers to health care for all northern residents, such as living in remote locations and limited access to medical professionals, there is still a significant difference between Indigenous and non-Indigenous populations. This indicates that there must be additional or other barriers for northern Indigenous peoples to receiving health care compared to non-Indigenous, northern residents. The disparity in health status between Indigenous and non-Indigenous populations in the North is not immediately explained in the literature. This leads to the question of whether the additional barriers to health in northern Indigenous communities are similar to southern latitudes or if there are northern-specific barriers that increase this discrepancy.

4.6.4 Water Quality

The relationship between unsafe water sources and poor health outcomes in communities has been widely recognized by the health community (Plummer *et al*., 2012). Several aspects related to water quality were highlighted, including guidelines, risk of exposure, gender and age (Fig. 4.7), and all of these relate to some extent to contamination of water.

A major concern noted in the research was the potential for increased contamination to freshwater in the Arctic from increased exploration and development activities resulting in adverse effects on ecosystem and human health in the future (Thienpont *et al*., 2013). An increase in exploration and development activities, such as mining, could result in an increase in the number of potential point-sources of pollution, such as PAHs and other POPs in the Arctic. These concerns were particularly high for Inuit populations as they face elevated exposure to metals, such as lead, and POPs compared to other populations in Canada (Section 4.2.2) (Laird *et al*., 2013). DDE, DDT and some other POPs have been linked with obesity and diabetes. Elevated risk of exposure to Inuit means elevated risk to chronic diseases associated with these contaminants (Laird *et al*., 2013). The elevated risk of exposure to contaminants was not consistent across Inuit communities. For example, Laird *et al.* (2013) found that exposure and risk depended on both gender and age. In general, the level of POPs, PCBs and Chlordane were found to be lower in Inuit women of child-bearing age than the rest of the adult Inuit population (Laird *et al*., 2013).

The GNWT HSS produced a set of guidelines for drinking water quality that included the maximum allowable concentration of potential contaminants and aesthetic objectives, as well as a brief explanation of the potential impacts on health for each potential contaminant (Appendix B). The list of potential contaminants included in the guideline is extensive and appears to cover many of the contaminants of concern to local residents (GNWT HSS, 2011). Not all of the potential contaminants included in the guidelines are detrimental to human health. Some are actually beneficial to human health while others are only harmful if found in very high concentrations (GNWT HSS, 2011). However, it does not cover all contaminants found in the Arctic. Noticeably absent from the guidelines are POPs, even though the link between long-term exposure to metals and POPs and adverse health effects has already been made (Laird *et al.*, 2013). Because of the negative impact on human health, including both neurological and physical health effects (Laird *et al*., 2013), dissolved hydrocarbons and metals will be important to monitor (GNWT ENR, 2012b).

Notably absent from a majority of the discussion on water quality was the topic of mercury. Bioaccumulation of mercury is a popular topic of interest and concern to Inuit and other northern residents (Arctic Monitoring and Assessment Programme [AMAP], 2011; Inuit Circumpolar Council, n.d.). However, there was very little mention of mercury or bioaccumulation as they relate to water and health. The link between mercury, bioaccumulation and animal health was often made in the literature. However, the link to human health was generally lacking.

4.6.5 Summary

A number of important conclusions about the relationship between water and health can be drawn from the literature. These include:

1. There is an inextricable link between water quality, quantity and health. Having access to a sufficient amount of clean water is essential to human health.
2. Community water fluoridation is known to reduce the number of cavities. Despite this, oral cavities and severe dental disease rates in Inuvik are still significantly higher than non-Indigenous populations.
3. Proper water management, which involves cooperation and planning, is essential to human health and well-being at a watershed scale.
4. There is a significant disparity between the health status of northern Indigenous populations and non-Indigenous, northern populations. This discrepancy could be related to the delivery of health care in the region but may also be a result of additional barriers not mentioned in the literature. More than likely, it is a combination of both.
5. PCBs and POPs were not mentioned in the HSS Guidelines. Yet, it was found that Inuit populations face elevated exposure to metals and POPs which increases their risk of developing chronic diseases and other negative health outcomes. This risk is not uniform across the population; it varies by age and gender.

CHAPTER 5: DISCUSSION

The study by Norman *et al*. (2011) identified several drivers of water insecurity at the national level according to water managers, policymakers and practitioners across Canada (Table 2.1). The results of this thesis identified several drivers of water insecurity in the ISR based on the available literature (Table 5.1). The similarities and differences between Canada and the ISR emerging from the literature are discussed in the following sections.

5.1 SIMILARITIES BETWEEN CANADA AND THE ISR

When comparing the identified drivers of water insecurity in Canada to those that emerged from the literature on the ISR, several similarities can be drawn. At the national level, drivers of water insecurity include water quality, governance, climate change and funding (Table 5.1). Similar drivers of insecurity in the ISR included the contamination of water resources, jurisdiction, legislation and regulations, climate change and funding.

Table 5.1: Drivers of water insecurity in Canada compared to the ISR.

DRIVERS OF WATER INSECURITY	
Canada	**Inuvialuit Settlement Region**
- Water quality issues - Governance (government/planning and regulatory issues) - Quantity/supply issues (availability) - Infrastructure - Groundwater - Access/source protection "security" - Insufficient data/lack of knowledge - Climate change - Funding - Industry	- Climate change - Cultural practices - Infrastructure - Health and well-being - Funding - Human capacity - Contamination of water resources - Jurisdiction - Legislation and regulations - Devolution

* Drivers of water insecurity in Canada were adapted from Norman et al. (2011), p. 58. Drivers of water insecurity in the Inuvialuit Settlement Region are those that emerged from the literature (Chapter 4).

5.1.1 Water Quality Issues

Similar to Canada, the contamination of water resources in the ISR was noted as a challenge for achieving water security (Table 5.1). The contamination of water resources can be related to three of the main challenges identified by Norman *et al*. (2011): water quality issues, source protection and industry. Changing water quality was shown to be a result of natural processes, climate change, and local and long-range industrial and economic activities. These were shown to have varying impacts on water resources across the region, including: increasing water temperatures, change in the composition of water resources, change in water salinity, and increased contamination of water resources.

While there are lower levels of contaminants in the NWT compared to other regions in Canada, contamination of water resources still emerged as a major area of concern for northern residents. Increasing industrial activities in the ISR, adjacent lands and within the Mackenzie Watershed increase the potential for the contamination of water resources in in the region. Development, mining, exploration, hydroelectricity, municipal water use and infrastructure increase contaminant input. PAHs, produced from oil and gas activities, acid mine drainage, metal contamination, chemical pollution and long range atmospheric transport of mercury are all associated with industrial activities and are of great concern in the Arctic (Braune *et al*., 1999; French *et al*., 2014; Thienpont *et al*., 2013). The disposal of drilling waste fluids generally involves containment in the ISR, which is assumed to be permanent because fluids would freeze in-situ in permafrost (AMEC, 2005; Thienpont *et al*., 2013). However, flooding, thawing, ponding, ground cracking and thaw slumping all increase the likelihood of nearby surface water contamination and were all shown to be present in the ISR (section 4.2.3.2) (AMEC, 2005; Thienpont *et al*., 2013; Wootton *et al*., 2008). In this case, the potential impacts from industrial water use and waste are compounded by environmental changes being observed in the region (Section 5.1.3).

The spatial distribution of contaminants was shown to be unequal across the region. For example: organochlorines, such as toxaphene and PCBs, were found in concentrations of 2-10 times greater in the ISR than in nearby Horseshoe Bend, which is adjacent to the ISR (Braune *et al*., 1999). The spatial distribution of contaminants is affected by a number of factors that are both natural conditions of the environment in the region and as a result of human actions. For example, the distribution of heavy metals is affected by factors such as forest fires, natural oil and gas deposits, and oil and gas development (Braune *et al*., 1999; GNWT ENR, 2012b). Underlying bedrock and the milling process are sources of arsenic in the region (GNWT ENR, 2011a). Long term data has shown that arsenic levels have frequently been above guideline recommendations for human consumption (GNWT ENR, 2012b).

Mercury is another contaminant of concern for ISR. The spatial distribution of mercury is affected by river discharge, thawing permafrost, forest cover, forest fires and weathering of bedrock as mercury is a natural constituent of bedrock in the region (Braune *et al*., 1999; Leitch *et al*., 2007; French *et al*., 2014). Open waste burning can also increase air and water pollution (GNWT ENR, 2011a). The abovementioned activities range from local to regional in scale and take place in or around the ISR and NWT. However, contamination of water sources in the region has also been linked global contaminant use, emissions and long-range atmospheric transport (Thienpont *et al*., 2013). Increased weathering of the bedrock as a result of climate change is another example of larger scale impacts (GNWT ENR, 2011a).

The contamination of water sources in the ISR not only affects the ecosystem and its functions but also human health. The potential increase in the contamination of water resources could eventually require changes to water treatment in the region. The current system requires minimal treatment, with the addition of chlorine being the only requirement (except for Inuvik) (EarthTech, 2008). The requirement of more substantial treatment systems to deal with further contamination of the water resources could add a significant financial burden to communities that are already stretched.

Beyond the threat to health from contaminated water sources is the potential threat to human health through the contamination of food sources. As described in the results, subsistence hunting is a common practice in the region. Contaminants in the water have the potential to bioaccumulate through the food chain before being consumed by local residents. As a result, increased concentrations of contaminants in the water sources of the region could increase the exposure of contaminants to humans, which could in turn increase the risk to human health. This is particularly troubling since it has already been shown that Inuit face elevated exposure to heavy metals and POPs than the rest of the Canadian population, which increases risk to chronic disease and other negative health outcomes (Laird *et al*., 2013).

Finally, the protection of source waters was identified in Norman *et al*. (2011) and also emerged as an area of concern in the literature, as evidenced by the development of the GNWT's SWAP (GNWT 2010a). Again, the protection of source waters is one way of addressing the issue of water contamination; the best way to protect water resources is to prevent contamination in the first place.

5.1.2 Governance

Governance was also identified as a driver of insecurity across Canada and within the ISR. At the national level, Norman *et al*. (2011) identified governance issues as government planning and regulatory issues. While these were shown to be important in the ISR, specific aspects of governance identified as having an impact on water security were jurisdiction, legislation, regulations and devolution (Section 5.2.5) (Table 5.1).

The interjurisdictional nature of water governance emerged as one of the main barriers to water management in the ISR. This is also true for other watersheds across Canada, which share many borders, including with the US. Particularly at the watershed scale, there is an imbalance of power and control between jurisdictions, e.g. downstream jurisdictions have no physical control over upstream water use but are inevitably impacted by its use (Gordon Foundation, 2011). Four ISR communities are located within the Mackenzie Delta region, making them the group that resides the furthest downstream in the Mackenzie River Watershed. To manage the waters at a watershed scale requires the cooperation of multiple stakeholders. Further complicating this cooperation is the fact that the Mackenzie Basin crosses multiple provinces and territories in Canada. This means that they not only require cooperation with the GNWT and other nearby stakeholders, but also the cooperation of multiple provincial and territorial governments and stakeholders (Section 4.1).

Being the furthest downstream is also a disadvantage when it comes to obtaining cooperation and protecting their waters. Downstream communities arguably have to deal with the greatest challenges, often not as a result of their own actions but the actions of upstream water users. The ISR has control over a limited surface area within the Mackenzie watershed boundaries, but are affected by the actions of upstream water users who have little vested interest in maintaining the quality of water sources as they flow downstream from their communities. The modern legal approach to transboundary agreements seeks to address this imbalance of environmental impacts experienced by downstream jurisdictions by acquiring moral and legal rights for downstream jurisdictions to offset the reality of living downstream (Gordon Foundation, 2011). According to the Gordon Foundation (2011), territorial leaders lack sufficient jurisdiction and resources to protect their waters for future generations. Despite what the Gordon Foundation (2011) expressed, the GNWT believes that progress on their transboundary water agreement negotiations for water entering the NWT with Alberta has been made (GNWT ENR & AANDC, 2013).

Apart from jurisdiction, lack of federal legislation and changing regulatory requirements were also identified as challenges to water security. First, changing regulatory requirements can be a challenge for resource management. For example, there was concern that regulatory requirements for water treatment and disposal systems are rapidly changing and increasing which is leading to unforeseen costs to community governments in complying with these requirements (GNWT, 2004).

Second, not all aspects of water management are addressed in federal legislation, which can pose some challenges to planning and implementation. For example, the federal government is ultimately responsible for the protection of water resources in the ISR yet, there is currently no federal legislation that deals directly with the discharge of municipal wastewater (Wootton *et al*., 2008). Instead, as Wootton *et al*. (2008) point out, municipal wastewater in the ISR falls under the jurisdiction of several federal departments including AANDC, DFO and EC. According to the ENR, the national strategy for municipal wastewater in the NWT continues to be implemented (GNWT ENR & AANDC, 2013).

Lastly, developing a water management policy that suits every community or situation is a challenge (Plummer *et al*., 2012). No water policy can fit all situations and all communities because the values, relationships and experiences of people within the community impact the level of acceptance, uptake and effectiveness of the policy (Fresque-Baxter, 2013). In other words, communities are unique because of the people that live in them; therefore, there is no one-size-fits-all water policy solution.

5.1.3 Climate Change

Climate change was also identified as driver of water insecurity by Norman *et al*. (2011), but there was no explanation of what aspects of water security were affected by climate change at the national level. While climate change was recognized as important, only 13% of respondents reported climate change as a driver of water insecurity (Norman *et al*., 2011). By contrast, there was a much greater emphasis on the impacts of climate change on water security in the literature related to the ISR. This is likely due to the fact that temperatures are warming at an increasing rate in the Arctic compared to the rest of Canada. It could also be a reflection of the opinion that other water-related issues, such as access to clean water, are more pressing than climate change. Because the opinions about the level of importance of the drivers of water insecurity in Norman *et al.'s* (2011) paper are based on interviews with water managers and policy-makers, this difference could also be a reflection of a disconnect between academic literature and water management and policy-makers.

Water is arguably "the" defining feature of the environment in the ISR; surface water resources occupy up to 30% of the landscape while the rest of the surface is covered in snow and/or ice for most of the year (Baki *et al*., *2012*). There are many sources of freshwater in the ISR, including: lakes, rivers, ice-rich permafrost, precipitation (snow, rain, etc.), ground ice, glaciers, snowpacks and groundwater (AMEC, 2005; Ayles & Snow, 2002; Dugan *et al*., 2012; Emmerton *et al*., 2007; Ensom *et al*, 2012; GNWT ENR, 2011a; Goulding *et al*., 2009; Kokelj & Burn, 2003; Lesack & Marsh, 2010; Marsh *et al*., 2009; Newton *et al*., 2014b; Prowse *et al*., 2009; Szeto *et al*., 2008; Utting *et al*., 2013; White *et al*., 2007; Woo & Thorne, 2003). The spatial distribution of water naturally varies across the region. Conditions specific to the region that impact the spatial distribution of resources include:

- *Permafrost*: controls the distribution of groundwater, acts as a flow path for water and is a significant storage of water; ice-rich zones at the top of permafrost could become important hydrologic reservoirs (Kokelj & Burn, 2003);
- *Precipitation*: low annual precipitation, snowfall is the major form of precipitation (Woo & Thorne, 2003);
- *Snow cover*: seasonal snow cover timing, duration, thickness and distribution have important implications for other aspects of the water cycle (e.g. streamflow, runoff, groundwater recharge, etc.) (White *et al*., 2007);
- *Ice cover*: ice-jam flooding is the main source of recharge for many lakes in the region and is particularly important for replenishment of small lakes (Goulding *et al*., 2009; Marsh & Hey, 1994)

Because the northern landscape is dominated by water in various frozen states, it is particularly sensitive to temperature rise. Rising temperatures as a result of climate change will substantially alter water across the region in many ways, including:

- *Water composition*: a change in the chemical composition of surface and groundwaters through increased runoff and increased salinity as a result of rising sea levels and increasing magnitude and frequency of storm surges (Kokelj *et al*., 2012; Papik *et al*., 2003; Thienpont *et al*., 2012);

- *Lakes*: increased sedimentation in lakes as a result of increased runoff and longer open water seasons, increased lake initiation as a result of permafrost thaw, increased lake drainage as a result of growing permafrost active layer depth, decrease in lake size and/or catastrophic lake drainage as a result of retrogressive thaw slumping, reduction in lake levels as a result of increased evaporation – also a consequence of longer open water seasons, and reduction in lake water recharge as a result of changing flood frequencies (particularly significant for delta region where lakes are primarily recharged from flood waters) (Emmerton *et al*., 2007; Lesack & Marsh, 2010; Marsh *et al*., 2009; Pearce *et al*., 2011; Prowse *et al*., 2006; Szeto *et al*., 2008);
- *Snow*: decreasing snowfall on land, shorter snowfall accumulation season, smaller snowpacks, earlier snowmelt as a result of rising temperatures and increased runoff, and increased net precipitation from higher atmospheric temperatures (poleward transport of moisture) (Emmerton *et al*., 2007; Goulding *et al*., 2009; Woo & Thorne, 2003);
- *River flow*: increased river flow and bank erosion as a result of increased runoff, earlier peak flow in spring, decreased late spring, summer and early fall river flow, and increased winter flow (Abdul-Aziz & Burn, 2006; Ayles & Snow, 2002; Baki *et al*., 2012; Emmerton *et al*., 2007; Lesack *et al*., 2014; Newton *et al*., 2014a; Prowse *et al*., 2006);
- *Ice Cover*: later ice freeze up, earlier ice break-up as a result of warmer temperatures, less severe ice break-up and resulting flooding (Burn, 1995; Carrie *et al*., 2010; Emmerton *et al*., 2007; Lesack *et al*., 2014; Pearce *et al*., 2011; Pearce *et al*., 2012; Prowse *et al*., 2006);
- *Permafrost*: increased thawing of permafrost, increased retrogressive thaw slumping, groundwater outflow increase as active layer deepens, potential shift from groundwater to surface water dominated system and redistribution of moisture and solutes deeper in the soil (Cott *et al*., 2008; GNWT ENR, 2011a; Kokelj & Burn, 2003; Pearce *et al*., 2011; Pearce *et al*., 2012; Prowse *et al*., 2006; Prowse *et al*., 2009; Quinton *et al*., 2011; Utting *et al*., 2013).

The abovementioned changes to the landscape as a result of climate change also have an impact on socio-cultural practices, industrial activities and development, and the health of local residents. For instance, changes in salinity can affect the cultural uses of water. One example of this impact from the results is the observed increase in the salinity of water at Big Fish River, a culturally significant fishing location, which was attributed to a decline of char in the river (Papik *et al*., 2003). Changes in the water levels of lakes and rivers in the ISR have also been shown to impact cultural practices. For example, lower water levels, which have been attributed to increased water temperatures, affect the quality of fish meat and spawning time of fish and result in more hazardous travelling conditions by making navigation by boat impossible, putting added stress on ATVs and skidoos as a result of forced travel over rocky and muddy terrain, and forcing people to travel on the ocean because of less snow (Community of Aklavik *et al*., 2005).

These examples demonstrate how changes to the environment can impact culturally significant locations, important food sources in the region and the physical safety of residents when participating in subsistence activities. Environmental changes associated with climate change impact the safety and convenience of travel between communities by changing the stability of ice and snow and increasing travel time by forcing people to take alternative routes. It can also increase the financial burden of those participating in cultural activities by adding stress to equipment, thereby reducing the equipment's life span.

5.1.4 Funding

Lastly, funding was also identified in Norman *et al*. (2011) as a driver of water insecurity, and a similar emphasis emerged in the ISR (Table 5.1). In the North, there is a limited amount of resources available for use. Resource use is often limited by seasonal conditions. Within the ISR, specific challenges related to funding included the limited amount of funding for stewardship initiatives as well as more specific challenges, such as the high cost of materials and seasonal limitations related to the remoteness of communities and cold arctic temperatures. For example, during the development of the NWTWS, limited financial resources were identified by communities as one of the main barriers for developing water stewardship initiatives (GNWT ENR, 2013). While access to funding programs for management planning and implementation exist, the amount of funding available has been shown to be inadequate for meeting the needs of the communities. Without the appropriate financial resources, it is not possible to set up and implement water monitoring programs and deliver on water management initiatives.

5.2 UNIQUE ASPECTS OF WATER SECURITY IN THE ISR

Not all drivers of water insecurity identified at the national scale were found to be relevant to the ISR. For example, water quantity issues and groundwater were identified as drivers of insecurity across Canada (Table 5.1). However, neither groundwater nor water quantity emerged as key challenges to water security in the ISR. Groundwater is used by many communities across southern Canada for municipal supplies (CCME, 2010). That groundwater did not emerge as a challenge to water security in the ISR is likely tied to the fact that community water sources in the ISR are drawn from surface waters. This is not to say that groundwater is not important in the ISR, but rather that it is not a key concern for water security for the region. Similarly, access to an adequate supply of water was identified as a key factor across Canada. In the ISR, there is an abundance of water for a very small population. Therefore, water quantity did not emerge as a key driver of water insecurity. Again, this does not imply that water quantity is not an issue but that other factors are more important. For example, an abundance of water does not ensure water security if appropriate infrastructure and systems for water treatment, distribution and wastewater management are not established.

While the section above demonstrates that there are similar drivers of water insecurity at the national level and in the ISR, there are some aspects of water security that are specific to the ISR. These include cultural practices, health and well-being, and human capacity (Table 5.1). Other drivers of water insecurity, while recognized at a national scale, have very unique elements that are only applicable in the ISR and NWT, such as infrastructure and devolution (Table 5.1). These are discussed in the section below.

5.2.1 Cultural Practices

Cultural practices, such as subsistence hunting and gathering snow and ice for drinking water, are unique aspects of water security in the ISR that did not emerge at the national scale. Changes to the environment that impact water, snow and ice affect the ability of ISR residents to participate in subsistence activities. While this can be said for other regions in Canada, what makes it particularly important in the ISR is the heavy reliance on subsistence activities to support dietary preferences and food security. Subsistence practices depend greatly on water: waterways are used for travel; lakes and rivers are used for fishing; and, snow and ice are used for travel, drinking water, fishing and harvesting. Water in the form of snow and ice is of particular significance in the ISR, and across the Arctic. Use of and travel across snow and ice is a central aspect of cultural subsistence practices because of their presence for a large portion of the year (Peace & Myers, 2012). Spending time on the land and participating in subsistence activities are particularly important aspects of Inuvialuit culture (Alessa *et al*., 2010; Pearce *et al*., 2006).

Subsistence activities, such as fishing, are often place-specific because they tend to take place at culturally significant locations. Preferred sites are often chosen because they provide a preferred species for consumption, are a reliable source of food and are easy to travel to. TK about these sites is often place-specific, such as seasonal water levels, seasonal water flows, seasonal turbidity and salinity, migration timing of preferred species, and wildlife health, to name a few (Wesche & Chan, 2010). However, TK is also often dependent on an understanding of the broader regional surroundings (Furgal & Seguin, 2006). While activities such as hunting and fishing may take place in specific, locally preferred sites, getting to a preferred location may require travel across large distances of land (Condon, Collings & Wenzel, 1995; Nuttall *et al.*, 2005; Sharma, 2010). To travel safely, it is essential to have general knowledge about the surrounding region, such as: general weather conditions, patterns, and seasonal changes and how they affect preferred locations; snow thickness, texture and sound; and, ice thickness and colour (Pearce *et al*., 2006). Therefore, safe travel requires not only general knowledge about the land, but also a constant re-evaluation of the current location over the course of travel.

A change in the ability to spend time on the land could have an impact on these practices. For example, the transfer of TK often takes place through land-based learning. Decreasing time spent on the land could lead to a decrease in the transfer of TK from older to younger generations. This is a challenge to cultural continuity as it decreases the opportunities and strength of cultural knowledge transmission through stories, oral history, and personal collected experience. Results showed that younger generations are not participating as much in subsistence activities and are therefore not accumulating the necessary experience to make appropriate decisions while out on the land. In the process, they are losing their connection to the land, which can influence their identity. Losing connection to the land also poses some threat to human safety. TK comes from a profound understanding of the environment as well as an ability to adapt to environmental changes. Without this knowledge, many young people lack the skills necessary to assess risk when they do go out on the land. This adds an element of danger when travelling between communities and for hunting purposes.

Another important cultural use of water is the use of untreated water from snow, ice and surface waters as a source of drinking water. Gathering water from the land is a common practice among Inuit communities across the Arctic. For example, Nunatsiavummiut (Labrador Inuit) have gathered water from brooks, lakes, ice-melt and ice from land and sea for drinking water for generations and for many, this remains the preferred source of drinking water (Goldhar, Bell & Wolf, 2013). Nunavimmiut (Quebec Inuit) often gather water from lakes, creeks and rivers in the summer and melt snow and ice for use in the winter and spring, with as many as 29% of Nunavik residents using this as their primary source of water (Martin *et al*., 2007). Among Inuvialuit communities, collecting ice for drinking water is an important cultural skill that is taught through land schooling and is part of daily practices (Pearce *et al*., 2011). This is an informal but significant use of water in both frozen and liquid states across the region.

In general, water is gathered in plastic buckets by foot, snowmobile or all-terrain vehicles from nearby locations and is a physically demanding process (Goldhar *et al*., 2013). Because it is physically demanding, those whose sole access is by foot have limited access to water for this particular use. Access is tied to the amount that can be physically transported and the distance that can be travelled by foot. Those with snowmobiles and all-terrain vehicles have a greater access to this water resource but are still limited by the capacity of the snowmobile or all-terrain vehicle and the distance/speed they can travel. Therefore, changes to the environment that affect the stability and predictability of snow, ice and surface water conditions will impact the ability to gather drinking water from the land.

5.2.2 Health and Well-Being

The connection between health and well-being emerged from the literature but was not identified by Norman *et al*. (2011) at the national scale (Table 5.1). The results demonstrated that water is important for social, cultural and spiritual well-being (Alessa *et al*., 2010; Council of the Federations, 2010; GNWT, 2014a; GNWT, 2007; GNWT ENR & INAC, 2010; GNWT ENR & INAC, 2008; GNWT, 2012a; Gordon Foundation; Plummer *et al*., 2012; Prowse *et al*., 2009; Vaux Jr., 2010; GNWT ENR & INAC, 2008; Fresque-Baxter, 2013). This includes participating in subsistence activities. As mentioned in the results, the decline in participation in subsistence activities was said to be the most serious cause of the decline in well-being of residents. The close relationship with and reliance on the land for cultural practices, and climatic changes and the unpredictability that comes with them, make subsistence activities more difficult to partake in and less appealing, affecting the cultural link to land.

Apart from physical safety being a concern, there are many aspects related to mental health. For example, some people fear partaking in subsistence practices because they believe that it could lead to an increased exposure to contaminants (Carrie *et al*., 2010). As shown above, this fear is not necessarily unfounded. While there was no other direct link to mental health made specifically in the ISR, research in other Arctic Inuit communities suggest that spending time on the land is essential to emotional and mental well-being. For example, a study by Cunsolo Willcox *et al*. (2012) in Rigolet, Labrador found that community members felt a strong connection between time spent on land and mental health:

> "For many people, going out on the land around Rigolet made them feel more "fulfilled" and "complete", and being on the land was "relaxing" and "healing" because people could "go out there and get rid of all the stress"… people also reported that they were feeling "depressed" and "down" and that their sense of mental health and well-being was suffering due to climatic and environmental changes". (p. 543)

The link between water and well-being was made in several of the management plans as well. For example, Inuvik ICSP concluded that "collaboration on decision-making and actions of all government and local groups, ensure that people's well-being – culture, health, recreation, education and opportunities – expand personal and professional goals, and overall basic needs" (Kavik-AXYS & Stantec Consulting Ltd., 2010, p. 9). Similarly, the GNWT LUSF acknowledged that land use management should help protect the health of residents and ecosystems and that the management of water quality, quantity and flow should be done in a sustainable manner to support the health and well-being of NWT residents (GNWT LUSF, 2012). However, determining what management actions will result in the best health and well-being outcomes for the most amount of people is difficult because well-being and mental health are subjective.

5.2.3 Human Capacity

The link between building human capacity and water security was another unique challenge to emerge from the literature (Table 5.1). While access to qualified personnel is affected by the remoteness and small size of northern communities, the connections between economic stability, wage-earning opportunities, socio-economic status (reliance on social services) and subsistence activities also need to be recognized. For example, many of the wage-earning activities in the NWT are tied to the extraction of non-renewable resources in the region, meaning they are often temporary, seasonal and limited (Pearce *et al*., 2012). The high cost of living, remoteness, small community size with limited economic base and mostly government jobs, amongst other social and economic factors, limit the number of wage-based jobs and educational opportunities in Inuvialuit communities. There is a strong reliance on subsistence practices to sustain households. However, environmental changes are making this more difficult, as well as the need for money to finance the equipment and time to engage in subsistence activities. The unpredictability of weather is leading to a decrease in the participation in subsistence activities and an increased reliance on social services.

Some management plans are addressing the concern of limited capacity in Inuvialuit communities. For example, one goal of the Inuvik ICSP is to increase local employment by:

- promoting and supporting local businesses and contractors;
- encouraging the NWT to support local business incentives and training programs;
- encouraging southern workers to stay in town year-round by promoting opportunities;
- creating innovative and interesting cultural activities; and,
- communicating the benefits of living in the north (Kavik-AXYS & Stantec Consulting Ltd., 2010).

Building human capacity through education and training is important for water security. The operation and maintenance of water treatment and distribution systems cannot function effectively without qualified personnel. These were noted as specific challenges for water treatment in the ISR and across the NWT. Funding for education and training to build capacity was a main goal in many of the management plans addressing water in the ISR. This is of particular importance in the ISR because of the limited access to qualified personnel, partly a result of location.

5.2.4 Ice as Infrastructure

Water is also an important aspect of economic development in the ISR and across the Arctic. While development activities, such as mining, require great amounts of water for processing, exploratory drilling, hydrostatic testing of pipelines and camp use (Cott *et al*., 2005; GNWT ENR & INAC, 2010; INAC, 2010b), what is distinct to the North is the use of water in its frozen state to create infrastructure (Table 5.1). This includes the use of snow and ice for multiple purposes, such as winter roads, ice drilling pads, ice landing strips and ice crossing construction, which are essential to northern resource exploration and extraction (Cott *et al*., 2005; Cott *et al*., 2008; Council of the Federations, 2010; GNWT ENR & INAC, 2008; Hirose *et al*., 2008). Winter roads are constructed across frozen ground, lakes and rivers using compacted snow, applied ice caps and ice aggregates, and are therefore limited to the winter season (Stephenson, Smith & Agnew, 2011). The timing of ice road usability varies, but the typical period is November-December to March-April (Prowse *et al*., 2009).

These industrial activities require significant amounts of water (Hirose *et al*., 2008). There are a limited number of permanent roads in the NWT, therefore these roads are relied on to transport supplies to communities and development sites (section 4.3.1) (Cott *et al*., 2005; Cott *et al*., 2008). As a result, development projects are often carried out over the winter months, when snow and ice are readily available for road, runway and drilling pad construction and temperatures are stable enough to prevent thawing (Cott *et al*., 2005; Pearce *et al*., 2010). Resupply of resources to existing mines, such as materials, heavy equipment and fuel, is also generally limited to winter months due to the operating season of ice roads (Prowse *et al*., 2009).

In general, winter road construction is a relatively inexpensive way to transport materials to remote locations, which may otherwise be uneconomic to access due to the high cost of permanent roads and aircraft use (Prowse *et al*., 2009; Stephenson *et al*., 2011). A reduction in the availability and duration of ice roads as temperatures rise in the North poses a concern about mine access, which is expected to see a reduction in access by winter roads and a reliance on alternative forms of access, such as all-season road construction or water-based transportation (Prowse *et al*., 2009; Stephenson *et al*., 2011). Changes in snow cover and permafrost thawing can increase the unpredictability of the winter season and winter ice road duration, which will require greater flexibility in the scheduling of exploration and extraction activities (Prowse *et al*., 2009). Changes related to climate change, such as permafrost thaw, stronger winds, and changing water levels, can also weaken the structural integrity and safety of ice roads and make it more difficult to maintain a sufficient thickness to support heavy traffic flows (Pearce *et al*., 2010). This is of particular concern as expanded mining activity is also expected to increase truck traffic on ice roads, which would add additional stress (Pearce *et al*., 2010).

Delayed openings of winter roads and earlier closures expected in the future could result in some industrial developments becoming uneconomic over time as the window for ground transport shortens (Stephenson *et al*., 2011). Some economic losses as a result of warmer temperatures have already been felt. For example, unseasonably warm winter temperatures in the winter of 2006 meant that ice road networks in the NWT were only open for a total of 42 days (Hall, 2013; Ford *et al*., 2010; Pearce *et al*., 2010). The financial costs to mining companies as a result were high. Approximately 60% of the trucks on ice roads in the NWT transport fuel to industrial sites; the shortened season in

2006 resulted in the Diavik mine being required to fly 15 million liters of fuel in to camp, which is far more costly than transport over ice roads. Based on some estimates, Diavik would have spent an extra $11.25 million to fly fuel in to the mine site for 2006 (Ford *et al*., 2010; Pearce *et al*., 2010). Shortened seasons like 2006 could become more regular. By some projections, the Tibbitt to Contwoy Winter Road is road is expected to lose up to 17% of its operating season by 2020 (Stephenson *et al*., 2011).

Water infrastructure is also connected to many factors, such as funding, human capacity for operations and maintenance, physical distance to water resources and water quality, to name a few. These all emerged as challenges for building water security in the ISR (Table 5.1).

5.2.5 Devolution

While governance was noted as a challenge at both the national scale and within the ISR, the issue of devolution is more specific to the NWT, including the ISR (Table 5.1). Through the process of devolution, the GNWT has assumed the obligations held by the federal government in relation to land and resource management in the NWT (GNWT LUSF, 2012; Canada, *et al*., 2013). This means there will be an increase in the level of interaction between the ISR organizations and the GNWT (Figure 4.1). While this makes some changes in the ISR in terms of whom they will rely on or need to negotiate with on water management issues, the federal government still maintains a number of responsibilities associated with water in the region. This is due to the presence of federal lands, national parks, highways and shipping routes in the ISR, which remain federal responsibilities.

One of the challenges for the GNWT will be that the federal government is devolving policy responsibility but not financial resources in the NWT, meaning they don't have complete control over their resources (Vaux Jr., 2010). In addition, even though the GNWT will assume responsibility for resources management and enact territorial legislation to replace the existing federal legislation, territorial acts must mirror federal acts and any changes to federal acts for a period of 20 years (GNWT, 2012a). For example, consent from Canada is required to make any regulatory changes to the NEB functions in the ISR and any federal changes to NEB-related legislation must be substantially mirrored in the territorial equivalent legislation (INAC, *et al*., 2013). This means that while the GNWT assumes control over natural resources, their ability to control resources is still limited for at least 20 years.

The process of devolution was expected to result in some conflict across the region (Rosenberg Forum, 2009). The elimination of regional land and water boards and the consolidation into one super board, the MVLWB, was said to create an atmosphere of distrust and has led to a conflict with Indigenous governments in the NWT. For example, the Tlicho are suing the NWT over the removal of their land and water board and subsequent consolidation into a super board for the Mackenzie region, and have recently received and injunction (Pape Salter Teillet LLP, 2015). As a result, this consolidation is being put on hold. While the super board would not affect the functions of the Inuvialuit Water Board (IWB) because the IWB is not a part of this consolidation, it would affect the Gwich'in Land and Water Board (GLWB), which has jurisdiction over Inuvik, the ISR's largest community. If this change eventually goes through, it would increase the level of interaction between the Inuvialuit and other regional governments and organizations across the NWT.

However, not everything will be affected by the change. For example, the Dominion Water Power Act is not affected by the Devolution Agreement (INAC *et al*., 2013). The IRC and Inuvialuit communities can still seek funding from federal programs because nothing in the Devolution Agreement affects their eligibility (INAC, *et al*., 2013). Despite concerns about devolution, several opportunities have also been identified. For example, the DAAIR considers devolution as being necessary to gaining control of resources, gaining independence and self-determination, and gaining control over resource revenues (GNWT DAAIR, 2011a). Collaboration and cooperation is mentioned as necessary for successful devolution (GNWT, 2012a). This need is stressed in the DAAIR's vision for the next 20-30 years, which included the cooperation between all NWT governments (GNWT DAAIR, 2011a). Because devolution is new (it came into effect over the course of this thesis), how well the GNWT takes on the added responsibilities previously held by the federal government and how well they work with Indigenous governments and organizations, such as the IRC, remains to be seen.

This chapter presented several connections between the various aspects of water security, some specific to the ISR and others more broadly to Canada. The distribution of surface water, groundwater, permafrost, snow and ice vary substantially across the region, as do the impacts associated with climate change and contamination from human activities and natural conditions of the environment. Socio-cultural practices and the physical and mental well-bring of residents is intimately tied to the land. Changes to all types of water in the region can and do impact cultural practices, cultural identity, physical safety, mental and emotional well-being. The interjurisdictional nature of water management and devolution require collaboration and cooperation among multiple stakeholders. It must also address climatic changes affecting the landscape and water resources in the region and include multiple types of knowledge in order to be successful. Infrastructure and industrial activities are greatly affected by changes to water distribution, snow and ice. These in turn impact economic development and human capacity, which are affected by limited funding and other financial barriers, such as the high cost of materials and operations in remote, Arctic locations.

CHAPTER 6: CONCLUSIONS

Through a systematic literature review, this thesis has identified several unique challenges in the ISR in an effort to contribute to developing a more tailored vision of water security that can account for the geographic, socio-cultural, and political context of the region. The thesis had a number of objectives (Chapter 1), which together helped to better understand water use and management across scales, and important considerations for a more refined vision of northern water security.

The first objective was to determine the relevant governing bodies and their responsibilities with respect to water in the ISR. The literature analysis showed that there are 36 governing bodies implicated in water governance at multiple levels of jurisdiction. This included: 8 federal departments and agencies, 5 territorial departments, 15 land claim organizations, and 8 co-management boards. The literature review showed that the greatest level of interaction for water management in the region was between the federal departments and agencies, and the land claim organizations arising from the Inuvialuit Final Agreement, and the subsequent creation of multiple co-management boards (Figure 4.1). Since the completion of the thematic analysis for this thesis, the federal government has officially devolved responsibility for natural resources in the NWT to the GNWT. This shift should result in greater autonomy for the NWT and increased interaction with the ISR organizations. However, since there are federal lands in the ISR, the federal government will still retain many of the responsibilities it currently has to the ISR. This may also increase the level of interaction and cooperation between the federal and territorial departments and organizations which, prior to devolution, had minimal interaction.

The second objective of the thesis was to characterize water use in the ISR. Results from the literature review showed that water is used for a multitude of purposes, including: economic uses, such as industry and development; water management and the delivery of health services; and, socio-cultural uses, such as subsistence activities, recreation, travelling and domestic activities. While development activities require water for daily operations, they were also shown to rely heavily on snow and ice to create infrastructure, such as ice roads, to facilitate annual resupply of materials and access by workers over the winter months. Snow and ice were also central components of water use for socio-cultural activities. Snow and ice are used for travelling and for subsistence activities, such as fishing and hunting. Ice was also noted as an important, informal source of drinking water for many community members in the ISR. In general, the use of snow and ice, along with surface waters, was a unique and fundamental aspect of water use across the region.

The third and final objective of the thesis was to identify the water security challenges unique to the ISR, based on the connections made through the literature analysis. Challenges emerging from the ISR-specific research were compared to those identified by Norman *et al*. (2011) as key drivers of water insecurity in Canada according to water managers and policy-makers across the country. A number of similar and unique challenges to achieving water security in the ISR were thus highlighted through this comparative analysis (Chapter 5). Challenges to water security experienced both at the national scale and in the ISR include:

- water quality issues arising from industrial development and long-range atmospheric transport of contaminants;
- governance complexities reflecting Indigenous land claims and the interjurisdictional nature of water management;

- climate change sensitivities due to the dominance of the cryosphere in landscapes, lifestyles, and livelihoods at these high latitudes; and,
- limited funding and high costs of remote community and development locations.

Many aspects of water security unique to the ISR were also identified, including:

- cultural practices, which include diverse uses of water, snow and ice for travel, subsistence, and cultural continuity, and are embedded in Inuvialuit knowledge and cultural values;
- health and well-being, which are tied to cultural practices, knowledge, and values, and consequently, to broad potential impacts of climate and socio-economic changes;
- ice as infrastructure for industrial development, construction, and transportation; and,
- devolution of decision-making powers from the federal to territorial government, which will have implications for land claims organizations, co-management boards, and relationships with the federal government.

Norman *et al*. (2011) also identified a number of key themes necessary for achieving water security in Canada (Table 2.2). The majority of these themes address Canadian water governance. Many of them were also present in the literature in reference to the ISR, in particular: the coordination of datasets, increased funding for local and regional stewardship projects and better coordination across political jurisdictions. The watershed approach and the holistic approach to water governance were also addressed in the literature. A holistic approach to water governance was consistently emphasized by Canadian water managers as well as throughout the ISR-relevant literature, suggesting the need for more integrated ecological, health, economic and cultural considerations in water management. Cultural and well-being considerations within the ISR were closely tied to water security. However, this was not reflected in the factors to achieve water security outlined by Norman *et al*. (2011).

Better communication between academic research, policy-makers and communities was another key theme identified as important for achieving water security in Canada (Norman *et al*., 2011). This was mentioned as being particularly important in relation to working with rural and First Nations communities (Table 2.2). While it is important to recognize the challenges that First Nations communities face in relation to water security and water governance, it is interesting that the results only refer to First Nations rather than all Indigenous communities. Used in this context, it almost implies that Inuit communities do not have challenges to water security or that Inuit water security challenges are not important at the national scale.

Better monitoring of ecological systems and better coordination of ground and surface waters were others key themes identified by Norman *et al*. (2011). Better coordination of datasets as well as better coordination of ground and surface water systems are fairly similar suggestions. Coordination for ground and surface waters was identified as important in the ISR in some of the management plans. Snow and ice are also important aspects of the water cycle in the ISR that need to be coordinated and monitored in conjunction with ground and surface waters. At present, there is a community-based monitoring program set up for the ISR. Beyond its existence, there is very little publicly available information about the program or its activities. The information provided explains that it is a volunteer-based program. There are some potential issues with volunteer-based systems, such as: inconsistent monitoring techniques, inconsistent data collection/observation and inconsistent types of data collected (e.g. snow pack conditions in one community and lake ice conditions in another). However, it still makes sense for the program to be run through this voluntary approach since monitoring in remote locations is expensive, funding is limited, there are a limited number of people to occupy the positions and there is a large expanse of land to be monitored.

While the above-mentioned suggestions are useful for addressing water governance issues at the national scale, and to some degree in the ISR as well, there are many aspects of water security specific to the ISR that were not addressed in any of the key themes identified for achieving water security in Canada. For example, there were no suggestions on how to deal with: infrastructure and industry-related challenges; changing climatic conditions; or, water quality issues (apart from increased monitoring).

Lastly, with Norman *et al.'s* (2011) list of needs to achieve water security, there was no mention of snow and ice and their importance to the water cycle, and seasonal water use or availability. Snow and ice were shown to be distinct aspects of water security in the ISR as they are the dominant form of water accumulation and storage annually, and have important implications for watershed hydrology. Changes to snow and ice in the region were shown to impact:

- the quality, quantity, flow and location of water resources across the region;
- the ability to participate in subsistence-based activities;
- physical, mental and emotional safety and well-being; and,
- economic stability and industrial development.

Because of their importance, any plan addressing water security in the ISR must also address these important cryospheric considerations. Water management should consider the protection of snow and ice, as well and sources of surface and groundwater, in order to ensure northern water security.

Cook and Bakker (2012) provided a broad definition of water security for Canada (Section 2.3). A definition of water security for the ISR cannot be developed without working directly with ISR communities, Inuvialuit and other Indigenous organizations, government departments and agencies, and co-management boards. However, the systematic literature review and thematic analysis conducted for this thesis provide a strong base for understanding the core challenges of water security unique to the ISR. Therefore, using the available literature is an important first step in developing a more tailored, operational understanding of water security that accounts for the specific geographic, socio-cultural, and political context of the ISR. In moving towards this goal, this would mean:

- Recognizing that the small community sizes and the remote location of the ISR provide limited access to materials and qualified personnel to operate, maintain, distribute and monitor standards of water treatment and distribution;
- Accounting for the complex governance system that has arisen in the ISR from the land claim settlement, including the land claim organizations and the multiple co-management boards, which overlap with Gwich'in territory;
- Addressing the reality of living downstream in a large watershed that encompasses multiple provinces and territories with competing interests, and with limited legal avenues to enforce restrictions on upstream water users outside of the ISR;
- Recognizing the link between cultural practices, water use, snow and ice. As a result, environmental changes have implications for cultural practices, which have an effect on health and well-being;
- Acknowledging that Indigenous peoples comprise the majority of the population, recognizing that TK is culturally important and that its incorporation in policy and management planning and decision-making is required;
- Accounting for the remoteness of the ISR and its limited baseline data, which pose challenges for monitoring and managing water across the region, and render such initiatives more expensive;
- Being aware that water accumulates and is stored as snow and ice for most of the year, and that the impacts of climate change are exacerbated at these high latitudes, affecting all aspects of seasonal water quantity, quality, availability, and watershed hydrology;
- Recognizing that water quality is impacted by industrial development in the North, but much of the concern around water contamination is originates from concerns about long-range atmospheric transport, which is diffuse, difficult to control and impossible to regulate; and,
- Recognizing that, due to the remoteness of the ISR, cold climate and challenging terrain, ice is a critical component of infrastructure that needs to be accounted for because of its facilitation of development activities, economic prosperity, community resupply, and travel between communities.

While the key considerations that emerged from this thesis form an initial foundation for understanding water security in the ISR, to truly arrive at an Inuvialuit-specific definition of water security, future research would need to engage directly with ISR community organizations, residents, co-management boards, and newly established departments in a self-government system. This would involve more participatory methods, such as in-depth interviews, focus groups and community-based participatory research that seeks to learn from Inuvialuit knowledge in conjunction with scientific knowledge. Future research directions could also explore any number of the gaps highlighted throughout the Results and Discussion chapters, including:

- the health disparity between northern Indigenous and non-Indigenous populations;
- the lack of connection between water contamination, bioaccumulation and health, particularly as they relate to mercury;
- the oversight of snow and ice in broader water security considerations; and,
- the lack of focus on the link between water security, environmental changes and mental health and well-being.

Overall, this thesis provided a number of important insights about water security in the ISR, and more broadly, to the Canadian Arctic. The literature analysis also provided a valuable baseline for future research on water security in the North. The systematic literature review method allows for easier comparison with future research, while drawing on the multicausality emphasis in PE allowed for integrated analysis of the many interconnected aspects influencing water security. These approaches are important because the federal responsibilities for water were recently devolved to the territorial government. This work comprised a comprehensive review of the available literature up to the date of transfer of responsibilities. Future research could focus on comparing the key considerations for water security after devolution. Similarly, the Inuvialuit recently signed an Agreement-in-Principle for self-government, which should provide the ISR with more autonomy and decision-making powers. Future research could thus also focus on how implementing an Inuvialuit Self-Government Agreement contributes to water security in the region.

This thesis contributed to water security literature by refining the broader, Canadian concept of water security to include considerations necessary for achieving water security in the North. These key considerations can be used to inform future water management initiatives in a northern context, and can contribute to water policy development in northern and Indigenous populations. These considerations can also help to inform future legislation and regulation development, particularly in the ISR as they move towards greater autonomy through their self-government agreement and the NWT as it continues to take a more active role in water management since devolution.

Appendix A: Literature Search Excel Spreadsheets

Excel spreadsheets of the initial literature search including information about the publications source, publication type, relevant level(s) of governance and relevant water security themes.

Source Information			Publication Type				Level of Governance					Water Security Themes					
Auth.	**Date**	**Database**	**Pub.**	**Acad.**	**3P**	**Grey**	**Fed.**	**Terr.**	**Local**	**Reg.**	**Other**	**Health**	**Env.**	**Soc.**	**Econ.**	**Gov.**	**Cult.**
AANDC	2013	ASTIS	1				1	1				1	1				
Abdul-Aziz and Burn	2006	Scopus		1						1			1				
Andrachuk and Pearce	2010	Scopus		1					1			1	1	1	1		1
Ayles and Snow	2002	Geobase/ Georef		1			1	1					1	1		1	1
AMEC Earth & Environment	2005	ASTIS			1					1			1				
Baki et al	2012	Web of Science		1						1			1				
Beaulieu et al	2011	Geobase/ Georef		1						1			1				

Braune et al	2009	Web of Science		1				1		1		1	1				
BREA	2013		1				1	1			1 (Inuvialuit)		1	1	1		1
Brisco et al	2009	Scopus		1						1			1				
Brock et al	2009	ASTIS		1						1			1				
Burn	1995	Geobase/ Georef		1						1			1				
Calmels et al	2007	Geobase/ Georef		1						1			1				
Canada Newswire	2007	CBCA Complete				1				1			1		1		
Carrie et al	2010	Scoppus		1					1				1				
Carrizo and Gustafsson	2011	Scopus		1						1			1				
Carron et al	2008	Geobase/ Georef		1						1			1		1		
Careau and Dewailly	1995	Geobase/ Georef		1						1			1				
Cott	2005	ASTIS	1				1	1					1			1	

et al																	
Cott et al	2008	Geobase/ Georef		1				1					1				
Coulombe-Pontbriand et al	1998		1				1					1	1				
Council of the Federation	2010		1				1	1								1	
De Rosemond and Liber	2004	Scopus		1					1				1				
Derkson et al	2012	Web of Science		1						1			1				
DiFrancesco	2000	Scocial Sciences Full text		1				1					1	1	1	1	1
Downing and Cuerrier	2011	ASTIS		1						1		1	1	1			1
Droppo et al	1998	Web of Science		1						1		1	1				

Dugan and Lamoureux	2010	ASTIS		1 (Thesis)					1				1		1		
Dugan et al	2012	Web of Science		1					1				1				
EISC	2004	ASTIS	1					1					1			1	
Earth Tech Inc.	2008				1				1			1	1		1		
Emmerton et al	2007	Scopus		1						1			1				
Ensom et al	2012	Geobase/ Georef		1						1			1				
Evans et al	2005	Web of Science		1						1		1	1	1	1		1
Fassnacht	2000	Geobase/ Georef		1						1			1				
Ford et al	2010	ASTIS		1						1		1		1		1	1
Fresque-Baxter	2013	ASTIS		1					1				1	1			1
Frey and McClelland	2009	Web of SCience		1						1			1				

Furgal and Seguin	2006	ASTIS		1					1	1			1				
Furgal and Prowse	2008	ASTIS		1						1		1	1		1		
Gantner 2014	2014	ASTIS		1						1			1				
Gibson et al	1998	Web of Science		1					1			1	1		1		
GNWT	N/D		1							1		1			1	1	1
GNWT	1998		1					1								1	
GNWT	1998		1					1					1			1	
GNWT	2005		1					1								1	1
GNWT	2007		1				1	1								1	
GNWT	2007		1					1								1	
GNWT	2011	ASTIS	1					1					1	1			
GNWT	N/A		1					1								1	
GNWT	2012		1					1								1	
GNWT	2009	ASTIS	1					1					1			1	1
GNWT	2010		1					1					1			1	

GNWT	2014		1					1					1			1	
GNWT	2012		1					1					1			1	
GNWT	2014		1					1								1	
GNWT	2012	ASTIS	1					1					1		1	1	
GNWT	2007	ASTIS	1					1				1	1	1			
GNWT	2013		1					1								1	
GNWT	N/A		1					1								1	
GNWT	2011		1					1					1			1	
GNWT	2008		1					1					1		1	1	1
GNWT	2010	ASTIS	1					1						1		1	1
GNWT	2014		1					1					1			1	
GNWT DAAIR	2007		1					1							1	1	
GNWT DAAIR	2011		1					1				1	1	1	1	1	1
GNWT DAAIR	2011		1					1								1	
GNWT	2011		1					1					1			1	

DAAIR																	
GNWT ENR	2011		1						1				1	1			1
GNWT ENR	2012a		1					1					1			1	
GNWT ENR	2012b		1					1					1	1			
GNWT ENR	2013		1					1					1			1	
GNWT HSS	2009		1					1				1	1			1	
GNWT HSS	2011		1					1				1	1			1	
GNWT MCA	2004		1					1							1	1	
GNWT MCA	2012		1					1							1	1	
Gordon Foundation	2011	ASTIS			1					1			1			1	
Goulding et al	2009	Scopus		1						1			1				

Government of Canada/GNWT	1987		1				1	1					1			1	
Government of Canada/GNWT	2011	ASTIS	1					1					1			1	
Government of Canada/GNWT	2011	ASTIS	1					1					1			1	
Graydon et al	2009	Scopus		1						1			1				
Grimwood and Doubleday	2013	ASTIS		1						1				1		1	1
Haertling	1989	Geobase/ Georef		1					1				1				
Halliwell and Cato	2003	ASTIS		1						1			1				
Hill et al	2008	ASTIS		1			1	1								1	

Hodgson and Young	2001	Web of Science		1					1				1				
ILA			1							1			1	1	1	1	
INAC	1997	ASTIS	1				1	1								1	
INAC	1997	ASTIS	1				1	1								1	
INAC	1997	ASTIS	1				1	1								1	
INAC	2003	ASTIS	1					1					1			1	
INAC	2006	ASTIS	1				1	1								1	
INAC	2010		1					1					1			1	
IRC	2009		1					1		1						1	
Iwakun et al	2012	Geobase/ Georef		1					1			1	1				
Kapoor et al	2004	Scopus		1							1		1				
Kokelj and Burn	2003	ASTIS		1					1				1				
Kokelj et al	2005	Geobase/ Georef		1						1		1	1				
Kokelj et al	2012	Geobase/ Georef		1						1			1	1			1
Laird et al	2013	Web of Science		1						1			1				
Leake et al	2008	Web of Science		1					1			1					

Leitch et al	2007	Scopus		1						1			1				
Leroux et al	2007	Scopus		1						1			1				
Lesack and Marsh	2010	ASTIS		1						1			1				
Lesack et al	2014	ASTIS		1					1				1				
Marsh and Hey	1994	Geobase/ Georef		1						1			1				
Marsh et al 2009	2009	ASTIS		1						1			1				
Macleod Institute	2002	ASTIS			1			1								1	
Milburn et al	1994	ASTIS	1					1					1		1		
Millot et al	2003	Geobase/ Georef		1						1			1				
Mishra and Coulibaly	2010	Web of Science		1				1					1			1	
Mouchot et al	1991	Geobase/ Georef		1						1			1				

Newton et al	2014a	Scopus		1						1			1				
Newton et al	2014b	Scopus		1						1			1				
Nuttall	2010	ASTIS		1	1					1			1		1	1	
Ortega-Retuerta et al	2013	Scopus		1						1			1				
Papik et al	2003	ASTIS	1							1			1	1			1
Pearce et al	2010a	ASTIS		1					1			1	1	1			1
Pearce et al	2010b	ASTIS		1						1		1	1	1	1		1
Pearce et al	2012	Google Scholar		1					1			1	1	1	1		1
Phillips and Grosewa	1977	ASTIS		1					1				1				
Pienitz et al	1995	Geobase/ Georef		1						1			1				
Pohl et al	2009	Scopus		1					1				1				
Prowse et al	2009	ASTIS		1						1		1	1		1		

Quinton and Pomeroy	2006	Geobase/ Georef		1					1				1				
Quinton et al	2009	Geobase/ Georef		1					1				1				
Quinton et al	2011	Web of Science		1					1				1				
Reedyk et al	1995	Geobase/ Georef		1					1				1				
Reid and Faria	2004	Geobase/ Georef		1						1			1				
Ritter	2007	Geobase/ Georef		1						1		1	1			1	
Rollo and Jamieson	2006	Geobase/ Georef		1					1				1				
Rosenberg International Forum on Water Policy	2009	ASTIS		1	1			1		1			1	1	1	1	1
Schindler and Smol	2006	Web of Science		1						1		1	1	1			

SENES Consultants	2005	ASTIS			1			1					1	1	1	1	1
SENES Consultants	2011	ASTIS			1			1					1	1	1	1	1
Spence	2002	Geobase/ Georef		1						1			1				
Stanley	1965	ASTIS		1						1		1	1			1	
Stadnyk et al	2005	Geobase/ Georef		1						1			1				
St. Amour et al	2005	Web of Science		1						1			1				
Stevens and Wolfe	2012	Scopus		1					1				1				
Szeto et al	2007	Scopus		1						1			1				
Taiga Environmental Laboratory	2006	ASTIS	1					1					1			1	
Thienpont et al	2012	Web of Science		1						1			1				

Thienpont et al	2013	Web of Science		1						1		1	1		1		
Todd et al	2014	Web of Science		1						1		1	1				
Town of Inuvik	2010		1						1				1	1	1	1	1
Utting et al	2013	Geobase/ Georef		1						1			1				
Vaux Jr.	2010	Geobase/ Georef		1				1		1			1		1	1	
Wenzel	2009	ASTIS		1						1			1			1	1
White et al	2007	ASTIS		1						1			1				
Williams et al	2013	Geobase/ Georef		1					1				1				
Wilson and Cheema	1989	SCopus		1				1					1			1	
Woo and Thorne	2003	Geobase/ Georef		1						1			1				
Wootton et al	2008				1					1			1	1	1	1	1
Wootton and Yates	2010	ASTIS	1						1			1	1				

Wright et al	2008	Geobase/ Georef		1					1				1				
Yeung et al	2013	Geobase/ Georef		1					1			1	1				
			55	**91**	**9**	**1**	**12**	**60**	**30**	**68**	**1**	**28**	**129**	**26**	**29**	**64**	**26**

Appendix B: Contaminant Guidelines for the Northwest Territories

Guidelines for Contaminants in the NWT. Table contains a general summary of the information about the potential contaminants and guidelines for drinking water that can be found in the GNWT HSS Drinking Water Report (Adapted from GNWT HSS, 2011, pp. 14-17).

COMPONENTS	DESCRIPTION	AESTHETIC OBJECTIVE	MINIMUM ALLOWABLE CONCENTRATION
Contaminants			
Aluminum	No guideline available, number provided applies only to water treatment plants using aluminum-based coagulants.	n/a	n/a
Barium	Trace element in igneous and sedimentary rocks.	n/a	1.0 mg/L
Cadmium	Guideline established based on health considerations	n/a	0.005 mg/L
Chloride	Widely distributed in nature. Several sources of chloride, both natural and not. Generally present in low concentrations in surface waters.	250 mg/L	n/a
Chromium	Guideline based on health considerations. Some forms are found in nature and are essential for health (e.g. trivalent chromium). Considered non-toxic but if found in raw water, may be oxidized during chlorination.	n/a	0.05 mg/L
Copper	Not a health concern, essential for human metabolism. Occurs in nature in minerals.	≤1.0 mg/L	n/a
Cyanide	Toxic to humans, can result from waste effluents from organic chemicals and various industries (e.g. gold mining).	n/a	0.2 mg/L
Fluoride	Can occur naturally in surface and groundwaters from leaching of rocks or plant and animal tissues. Added to drinking water to prevent dental cavities.	n/a	1.5 mg/L
Iron	Not a health concern. Naturally occurring but can also come from mining/industry.	<0.3 mg/L	n/a
Lead	Guideline set for health concerns. Leah is present in some plumbing systems, amount dissolved depends on acidity/softness and standing time of water.	n/a	0.01 mg/L
Manganese	Not a health concern but its presence could lead to an increase in microbial growth.	0.05 mg/L	n/a

Mercury	Toxic to humans. Main source of concern is bioaccumulation in aquatic and terrestrial biota. Can cause neurological symptoms.	n/a	0.001 mg/L
Nitrate	Not a health concern.	n/a	45 mg/L
Selenium	Guideline based on health considerations. Not considered a contaminant of concern in the NWT.	n/a	0.01 mg/L
Sodium	Not related to health concerns. Not considered a toxic element. Taste of water can be considered offensive in high concentrations.	≤200 mg/L	n/a
Total Coliforms	Most are harmless, some are not. Easily treated with chlorine. Presence in drinking water can be an indication of an inefficient or malfunctioning water treatment/distribution system.	n/a	n/a
Sulphate	Aesthetic objective is based on taste considerations. Not of great concern but can cause physiological effects in high concentrations.	≤500 mg/L	n/a
Uranium	Guideline based on health considerations. Considered to be toxic. Can come from both natural sources (leaching) and industry (mill tailings, emissions from nuclear industry, coal and other fuel combustions).	n/a	0.02 mg/L
Zinc	Considered non-toxic. Not of concern in the NWT. Important element for nutrition.	5.0 mg/L	n/a
Properties			
Colour	Not directly related to health but can indicate the presence of some metals. May lead people to turn to alternative sources that could be unsafe.	15 TCU (total colour units) or less	n/a
Pathogens	Micro-organisms that cause disease.	n/a	n/a
pH	Water that is too acidic (↓6.5) can cause corrosion in pipes while water that is too basic (↑ 8.5) can result in scaling and incrustation problems. An increase in pH also reduces the efficiency of the chlorine disinfectant process.	n/a	n/a

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