INDIGENOUS WATER CHALLENGES
AND CANADIAN POLICY:
CONNECTIONS ACROSS A
WATERSHED MANAGEMENT SYSTEM

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By

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This thesis was given permission to use data measured by a Nutrient Smartphone App developed by the Global Institute of Water Security at the University of Saskatchewan, nutrient measurements gathered through laboratory methods by Helen Baulch, Katy Nugent, and Cameron Hoggarth, and measurements gathered in 2019 by Myron Neapetung. Information and statements from interviews, gathered by myself, with participating Indigenous community members and Watershed Agents was also permitted. Permission was given for the use of interviews transcripts with Indigenous community members by Lalita Bharadwaj, Lori Bradford, and Kurt Belcher.

TREATY AND LAND ACKNOWLEDGEMENT

I acknowledge that the research conducted here, and study sites are on Treaty 4, 5, and 6 lands, the original lands of the Cree, Swampy Cree, Ojibwe, Saulteaux, Dakota, Nakota, Lakota, and Homeland of the Métis Nation. This research project was conducted in a reflexive and respectful manner, including sharing knowledge and expertise from all those who participated while upholding the values and practices of reconciliation.

POSITIONALITY

I am a woman with a university education who is a descendent of mixed Caucasian heritage, and I recognize that I have potential bias while conducting this research project. I have made efforts to prevent any bias from affecting my research quality and will continue to do so by seeking mentorship from Indigenous partners. My efforts involved taking Indigenous studies courses, communicating with community members in discussions and sharing circles, searching for and using peer-review articles written by authors with diverse backgrounds, participating in Indigenous conferences, and meaningfully involving Indigenous participants in the gathering and interpreting data within this research project to the extent that they request.

ABSTRACT

Approaches for managing water across landscapes that include Indigenous reserve land in Canada involve federal and provincial government competition, and authority hierarchies, leading to cross-jurisdictional conflict and a lack of accountability or action. For decades, the shared monitoring and collaboration in watershed management in regions that includes Indigenous lands have been lower than in other Canadian regions. The lower quality and minimal responsivity to water issues impacts community health, cultural sustainability, and financial stability in reserve communities, putting them at risk of experiencing difficulties retaining cultural practices and traditional lifestyles. Despite previous financial investments made by the Canadian government, many Indigenous communities continue to experience water challenges, including floods and drought, and surface water quality challenges such as algae blooms. As this, and other studies are demonstrating, the unbalanced power dynamics in the Canadian watershed management system have been influenced by the significant lack of interaction among individuals with different perspectives, categorizable through the 'ways of life' in Cultural Theory. The 'ways of life' (or perspective groups) in Cultural Theory provide a framework for how individuals of various views interact and how those interactions influence the quality of political, social, and environmental collaboration. This research project takes an interdisciplinary approach to investigate the environmental, social, and political components of watershed management problems in Prairie-based Treaty Areas 4, 5 and 6. I sought to identify barriers to effective watershed management using mixed methodologies and engaged scholarship framed by Cultural Theory, and provide recommendations for improving watershed management for Indigenous communities.

This thesis consists of three studies in the context of watershed management: monitoring of freshwater nutrient concentrations, cataloguing of toxic cyanobacterial development, and reviewing of policies affecting Indigenous watershed management alongside interviews of the perceptions of the policies. It is important to note that while I studied these three watershed management problems, the overall thesis focused on human behaviour in watershed management as the unit of analysis. Multiple qualitative and quantitative methods for data collection and analysis were conducted. Results show that despite previous efforts by the Federal Government, there remain weaknesses in how watershed management in undertaken in

regions with Indigenous reserve communities. Some common weaknesses include a lack of community involvement and knowledge-sharing, lack of or little capacity-building experienced by Indigenous communities and watershed agencies, and barriers faced from the rigid framework of the management systems. I found that select water policies suffer from weak enforcement and accountability, poorer or underdeveloped quality standards, and few inclusions of Indigenous knowledge systems. Policies did not account for the cultural, geographic, economic, and societal differences that can impact water management and desired management in Indigenous reserve communities. Policies designed by Indigenous authorities were found to be the most effective in maintaining watershed quality by providing detailed information about water values, protection, management, and enforcement protocols while respecting the rights of Indigenous Peoples, as well as their knowledge, and cultural practices.

The data I collected for more biological-based studies (Chapters 2 & 3) found weak correlations between established theories and western measurement approaches: precipitation patterns, nutrient concentrations, and cyanobacterial growth. These results emphasize that previous water quality monitoring methods may no longer be viable, and continuous place-based monitoring of nutrients and cyanobacteria within and outside reserve boundaries in watersheds is necessary as a preventative method to reduce potential health threats. With some suggested improvements, community science methods can be used to alleviate capacity issues and provide an opportunity for collaboration and knowledge-sharing among participating groups in a watershed. For watershed management to improve in watersheds with Indigenous communities, there should be more effort on recognizing when all Cultural Theory Ways of Organizing are represented in collaboration across watershed stakeholders and rights-holders. Canadian watershed management needs to shift from a rigid hierarchical structure to an inclusive adaptive one embracing multiple ways of organizing to better manage changing environmental and social conditions.

ACKNOWLEDGEMENTS

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KEYWORDS AND ACRONYMS

Asota – to make a promise in Nehiyawak (Plains Cree). Attribution: 2018-2019 SENS Indigenous Mentor, Anthony Blair Dreaver Johnston.

BMP – best management practice

BWA – boil water advisory

cHABs – cyanobacterial harmful algal blooms

Collaboration – a method of working together to complete a task or achieve a goal

Cultural Theory – a branch of comparative anthropology and social science that seeks to understand the relationships between individuals, environments, institutions, and everyday activities in operational and/or scientific terms

Cyanobacteria – blue-green bacteria (or algae) that are either unicellular or filamentous phototrophic aquatic organisms; the only organisms that can fix both carbon dioxide and nitrogen; several species are the cause of water pollution and can produce cyanotoxins

Cyanotoxins – toxic secondary metabolites produced by blue-green algae (cyanobacteria) that can poison and kill humans and animals; found in lakes and oceans of high phosphorus input and algal growth

Decentralized governance – a system of management that is controlled by several local offices or authorities rather than one

Eutrophication – a process whereby a body of water receives excess nutrients that induce algae growth; the process may result in oxygen depletion in a water body owing to frequent growth of algal blooms

DWA – drinking water advisory

Economies of scale – in this thesis, defined as the partitioning and allocation of fees to individual households to maintain a set level of funding based on the number of individuals involved, to help with a system's maintenance and operation

Governance – a system of methods (ethics, risk management, administration, and compliance) that is used to manage an organization or industry, including the practices and people within it, to how it operates and how those in it are held accountable

HABs – harmful algal blooms

INAC – Indigenous and Northern Affairs Canada

Indigenous – includes all people of First Nations, Inuit, and Métis heritage

Indigenous Knowledge – a set of perceptions, information, and behaviours that guide local communities in terms of how best to manage and use their natural resources and is passed down through generations

Indigenous Reserves – geographically-specified land for the exclusive use of First Nations, specified in the Indian Act, a piece of legislation enacted by the Canadian Crown

Management – methods and procedures that a management or executive team takes to oversee and allocate the necessary resources for daily operations of an organization

MOU – Memorandum of Understanding; an agreement between two or more parties as an expression of aligned will that indicates a common goal

Nutrient-cycling –the movement of nutrient elements through natural biological and hydrogeological processes

Nutrient Management – the science and practice of studying, monitoring, and controlling nutrient pathways and potential interactions of nutrient loading in the natural environment

Policy – structured framework for decision-making that can take the form of a law, regulation, procedure, incentive, administration action, or a voluntary practice

Sustainability – meeting our own needs without compromising the ability of future generations to meet their own needs; includes natural resources, social equity, and economic development

SWP – source water protection

SWPP – source water protection plan

UNDRIP – United Nations Declaration on the Rights of Indigenous Peoples

Watershed management – the study of the relevant characteristics of a watershed aimed at the sustainable distribution of its resources and the process of creating and implementing plans, programs, and projects to sustain and enhance watershed functions that affect the plant, animal, and human communities within the watershed boundary

Water Security – the reliable availability of acceptable water quantity and quality to sustain health, production, and life

CHAPTER 1: THE SUSTAINABILY OF CANADIAN WATERSHED MANAGEMENT

Sustainability is the process of fulfilling our present needs without compromising the ability of future generations from meeting their own needs (Brundtland, 1987). The concept of sustainability often considers three key, interconnecting components: the environment, social interactions, and economic development (Purvis et al., 2019; Figure 1.1). A balance between

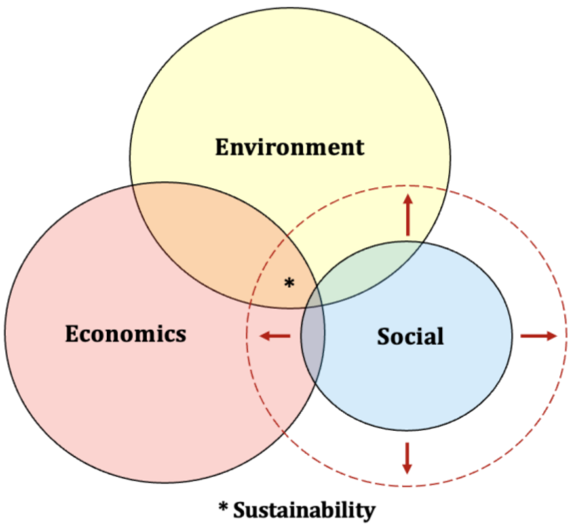

Figure 1.1: Venn Diagram of Sustainability.
This Venn Diagram presents the components to Sustainability adapted from You (2015). This diagram shows the social component as underdeveloped. Chapter 2 will discuss the connections between environment and economic pillars; Chapter 3 will discuss the connections between social and environment; and Chapter 4 will build up the social component to help balance the knowledge set for better sustainable watershed management.

these components is meant to create healthy and thriving communities that are diverse and remain resilient to extraction and other destabilizing forces on a resource. Academic research and literature have placed greater focus on the environmental and economic components than social, creating an unbalanced knowledge set on sustainability of various subjects (You, 2015). This thesis is meant to study the sustainability of Canadian watershed management by focusing on these individual sustainability pillars, where they overlap, and how different groups interact to gain an enhanced understanding of the areas of success and failure and the impacts they have on Canadians. This is of particular importance to many Indigenous communities who continue to struggle with watershed management challenges and barriers to resolving long-standing resource issues.

Twenty percent of the global freshwater reserves are in Canada, and the country is currently fourth in the world for drinking water quality in economically developed countries (Shrubsole et al., 2016). Most people in Canada have easy access to a water source (lake, river, or reservoir), but this does not reflect the complete picture of communities across the Canadian watershed landscape. For example, industrial operations and agricultural growth are contributing to worsening surface water quality in source waters (Westman & Joly, 2019; Shrestha & Wang, 2020). Political boundaries are also not respected by natural flows of water across the landscape; thus, jurisdictional issues arise about holding polluters accountable (Dunn et al., 2017). Worsening water quality has been associated with surrounding economic activities and a rapidly changing climate across the Canadian landscape (Hosseini et al., 2017; Weber & Cutlac, 2017), with water quality on the Canadian Prairies being more susceptible to agricultural activities. Hogeboom states, "Freshwater is a finite and vulnerable resource, essential for the conservation of life, maintenance of development and the environment" (2020, pg. 218). This quote emphasizes the need to protect essential water resources for the sake of preserving human survival, protecting sensitive ecosystems, retaining our quality of living standards, and preserving traditional identity and cultural practices of Indigenous Peoples.

Canada is a world leader of natural resource extraction (i.e., mining, oil reserves, forestry) and agricultural production, the majority of which are exported globally (Brooks & Kurtz, 2016). With an increasing global population, there is a parallel increase in demand for these resources, placing more pressure on the environments they are extracted from, often making them susceptible to further (and possibly irreversible) damage (Brisbois et al., 2019). Freshwater ecosystems are relatively stable and self-maintaining but only to a certain threshold (Wagenhoff et al., 2017). If that threshold is exceeded, the overall quality of the water and the health of the ecosystem will decline and impact those who rely on it. These aquatic ecosystems are often sensitive to excessive nutrient concentrations introduced by natural hydrologic cycles (Dodds & Whiles, 2010). In Canada, contaminants entering water systems have been a concern for a long time, especially in water meant for domestic and recreational use (Hossain et al., 2012; Warren et al., 2003).

1.1 Nutrients as Contaminants for Freshwater Sources

When we think of contaminants in water, we often think of inorganic chemicals, untreated sewage, garbage, and water-borne disease-causing organisms. Nutrient inputs are different from the traditional concept of contaminants in water. Nutrients that enter water systems, like phosphates, nitrates, and other compounds, can be naturally occurring and do not necessarily threaten consumers or ecosystems immediately (Smith & Schindler, 2009; Mekonnen et al., 2017). When these nutrients are within a certain concentration range, freshwater ecosystems may be healthy, but, with increasing economic activity and a changing climate, current nutrient loading can exceed what freshwater systems can handle, leading to ecological imbalances (Costa et al., 2020b; Marton et al., 2015; discussed in Chapter 2). Over the last half century, there has been an increase in cyanotoxin producing blooms due to excessive nutrient inputs, often seen in water systems surrounded by agricultural lands (Paerl and Paul, 2011; Kling et al., 2011; McKindles et al., 2019). Should nutrient input continue to stay above natural levels, cyanobacteria will continue to outcompete other algal species (Bogard et al., 2020; Sukenik et al., 2012; WHO, 2015).

At surface water recreational sites, water advisories are implemented due to harmful algal blooms (HABs) and cyanotoxin release, leaving the water unfit to drink or use for recreational purposes like bathing or washing (Patrick 2018; discussed in Chapter 3). Access to clean drinking water is a human right (UN General Assembly, 2010) and plays a role in the health, spirituality, and traditional ceremonies in Indigenous culture (Anderson et al., 2013). Not having accessibility to water for ceremonial and other purposes as non-Indigenous populations is both discriminatory and harmful to Indigenous identity (Hanrahan, 2017). Affected Indigenous communities continue to feel the effects of toxic algae within their water, such as persistent cases of illness, and limitations to recreation or traditional practices important to spiritual and cultural identity. There are also indirect impacts on communities through contaminated fish and animals meant for food and ceremony (Drobac et al., 2016). One of the most significant impacts this issue has on these communities is the harm it has put on the overall health of residents, including their emotional, mental, cultural, and spiritual health. Additionally, the persistence of water challenges on Indigenous lands has allowed for continued distrust in colonial management systems that often exclude Indigenous involvement and do not incorporate Indigenous traditions or knowledge into policy or design of solutions (discussed further in Chapter 4).

1.2 Cultural theory in Context of Watershed Management

Watershed management is a context where people who rely on the same land and water resources compete for access and use of that resource. While the watershed represents the physical area, the management aspect involves people, as individuals and representative groups, making decisions, together, about the physical area and its water. Frameworks for individual and group behaviour towards improved social sustainability can be helpful to understand how complex social actors including individuals and groups interact and work together to overcome problems, like deciding how to manage a watershed (Faber et al., 2010; Missimer et al., 2017). Some of the more commonly used frameworks to describe social actors and interactions in sustainability problems include: social capital and adaptive capacity (Plummer & FitzGibbon, 2006; Plummer & Armitage, 2010); social-ecological systems (Ostrom, 2007; Ostrom & Michael, 2010); hegemony and in the case of water, hydro-hegemony (Goodman & Salleh, 2013; Zeitoun &Warner, 2006); wicked problems (Rittel & Webber, 1973; Head, 2008; Jentoft & Ratana, 2009); and panarchy (Walker et al., 2004; Berkes & Ross, 2016).

In contrast to the theories mentioned above, which focus on the dynamics of a problem, the application of the Institutional Dynamics of Culture (Thompson, 2008), also known as Cultural Theory (CT), helps us to better understand the differences in perspectives among people; that is, the individuals and institutions, and how those differences can create both barriers and solutions to challenges in Canadian watershed management (Kiss et al., 2020). In CT, researchers posit that our perspectives evolve from our involvement with other individuals and groups; that is, our perspectives derive from our social interactions and experiences gained over the course of our lives. No two people will ever have the same set of social interactions and experiences, making our perspectives as unique as our DNA. It is important to note that CT is a way to categorize, and ways of life are not a trait of the individual; thus, a person’s perceptions can be different for different subject matters and can place them in more than one category simultaneously. The perspectives among a set of individuals may have some patterns suggesting similarity, which is how CT is able to categorize them into more simplified groups, based on the ways they live their lives and make decisions. Within CT, there are “Fives Ways of Life” (Dake

& Thompson, 1999): Hierarchy, Individualism, Egalitarianism, Fatalism, and Autonomy (Figure 1.2). These five categories are organized based on the degree of perception on power relations and competition within a subject matter. A person can be placed in different categories for different subjects or be a mix of categories due to the unique nature of individual perspectives or due to external factors, such as economic and environmental limitations. Further details on CT are discussed in Chapter 5. The most important point CT presents is that, as individuals, we all have differences in perspectives, knowledge, and experiences; thus, collaboration amongst people from each category is needed to gather multiple perspective for a holistic understanding of the problem, and thereby develop comprehensive and effective solutions.

We can also extend CT thinking and framing to how groups operate. Institutions can ascribe to certain 'ways of life' including making decisions in more hierarchical, egalitarian, or other ways. For complex problems involving multiple players - individuals, organizations, agencies, government bodies, interests' groups, and others - the best solutions, according to CT, emerge from the clumsy combination of ideas and offerings to satisfy the needs of the majority and provide an alternative benefit to the rest (Verweij et al., 2006; Ney & Verweij, 2015).

Watershed management systems in place in Canada have remained static for multiple decades, despite calls by citizens and researchers for evolution in the ways watersheds are managed (Shrubsole et al., 2016; Bakker, 2011). Like sustainability, watershed management involves environmental, societal, political, and economic components, and the overlapping areas between them; to treat each one as a separate part instead of understanding the connections between them is where issues arise (Lubell et al., 2009). Cultural Theory is a suitable framework to clarify the social drivers that influence the efficiency of Canadian watershed management, and the continuation of watershed management challenges experienced by Indigenous reserve communities. This theory emphasizes the necessity for individuals from each CT perspective category to be involved to achieve a solution that aids adaptation and survival in unexpected and new situations (Offermans, 2010).

Canadian watershed management is complex, with multiple jurisdictions involved in governance (deciding on and adapting governing policies) and management (enacting and policing those policies), and multiple groups carrying out on-the-ground activities towards their objectives, whether it is to increase crop yields while protecting sacred waterbodies and public safety from overland floods. Understanding how the perceptions of watershed management of individuals were developed by their unique set of knowledge, experiences, and backgrounds is key to understanding how a new system of watershed management can emerge which offers fair political power dynamics and overcomes current limitations in management policies (Figure 1.2). Bringing together people whose values and views on making ends meet within these perception categories may result in conflict; partly because their objectives may be at odds, but also because their ways of life can counteract (Robins, 2007; Karen, 2005). But these collisions are desired in CT, because they lead to the creation of a balance among the perspective groups. No single voice goes unheard.

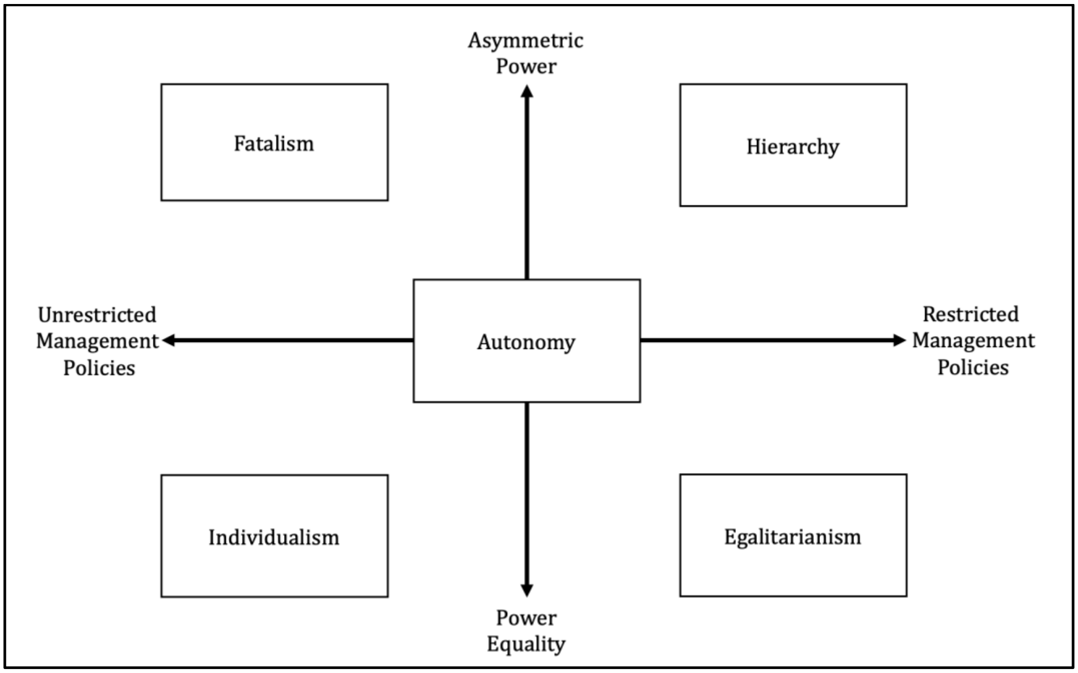

Figure 1.2: Cultural Theory's Five Categories of Social Solidarity and Perspectives in Watershed Management.
This image strategically organizes the five forms of solidarity and personal perspectives regarding select topics, particularly topics that involve making ends meet (Dake & Thompson, 1999). Each category is situated based on their agreeance on degree of competition (x-axis) and degree of shared power (y-axis).

Researchers agree that jurisdictional barriers, lack of accountability and responsibility, and insufficient collaborative practices in Canadian watershed management strategies are why watershed management issues persist, especially in contexts where Indigenous issues are central (Senecal & Madramootoo, 2005; Cuvelier & Greenfield, 2017). This is despite past financial support put in place to improve conditions and remove risks to affected communities (Alcantara et al. 2020; Bradford et al., 2018; Arsenault at al., 2018). Simply providing financial resources has not been enough to resolve watershed management challenges; a different means of action is necessary (Baijius & Patrick, 2019).

Some researchers suggest that establishing meaningful engagement and relationship building with individual Indigenous communities in watersheds is needed to: 1) prioritize their needs, 2) invite community participation in the watershed management discussions and project planning, and 3) provide public awareness and community-based monitoring programs to improve conditions (Simms et al., 2016). There should be greater effort to change unsuccessful methods into flexible solutions capable of withstanding changing conditions, and stronger partnerships between diverse stakeholders, knowledge-keepers, and governments involved in watershed management. Examining not just diversity among watershed management actors, but also the ways in which they enact decisions, build new policy, and monitor and manage watersheds is an ideal objective for researchers and policymakers to gather more insights for enhancing social sustainability of watershed management in Canada.

In this thesis, I will use the framing of CT to expose aspects of Treaty Areas 4, 5 and 6 watershed planning processes and practices where there is a lack of multiple perspective input included in management, resulting in impacts to the watershed and the social sustainability of Indigenous communities within it. In each of the following chapter prefaces, fictitious scenarios will provide context for how CT's 'way of life' categories interact in watershed management, mainly directed to the chapter's study focus, and how they influence the overall dynamics of sustainable watershed management. The synthesis-based use of CT will begin in Chapter 4 where results are presented from an environmental scan of agencies involved and their current practices, as well as interviews with watershed managers and Indigenous community members who share insights on the social dynamics at play in watershed management.

1.3 The Objectives of this Case Study Approach: Concurrent Multi-method Examination of Watershed Management in Three Treaty Areas in the Prairies.

This project emerged from Indigenous community-driven questions in 2018-2019, within professional relationships maintained over ten years by my committee members and supervisors through collaborative water quality and quantity projects. Faculty members from the University of Saskatchewan's School of Environment and Sustainability, School of Public Health, and Department of Community Health and Epidemiology worked together to propose this project to Environment Climate Change Canada with the reserve communities of James Smith Cree Nation (JSCN); Yellow Quill First Nation (YQFN); and the Northern Village of Cumberland House (NVCH), Cumberland House Cree Nation (CHCN), and Métis Local #42 (ML42). Research agreements were in place with the Cumberland House communities, while MOUs and *Asota's* were established with YQFN and JSCN. These communities were interested in knowing more about nutrients in their waterbodies and mitigating algal bloom frequency and dispersion in waterways in their traditional territories, home to diverse peoples who experienced various blooms in the past. Community leadership expressed to the university researchers that the algae blooms they are currently experiencing are different from those in oral histories and community records. The communities noticed that the blooms were worsening over time, which adds further argument for continued collaboration with communities on monitoring, project planning, and policy discussions. This collaboration in framing the research questions led to a grant application to Environment Climate Change Canada's Lake Winnipeg Basin Program who ultimately funded this work.

The overall collaborative study covered a broad range of information; for this particular thesis work, it was decided to examine three elements: nutrient concentrations in local water systems (Chapter 2), algal bloom growth, bloom composition, and the degree of cyanobacteria dominance (Chapter 3), and a review of water policies impacting watershed management with a focus on inclusion of Treaty Rights and local Indigenous communities framed using CT (Chapter 4). The connections between each area of study, and the overall interpretations, recommendations, and limitations of this work are discussed in Chapter 5.

1.4 Research Purpose and Objectives

The purpose of this research project is to gain a holistic understanding of the interconnections between the pillars of sustainability in Canadian Watershed Management to determine whether current watershed management practices and policies are meeting Indigenous community-based values of water as sacred, and a life-giving force, and whether protection of local waters in and around Indigenous-owned lands through the enhancement of social sustainability in prairie watersheds could be viable. This research project measured nutrient concentrations and algal growth in water systems that flowed through three participating Indigenous Reserves in Saskatchewan. This research also determined if watershed management policies and practices included Indigenous participation, acknowledged Indigenous knowledge systems,

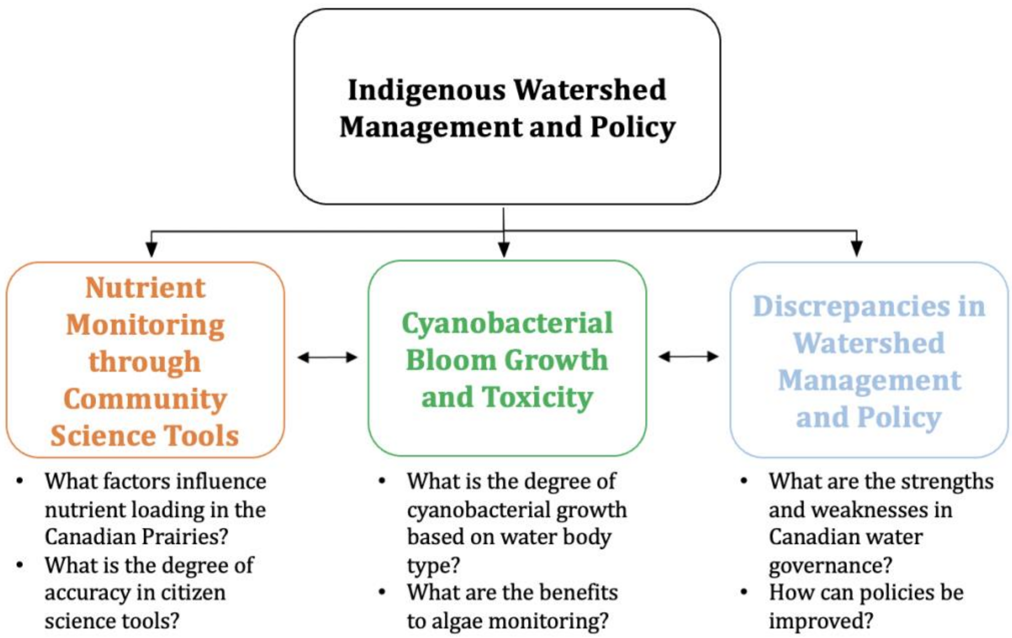

Figure 1.3: Thesis Research Project Flow Chart.

Chapter Two will discuss the environmental and economic components to sustainability and the interconnections regarding Indigenous drinking water challenges and will focus on the beneficial use of community science tools for effective nutrient monitoring (in orange). Chapter Three will discuss the environmental and social components and will focus on cyanobacterial growth in drinking water resources used by participating Indigenous communities and the impacts on community health and culture (in green). Chapter Four will build on the social component and will focus on Canadian water policies, their strengths and weaknesses, and areas in need of improvement (in blue).

traditions, and history, and whether there were appropriate methods in place for mitigating threats to watershed management (Figure 1.3)

Since this research explores a subject with many interconnections, mirroring Indigenous knowledge systems which emphasize interconnections, an interdisciplinary, mixed-methods approach co-designed with community leadership was employed to reach the project's four main objectives. This research aimed to:

1. Find drivers to nutrient loading to surface waters in and near Indigenous reserves.
2. Identify the gaps in watershed management for Indigenous engagement.
3. Examine existing documentation on Canadian watershed management policies for areas of success or improvement and provide suggestions to ameliorate current weaknesses.
4. Build on the social component in the sustainability of Canadian watershed management practices to align with Indigenous watershed management.

1.5 Multi-method Approach of Data Collection and Analysis

Inspired by the communities' holistic knowledge system, and driven by questions from community members about various aspects of the watershed system, this project used a distal interdisciplinary, concurrent mixed methodological approach. Distal interdisciplinarity has been defined as an approach that is: bold, draws resources, methods, and results from disparate disciplines, and seeks out patterns or explanation among the diverse findings to better explain a complex whole (Yegros-Yegros et al., 2015). Proximal interdisciplinarity, contrastingly, is more cautious research that can look beyond the immediate sub-discipline, but still draws on related knowledge, similar methods, and findings from within the same discipline (Yegros-Yegros et al., 2015). In this project, I drew from biological, toxicological, and social, management, cultural, and political science approaches, using biological, toxicological, and social science methods, to examine human ways of organizing as the main unit of analysis across three different studies. Study 1 involved water quality monitoring and comparison of community science tools' effectiveness. Study 2 involved identification of algal species in repeated site visits against geographical characteristics, precipitation, and seasonality. Study 3 involved a literature review, SWOT analysis, interviews and focus groups to understand management challenges. While each of these studies seems unrelated, the people involved, and how they are affected by and organize watershed management is the unifying factor. Next, I will describe the methods and analyses for each study individually, as well as how I used the CT framing the produce the overall results.

1.5.1 Study 1: Water Nutrient Monitoring and Comparison of on-site Indigenous Community Science Data Collection Methods

Community Science Device Accuracy

Community members were interested in learning to gather their own data on the quality of the waterbodies in their reserves and across the watersheds so they could understand why they were seeing more algal blooms. University faculty members, including my supervisor, were approached to design a plan and help in the selection of tools for community monitoring of waterbodies. Due to the COVID-19 pandemic, it was decided to use tools that could be used by individuals on reserves involving little interaction with urban-based scientists once the tools were learned, to reduce the chance that COVID would be spread to each community.

The measurement accuracy of two community science devices for nutrient monitoring by comparing device measurements to measurements gathered by an in-laboratory method (SmartChem) was selected. With the support of my supervisor, and the creators of one of the tools, a set of videos and instruction sheets were sent to community-based research coordinators, and through Zoom calls, I trained community coordinators to use the devices. The devices tested were a YSI 9500 Photometer and a Nutrient (Smartphone) App developed by Global Institute of Water Security at the University of Saskatchewan (Costa et al., 2020). The photometer measures chemical compounds in water samples by determining the absorbance of wavelengths of light and comparing the tested sample to the control sample. The Nutrient App uses a photograph of each tested and control sample together to calculate nitrate and phosphate concentrations (Costa et al., 2020). An algorithm is used with data that the researcher provides, including the colour difference in pixels between control and test samples and colour range reference label, ambient temperature, and light intensity (sunny, partly cloudy, shaded). For the community devices, measurements were made following the manufacturer's protocols which I showed each community member how to use, with water tested the same day of sampling. Sampling occurred somewhat consistently in two of the three reserve communities, and I sampled consistently once per week at nine sites outside of the reserves that provided upstream and downstream comparisons. This was due to borders of reserve areas being closed to prevent COVID transmission.

To assess the accuracy of the Photometer and the Nutrient App, a subset of samples (n =117), selected because it was the most complete, consistent data from community research coordinators, and where I was also able to get precipitation data, was analysed for the same nutrient compounds on a SmartChem 170 Discrete Analyzer (produced by Westco Scientific Instruments). Analyses on the SmartChem used U.S. EPA methods 365.1 Rev 2.0 1993, 350.1 Rev 2.0 1993 and 353.2 Rev 2.0 1993 for soluble reactive phosphorus, ammonia, and nitrate, respectively. The unit of measurement is the concentration level (mg/L) of each tested compound analyzed by each community science device and laboratory testing, then statistically analyzed with RStudio to determine how close device measurements were to laboratory measurements. For both devices, control samples (i.e., distilled water blanks) were tested to reduce error. For the Photometer, the distilled water blank is inserted into, measured, and recorded by the device before each tested sample for the three tested compounds. The Nutrient App compares the color difference in recorded pixels from the picture taken of control colour plate (provided by the test strip manufacturer) and test portions of a Hach Nitrate test strip or between separate test tubes of control and test samples in an API Phosphate test kit. Regressions of nutrient concentrations measured by laboratory (SmartChem) vs. community science instruments (Photometer and Nutrient App) were conducted using R version 4.1.3 in RStudio, with slopes and their confidence intervals and that overall goodness of fit (r^2) as indicators of accuracy and precision. Testing the measurement accuracy of community science instruments would provide empirical evidence of the trade-offs communities may need to navigate in deciding on community monitoring programs, in partnership with community researchers, and be more accepted by individuals from different perspective groups as a valid method for nutrient monitoring. Community leadership understood that community science tools can have error, they wanted to have measures of accuracy and precision to gauge whether to invest more widely in community tools such as a photometer or the nutrient app and their reagents.

Nutrient Concentration Pattern between Average and Adverse Weather Years

The nutrient concentration patterns between two summers with average (2019) and adverse (2021) weather conditions were compared. Samples were collected from surface waters flowing through Yellow Quill First Nation and James Smith Cree Nation reserve lands. Sampling sites were determined initially through communications between geospatial experts, community members, and research team members. Samples in 2019 were collected and tested by Yellow

Quill First Nation community research coordinator and council member, Myron Neapetung (April 8th to August 26th) and data were shared through a research agreement with the community. Samples in 2021 were collected and tested by myself (May 24th to September 20th) in as many as the same sites as in 2019 as possible given pandemic restrictions. The 2021 water samples were collected from eight additional sites, and a previously sampled site (Nut Lake Outlet) in 2019. Concentrations were measured with a YSI 9500 photometer and the Nutrient App; however, only phosphate and ammonia data were used based on results in the previous method. A Hanna HI98129 Combo pH/Conductivity/TDS Tester (handheld multimeter) was also used to gather data on water temperature, conductivity, and pH levels in each site at the time of sampling, and precipitation data were obtained from an online public Daily Climate Data site from the Canadian Government (https://climate-change.canada.ca/climate-data/#/daily-climate-data) to see if these factors were related to nutrient concentration levels.

The units of measurement for this study were the concentrations (mg/L) of phosphate, and ammonia over a temporal period and generated into line graphs on Microsoft Excel (Figure 2.6-2.7). The control group was the data collected in 2019 when there were average weather conditions (i.e., frequency and intensity of precipitation, temperature) and the test group of 2021 is the concentration data during adverse weather conditions (drought-like conditions). An analysis of variance (ANOVA as per Sthle and Wold, 1989) was used to compare ammonia and phosphate concentrations in the two years of study. For the shared sample site, Nut Lake Outlet, a one-way analysis of variance (as per Park, 2009) was conducted to compare ammonia and phosphate concentrations between a normal and drought year. This method is used to test whether environmental and social dynamics were closely connected (i.e., if agricultural activities increase natural nutrient concentrations in water systems, increasing the risk of negatively impacting downstream community health) and whether there was the continuation of nutrient loading from external sources despite changes in weather. This method builds on the argument that improvement in prediction and watershed management overall could be achieved by making changes in management practices to reduce excessive nutrient loading from social and economic sources.

1.5.2 Study 2: Nutrient-Algal Relationships and Cyanobacteria Monitoring

Study 2 was driven by community questions about relationships between nutrient levels and the species that exist within, depend on, and form food webs with other species in watersheds. Community leadership were interested in whether nutrient management strategies were needed to reduce risks to their community members given anecdotal reports of more algal blooms than in previous decades, and the community was also interested in risks that algal blooms might pose to all species (i.e., kin from an Indigenous worldview) from waters with unnatural levels of nutrients. To do so, it was suggested that identification and quantification of various algae species across a season would be a good start, with sampling occurring concurrently with existing nutrient sampling locations.

Water samples (n=79) were taken from the same sampling sites chosen for the 2021 sample set in Study 1. A vacuum filtration kit was used to filter 50 mL of sampled water through a 0.45µm membrane filter. Filters were dried for 3 days at 65ºC in a portable incubator, then a 1cm^2 piece from each sample was mounted onto a slide with a 70% glycerin mixture. A compound microscope was used to identify and quantify algal bloom species in a standard-sized field of view. Slides were examined for diatoms, harmless algae species, and cyanobacteria. Two keys for freshwater algae identification were used: A Key to the More Frequently Occurring Freshwater Algae (Bellinger & Sigee, 2010) and the Canadian Algae Identification Field Guide (Serediak et al., 2011). The unit of measurement is the individual cells of algae bloom species (diatoms, harmless algae, and cyanobacteria) in the field of view. Individual algae cells were counted and recorded to estimate the total abundance of each category (diatoms, harmless algae, and cyanobacteria), bloom composition, and average cyanobacterial biomass at each study site. Cell densities were calculated by multiplying the total number of cells counted in the 1 cm^2 aliquot by the total filter area (assuming an even distribution of cells across the surface of the filter), then dividing by the volume filtered.

The density (abundance) of cyanobacteria was compared to concentrations of ammonia and phosphate were measured with a YSI 9500 photometer (control data), corrected relative to measurements on a SmartChem Analyzer (Study 1) in a table (Table 3.4). Both nutrient concentrations and algal abundance were visualized in line graphs (Figures 2.5-2.6; 3.2-3.5) using Microsoft Excel, accounting for temporal lags between nutrient concentration and cyanobacteria abundance levels. This method was used to quantify the abundance of cyanobacteria of surface water flowing through Indigenous reserve boundaries and provides evidence of potential risk from cyanotoxin-producing species. It also supported the need for studying existing strategies and efforts for community engagement in nutrient management in the watershed so that concerns about cyanotoxin producing bacteria in reserve waterbodies could be raised with wider watershed management organizations through collaborative discussions and environmental programming with multiple perspective groups and knowledge-keepers.

1.5.3 Study 3: The Complexity of the Watershed Management System

Community-driven questions around how watershed groups managed waters that crossed reserve boundaries in upstream and downstream locations provided the impetus for Study 3 in this program. Community leadership were aware that in the past, members of their councils had been representatives on watershed decision bodies (such as the Nut Lake Watershed Authority near Yellow Quill First Nation), but were also not aware of current practices and plans being implemented for watershed management. Community leaders wanted to know the strengths and weaknesses of current strategies being used for watershed management, the successes of watershed management in other regions, and the Indigenous community and non-Indigenous community perspectives on watershed management. Thus, a concurrent, multimethod social science methodology was suggested involving 1) document review and SWOT analysis of watershed management strategies and other documents that community leadership shared including Indigenous interpretations of water rights from the Treaties, 2) interviews and focus groups with both Indigenous and non-Indigenous water managers from the watershed and surrounding areas. The specifics of those methodologies and the analyses used are described next.

Document Analysis

After a purposive search, driven by a set of search terms co-created with Indigenous community members used in databases such as Web of Science, PubMed, iPortal, Informit, Scopus, and Google Scholar, and snowballing with documents provided to me from community leadership, a total of twelve Canadian water acts, policies, and strategy documents relevant to Saskatchewan Treaty Areas were analyzed using the SWOT (method) as described by Robins (2007). This method of analysis was used to find the strengths, weaknesses, opportunities for improvement, and threats to Indigenous watershed management to determine the level of quality of each assessed document. The documents were assessed with consideration of additional documents; interpretations and legal findings from Indigenous scholars, as compiled and analyzed by a previous researcher in the Lake Winnipeg overall research program. The unit of measurement in the document analyses was the gaps identified between official watershed management documents and Indigenous Treaty Rights interpretation to determine to if current

Canadian watershed management is effective and aligned with Indigenous water rights as interpreted by Indigenous people in written accounts.

Government implemented water documents were closely examined for areas of strength, weakness, threats to Indigenous water rights, and opportunities for improvement for better watershed management practices. The hardcopy of some documents could not be obtained because of delays due to access to information requests and the pandemic, so further details were obtained through peer-reviewed articles and open-access government documents to discover counter arguments and multiple perspectives on each policy, act, or strategy. Using the interpretations and legal findings as the control for assessment, aspects of each document were organized into one of the SWOT categories on a table (Appendix B - Table 1) to indicate their degree of quality. A second document analysis, conducted by a former graduate student (Dr. Kelechi Nwanekezie, PhD), reviewed an additional set of documents specified by Indigenous leaders from the participating communities to be of interest to this study. In this second set of Indigenous-authored documents, no SWOT was conducted because it was deemed an imposition of a western evaluation system, so themes and conclusions from those documents were drawn in partnership with community coordinators (Appendix B - Table 2). By assessing Canadian water documents, the analysis of both document sets shows that policies and management practices are skewed towards settler ways of knowing, and the Hierarchical and Individualism perspective groups as described in Cultural Theory (Thompson, 2008), creating an imbalance of political control in the management system.

Interviews

To gain perspective from the watershed and stakeholder level on the efficiency of watershed management, both primary interview data, and secondary data through pre-existing interviews conducted for water emergencies such as floods and droughts, were used. Primary interviews and talking circles were conducted between 2019 and 2021 with Watershed Agents and Indigenous members from James Smith Cree Nation and Yellow Quill First Nation reserve communities. These interviews were open-ended and semi-structured (Hammer & Wildavsky, 2018; Roulston and Choi, 2018), and participation by interviewees was voluntary and occurred after informed consent (University of Saskatchewan BEH-2478). Questions were formatted to be general and neutral to reduce the *social desirability bias*. Questions were crafted by the lead researcher (Jaclyn Porter) and edited by the primary supervisor (Lori Bradford) and Indigenous community representatives. Some of the questions asked how watershed management decisions were made and who makes them, is there community engagement, what challenges does the agency/community experience, and how do they manage risk. Each interview was recorded and transcribed to remove the potential of missed information, and verified by participants.

Due to COVID-19 health restrictions implemented during the time of this research project, interviews with non-Indigenous watershed agents were done either over-the-phone or Zoom-mediated calls. Also due to COVID restrictions, sharing/talking circles with Indigenous community members were cancelled, and secondary data was used where possible; additional interview data from Indigenous members were gathered from transcripts in 2019 as a secondary source, discussing water-related emergencies. An opportunity to verify findings from interview data occurred during March 2022 at a water forum hosted by my supervisor at the University of Saskatchewan. I presented the interview findings, and two focus groups occurred with members of each community where the findings were discussed and verified.

All transcripts underwent further analysis to discern themes around the impact of current practices on water quality in Indigenous reserve communities until thematic saturation had been reached. Thematic saturation was deemed reached when the number of new themes per interview decreased consistently below 1. A graph depicting saturation can be found in Figure 4.2. The unit of measurement was the number and depth of themes that arose from interviewee responses. Interviews were thematically analyzed using induction (as per Williams and Moser, 2019) and findings of the SWOT framework. A coding guide (adapted from Schwartz and Thompson, 1990), can be found in Table 5.1, which helped sort phrases and sentences from transcribed interviews into CT categories. I then compared wording from each transcript across CT categories to ascertain the overall CT way of organizing represented by the transcript. The use of interviews provided social context and qualitative data to compare values, goals, and practices of watershed agencies and Indigenous communities based on their challenges and successes in water management. Interviews were also used to determine which current water policies and strategies are working from their perspectives, whether participants perceived that adaptations to strategies were needed, and if there are any barriers to improving current policies. Interviews also supported the continued study of human dimensions of watershed management alongside biophysical data analysis from Study 1 and 2. This helped Indigenous partners to find interrelations among the three studies with human behaviour being a main unit of analysis. The way in which I used that unit of analysis through applying Cultural Theory is described next.

1.5.4 Simple Correlation among Nutrient Concentrations and Cyanobacteria Abundance

A simple correlation of variables of interest (nutrient levels, weather) was conducted to find how closely these variables interact. The data used for this method is from the 2021 water sampling data from Study 1 and Study 2. Variable included the precipitation (total amount each week), ammonia and phosphate concentrations, and cyanobacteria abundance, and were organized into an Excel table. The z-score for each data value was calculated, using the total average and total standard deviation for each variable at each site. Various combination of variables, using the z-score values, were visualized on scatterplot graphs. (Figure 3.6). The r^2 values were calculated with Excel (Table 3.3). The r^2 values provided statistical evidence on how closely two variables correlate with one another; high r^2 value shows strong correlation, and low r^2 value shows weak correlation. This method provides statistical evidence on the weak correlation between precipitation, nutrient conventions, and cyanobacterial growth, supporting the argument that nutrients and algae monitoring should be done separately since previous prediction models are becoming less reliable.

1.5.5 Application of Cultural Theory to Sustainability

The framework of this research project is built on the principles of Cultural Theory (CT), which categorizes a person's perspective on a specified subject into one of five "Ways of Life" (Thompson, 2008; Figure 1.2), developed from a unique set of experiences, backgrounds, and how individuals 'make ends meet' or resolve internal conflicts. The categories are *Hierarchical, Individualism, Egalitarian, Fatalism,* and *Autonomous.* As a first step, I identified values expressed by people in the watersheds, and behaviours of watershed agents as described through the studies 1 and 2, such as applying nutrients to increase crop yield, creating irrigation canals to move water, fishing from a traditional site, monitoring water quality, or holding a traditional ceremony. Recognizing that each of these values and behaviours can be mapped to impacts on a watershed according to the three pillars of sustainability (economic, environmental, and social) I was able to categorize the values and behaviours that emerged from the data across two dimensions; the CT way of life, and the contribution to the sustainability pillars. Transcripts were also analyzed against the thirteen characteristics of the ways of organizing, adapted from Schwartz and Thompson (1990) (see Table 5.1).

Radial graphs were generated to shows a blending of Cultural Theory with Sustainability, based on the responses of interview participants in Study 3 (Figure 5.2). Interview responses were organized into the CT categories based on how they were worded. Identical responses were merged. These CT category lists were further organized into the three pillars of sustainability, based on the main subject of each response. The unit of measurement was how many of those responses (percentage) are environmental, economic, or social (pillars of sustainability). The purpose of this method is to visualize the connection between Cultural Theory to Sustainability and to present quantifiable data of the perspectives of watershed agents and Indigenous community members on sustainable watershed management.

1.5.5 Summary of Introduction

This introductory chapter has provided a background to the research problem, and a synopsis of important literature and methodologies used in this thesis. Each chapter expands on the literature, research objectives, methodologies, and then presents findings. This thesis will continue with chapter prefaces, setting the stage through vignettes, and then the insertion of the manuscripts which make up the bulk of the data collection and analysis. Finally, a discussion and conclusion chapter unites the findings into a comprehensive whole.

CHAPTER 2 PREFACE

A CT Story of Watershed Management: Part 1 Egalitarianism and Individualism

Suzanne has an egalitarian perspective. She works as a Watershed Science Technician for a local watershed association. The watershed association mainly works with landowners and farmers to implement best management practices (BMPs) to protect downstream communities and ecosystem health. Suzanne is responsible for delivering and assisting with various components of the watershed science and services programs. Her role is to contact farmers and landowners in the association's watershed, especially in areas where data has found hotspots for nutrient concentrations, and to provide advice and guidance to implement BMPs to their farming and land use activities. She believes that everyone should do what they can to protect the environment, so she is very enthusiastic about her job, though she does get frustrated when the people she reaches out to reject her suggestions on using BMPs. Suzanne assumes that the landowners and farmers make lots of profit, so she doesn't understand why some would refuse to do what they can to protect the environment. One of those people is Brett, whose agricultural activities are linked to nutrient concentration increases in a nearby freshwater lake.

Brett is a canola producer who is characterised as an Individualist. He also owns a small cattle herd. Brett farms on the same land his family has owned since his great-grandfather cleared the land. Despite changes due to technology and policy requirements altering some of Brett's farming methods, most have remained the same as they were for generations. Brett does not have a strong understanding of environmental processes or how his farming activities can hinder or exacerbate those processes. No scientist or environmental researcher has visited his farm, and there have not been any opportunities for Brett, or other agriculturalists, to participate in discussions about the impacts of farming in a changing environment. Climate change has made the region drier, resulting in lower crop yields, and inflation costs are making it more difficult for Brett to maintain equipment, purchase fuel and specialty feed, and pay veterinarian bills for his cattle. Due to these struggles, Brett is barely breaking even.

Suzanne from the local watershed association called him about implementing BMPs on his farmland. Brett does not want to use the BMPs Suzanne suggested because it would financially cost more than he has. The spare funds Brett saves is reserved for the maintenance of equipment and purchasing new ones if his current equipment fails. He does not want to risk using up his reserve funds in case one of his more vital pieces of equipment fails, preventing him from producing canola. After talking with other farmers in the region, Brett has learned that they are also experiencing the same financial contracts as him. Brett and other farmers know that the policy in the region does not require them to use BMPs; instead, the policy states BMPs are optional. Therefore, many farmers, including Brett, decided to not implement BMPs because they simply don't have enough funds to do so.

Story as Analogy: Part 1

This fictional story shows that sometimes the policy framework in watershed management, and local watershed management agency approaches, do not fully monitor, assess, and restrict the movement of agricultural nutrients and that information-sharing and stakeholder participation, in some cases, is lacking or conflicting. Some have suggested that situations such as this could be improved by changing policy strategies from optional to required, having more enforcement, or being co-designed and co-implemented. For example, one way for this to be more successful is if the installation of BMPs could be a gradual plan for the first few years after the policy is implemented to reduce the financial impact on farmers and landowners. Another plan could be that a certain portion of BMP costs are compensated by the provincial government. Should the policy allow BMPs to remain optional, then the government should incentivise the use of BMPs by placing higher value crops produced on lands using methods that improve environmental and social wellbeing.

Regardless of the implementation of BMPs, a social problem identified in circumstances that reflect the status quo for watershed management is that egalitarian and individualistic ways of living can conflict. At the egalitarian level, Suzanne should not assume that all landowners and farmers are experiencing the same thing and would have the same resources to implement BMPs. Both Brett and Suzanne should take the time to have a more in-depth discussion about the environmental and social drivers of agricultural nutrient movement to come up with a solution that best fits Brett's current (and future predicted) financial situation. This preface provides insight into how the diversity of perspective groups interact within watershed management and influence agricultural nutrient movement and environmental processes (Chapter 2), to a certain degree.

Now that I have provided one example of how watershed management plays out among those involved in applying nutrients, and those working on implementing plans to control nutrient movement, the chapter ahead actually provides primary data on those nutrients in Treaty 4, 5, and 6 territories as measured by three techniques. The chapter comments on those techniques and their implement-ability across watersheds that have Indigenous reserves within their boundaries. This chapter was submitted to the Canadian Water Resources Journal for publication in June 2022 and was written with co-authors L. Bradford, T. Jardine, L. Bharadwaj, G. Strickert, M, Neapetung, and J. Burns.

Image 1: Drying up stream that runs through agricultural land. This image is an example of climate change induced drought conditions resulting in high evaporation rates. Fencing in image is set up to keep cattle in agricultural pastures but not out of stream, allowing the addition of more nutrients through livestock wastes.

CHAPTER 2: WATER NUTRIENT MONITORING AND COMPARISON OF ON-SITE INDIGENOUS COMMUNITY SCIENCE DATA COLLECTION METHODS

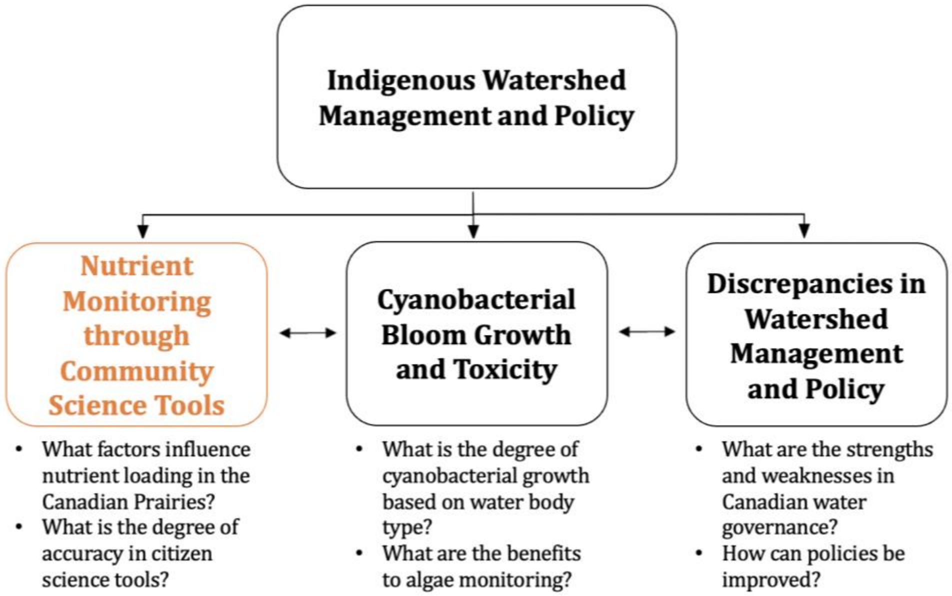

Figure 2.1: Research Flow Chart; focus on Nutrient Monitoring and Community Science Tools. This chapter will focus on the beneficial use of community science tools for effective nutrient monitoring (in orange). The study focuses on the connects among nutrient loading and concentration patterns (environmental), barriers to capacity-building and community engagement (economic), and the impacts on community health (social) in Indigenous drinking water challenges.

2.1 Introduction

Excessive nutrient loading in surface waters has become a recurring issue with radiating adverse effects on local communities and surrounding ecosystems. Since the mid-20th century, nutrient inputs have increased beyond the assimilative capacity of the natural environment due to intensive crop production methods and a changing climate (Paerl and Paul, 2011; Kling et al., 2011; McKindles et al., 2019). Compounding agricultural impacts and excessive nutrient loading occurrence is increasing in part from greater frequency of extreme weather such as flooding, heavy precipitation, and droughts (Akhtar et al., 2019; Gmitrowicz-Iwan et al., 2020). Monitoring nutrient inputs into freshwater systems in regions with high agricultural activity has therefore become even more important as a reductive action and precursor to adaptive environmental planning.

Nitrate, ammonia, and phosphate are of particular interest in agriculturally dominated regions, such as the Canadian prairies, since these compounds are common in cropland fertilizers and livestock wastes (Ginger et al., 2017). With increasing economic activities and changing weather conditions that facilitate the movement of nutrients from land to water, the health of at-risk communities (as defined by the US Environmental Protection Agency; URL: https://www.epa.gov/risk/about-risk-assessment#whatisrisk) is impacted, often in the form of exposure to harmful algal blooms (HABs). The growth of HABs parallels the human-induced increase of nutrient inputs, recurring more often than previously observed in past centuries, and becoming more toxic with large proportions of toxic cyanobacteria within each bloom (Paerl & Paul, 2011, Ginger et al., 2017). Indigenous Peoples living in rural locations have a higher likelihood of becoming ill from a water-borne contaminant because of traditional lifestyles and food harvesting, dependence on surface waters for drinking water sources, or ceremonies which rely on the use of local waterbodies (Galway, 2016; Patrick et al., 2019; Lam et al., 2017; McLeod et al, 2020). As the climate continues to destabilize, scientists can no longer confidently predict hydro-ecology and effects of hydrological change on algal bloom formation, creating monitoring and governance challenges (De Loë & Plummer, 2010). Therefore, continuous research and collaborative efforts between people with different knowledges and backgrounds and the involvement of affected individuals are needed (Kalcic et al., 2016). Doing so can further understanding of environmental issues, develop practical solutions, and embrace Indigenous knowledge while creating reciprocal relationships with communities (Sardarli, 2013; Latchmore et al., 2018).

Nutrient monitoring through community science methods is necessary to inform watershed management practices. Source Water Protection Plans (SWPPs) can mediate the effects of nutrient loading, but implementation of these plans can be difficult in remote locations and where there are jurisdictional and cultural barriers, allowing toxic algal blooms to develop before excessive nutrient loading is documented (Patrick, 2018; Pick, 2016; Collins et al., 2017). Examples like these highlight the need to monitor nutrients that ultimately cause algal blooms and develop cost-effective solutions to mitigate them.

An essential need in environmental research is data collected at appropriate local and temporal scales, which can be achieved through community science methods (Wehn and Almomani, 2019). The monitoring of nutrient loading is complex as various factors contribute to input levels, so increasing the capacity to monitor nutrients in waterways in rural and remote areas would be beneficial (Capdevila et al., 2020; Conrad & Hilchey, 2011). Despite some challenges in implementation, more researchers are recruiting local residents to engage in community science, making monitoring efforts more responsive and data more accessible, so intervention planning can begin before a problem becomes too severe (Kim et al., 2011; Aceves-Bueno et al., 2015). Previous work has also highlighted the benefits to Indigenous groups of collecting their own data (Luzar et al., 2011; Wilder et al., 2016; Hill et al., 2020).

Community science provides many benefits to environmental research efforts, such as reduced travel expenses, time, and need for personnel by involving local volunteers, the use of cost-effective methods and testing devices, and data sharing among all involved parties, leading to a unified data archive that can be useful for future research efforts. Some studies have shown that community science methods are reliable and should be employed in research (De Loë and Plummer, 2010, Herman-Mercer et al., 2018; Wilson et al., 2018), especially now that devices have been simplified to account for researcher error. The development of tools to simplify water data collection by any public individual, such as a secchi disk, handheld multimeter, and the

Nutrient App for smartphones (Costa et al., 2020), are examples of simple research devices that community scientists can use.

Community-driven nutrient monitoring in water systems is growing in Canada, and some monitoring projects include Indigenous participation (Wilson et al., 2018; Gérin-Lajoie et al., 2018, Herman-Mercer et al., 2018). A community-based research project conducted in the Yukon River Basin (Wilson et al., 2018) is one of many examples of the benefits of using community science methods and collaborating with Indigenous communities on research projects. There are many co-benefits of community science for all participants, such as awareness and education on the subject through practise, knowledge exchange, and an opportunity to participate in research that can bring positive outcomes to underserved communities. Involvement in such projects can provide experience with technology, strengthen relationships, increase Indigenous voice and youth involvement, and care of the land and people (Arsenault et al., 2018; Bradford et al., 2017). Many believe the co-design of the monitoring and management process with community members is necessary for the protection of source waters within Indigenous lands (Reed et al., 2021). But this proves to be tricky since there remain barriers to the inclusion of Indigenous Peoples in policy and management discussions around water, and push-back on the use of community science for decision-making (Bradford et al., 2018; Hanrahan, 2017).

In this paper, we test the capacity of two different nutrient testing devices (YSI 9500 Photometer, and a Nutrient (Smartphone) App) for in-field water monitoring and environmental community science. We use the Photometer to examine nutrient prevalence in surface waters in central Saskatchewan, flowing through reserve lands of two participating Indigenous communities (James Smith Cree Nation and Yellow Quill First Nation). We provide insight into the seasonal and inter-annual changes in nutrient concentrations in water systems and emphasize the importance of monitoring through community science methods as a long-term preventative action. Specifically, this study aims to:

1. Explore the degree of error in community science monitoring equipment for nutrients.
2. Identify potential nutrient hotspots in Treaty 4, 5, and 6 Territories.
3. Compare nutrient concentrations between years of average and low precipitation to point to possible factors affecting the nutrient status of Prairie waterbodies.

2.2 Approach, Materials, and Methods

The study described in this chapter is part of a longer-term program of research on issues of water security that has been occurring for over a decade on reserves. These issues have been investigated between researchers at the University of Saskatchewan, and partnered communities in Treaty Areas 4, 5 and 6. Researchers from the University of Saskatchewan on this piece (Bradford, Jardine, Bharadwaj) who collaborated in this study have been engaging in community-driven research projects with formal agreements (research agreements, memorandum of understandings) and informal agreements (mutual desire) to learn more about phenomena being noticed in communities. Researchers follow community-decided protocols (gift exchange, tobacco and water ceremonies, community blessings, involvement of youth and Elders) as requested. This specific project began because community research coordinators (Justin Burns and Myron Neapetung) had shared that their community members notice more frequent and extensive algal blooms in their lakes and waterways, and wanted to identify potential reasons why, and paths to take to reduce their health and cultural risks due to bloom formation. While the overall research program occurred in three different communities over three years, in this study, we focus on the most complete dataset for analysis from one community (Yellow Quill First

Nation) in 2019, and comparative data from another community (James Smith Cree Nation) where a more complete dataset was established in 2021. Yellow Quill First Nation is a Saulteaux community with about 800 on reserve residents, located about 250km east of Saskatoon, SK. The reserve surrounds Nut Lake, a lake with sacred value and a former fishing and drinking water source for the community. James Smith Cree Nation is a Cree community of about 1800 members on reserve located about 200km northeast of Saskatoon, SK. The reserve is located along the shore of the Saskatchewan River where members fish regularly, and across the river from the Fort a La Corne Forest, traditional hunting and harvesting grounds of the community, now a diamond mining site. A map showing study area is available in Figure 2.2. This research obtained ethics approval from the University of Saskatchewan Behavioural Ethics Committee in 2018 and has been continually renewed each year (BEH-REB 2478).

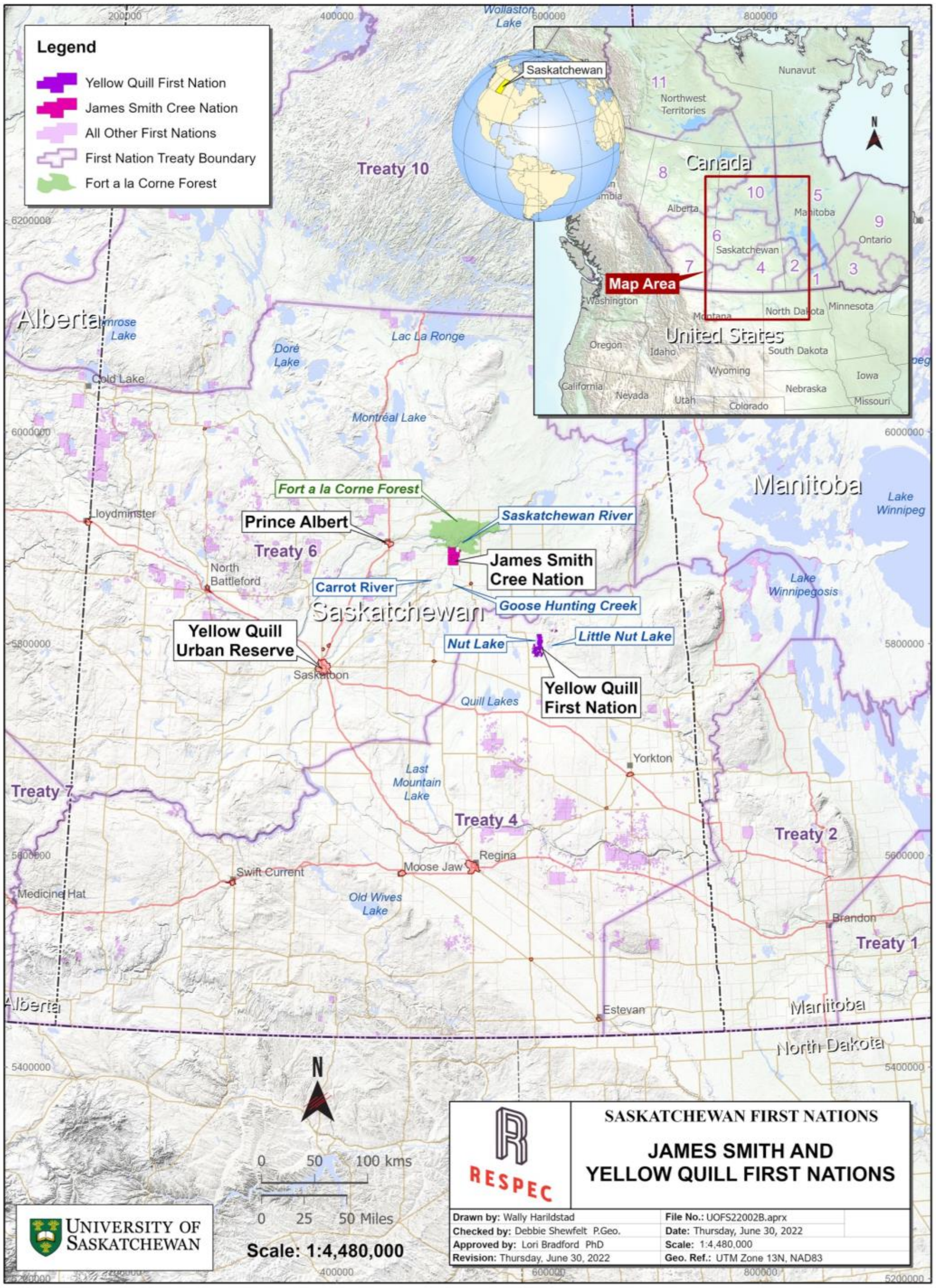

Figure 2.2: Map of Study Area.

Water Sampling: Sites and Collection

Water samples were collected from surface waters flowing through YQ and JSCN lands and were collected and tested by Myron Neapetung in 2019 and myself in 2021. Sampling sites in

YQ were determined through communications between geospatial experts, community members, and research team members. These sites included wetlands near roads and bridges, the centre of Nut Lake (*Pagāni-sāgahigan*) – a culturally important lake – and a wetland west of Rose Valley, SK. Water samples collected in YQ, and the surrounding area occurred weekly from April 8th to August 26th in 2019. In 2021, due to COVID-19 restrictions, water samples were collected from outside the boundaries of the YQ and JSCN. The 2021 water samples were collected from nine sites surrounding JSCN and YQ. These included eight additional sites, including the North Saskatchewan River, Little Nut Lake (*Pagāni-sāgahiganēns*), and a previously sampled site (Nut Lake Outlet) in 2019. The 2021 sampling period occurred weekly from May 24th to August 25th, then bi-weekly in September.

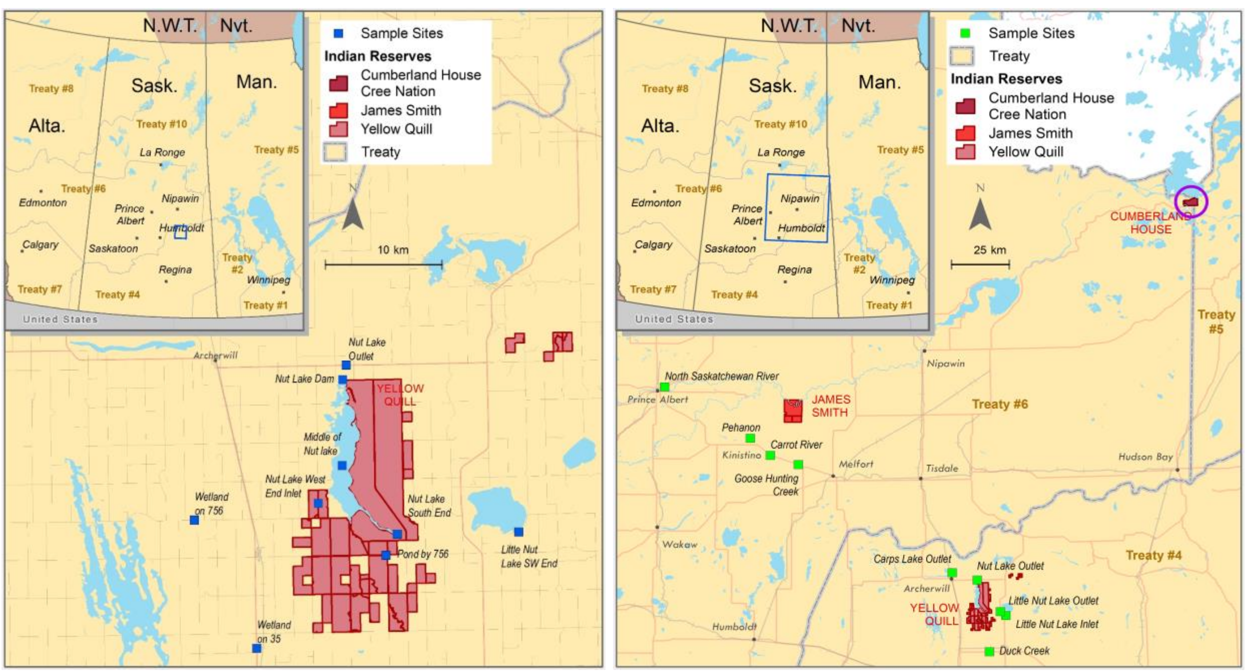

Figure 2.3: Map of sampling sites in 2019 (left) and 2021 (right).

Nutrient concentrations in water samples were measured with both a YSI 9500 Photometer, and a Nutrient (Smartphone) App developed by the Global Institute for Water Security at the University of Saskatchewan (Costa et al., 2020). A Hanna HI98129 Combo pH/Conductivity/TDS Tester (handheld multimeter) was used to gather data on water temperature, conductivity, and pH levels in each site at the time of sampling. Precipitation data were obtained from an online public Daily Climate Data site from the Canadian Government (https://climate-change.canada.ca/climate-data/#/daily-climate-data). For the site sampled in both 2019 and 2021, Nut Lake Outlet, a one-way analysis of variance was conducted to compare ammonia and phosphate concentrations to test for differences in nutrient concentrations in the normal and drought year.

To assess the accuracy of the Photometer and Nutrient App in 2021, a subset of samples (n =117) was analysed for the same nutrient compounds on a SmartChem 170 Discrete Analyzer (produced by Westco Scientific Instruments). Analyses on the SmartChem used U.S. EPA methods 365.1 Rev 2.0 1993, 350.1 Rev 2.0 1993 and 353.2 Rev 2.0 1993 for soluble reactive phosphorus, ammonia, and nitrate, respectively. In each case, stock standards analysed alongside samples had recoveries of 99 ± 4% (n =12), 96 ± 5% (n = 12), and 98 ± 2 (n = 8) for the three analytes. For the Photometer and Nutrient App, measurements were made following the manufacturer's protocols with water tested the same day of sampling. Regressions of nutrient concentrations measured in the laboratory (SmartChem) vs. those measured with community science instruments (Photometer and Nutrient App) were conducted using R version 4.1.3 in RStudio, with slopes and their confidence intervals and that overall goodness of fit (r^2) as indicators of accuracy and precision. An analysis of variance was used to compare ammonia and phosphate concentrations in the two years of study. Temporal differences in nutrient concentrations were visualized in Microsoft Excel.

2.3 Results and Findings

Community Science Device Accuracy

Within the 2021 study period, the degree of accuracy of ammonia, phosphate, and nitrate measurements between a YSI 9500 Photometer and a Nutrient App (Costa et al., 2020) were determined by comparing device measurements of samples also measured by laboratory methods (SmartChem), which provided the actual nutrient concentrations in samples.

Ammonia and Phosphate

The YSI 9500 photometer had better accuracy measuring ammonia (slope CI=0.62-1.62; r^2=0.38) and phosphate (slope CI=0.35–0.45; r^2=0.89) than the Nutrient App, but still needs some adjustments for improvement. Based on a confidence interval for the slope that did not include zero but did include one (Table 2.1), the ammonia results determined by the YSI 9500 photometer were significantly related to the actual concentrations in samples measured by SmartChem. These measurements indicate that the photometer has an acceptable amount of error (95% confidence interval that includes 1.00) for measuring ammonia concentrations and is an ideal alternative for in-field testing. Phosphate concentrations measured with the photometer were higher than those determined by laboratory methods. However, a strong correlation was observed between these two methods of phosphate measurement. The photometer's ability to measure phosphates is moderate but simple corrections can be applied to increase its accuracy. Phosphate measurement by the Nutrient App was poor. This was indicated by a wide confidence interval (0.04-0.55) and low r^2 (0.24, Table 2.1). The Nutrient App measured phosphate concentrations higher than the laboratory and varied between very high and low measurements compared to the Photometer, showing a weak correlation between methods (Figure 2.4).

Nitrate

Both the photometer and Nutrient App performed poorly when measuring nitrate. Nitrate measurements using the photometer were 5 times higher than those determined through laboratory methods. Regressions between the Photometer results and those from the laboratory yielded a zero within the confidence interval, indicating that photometer measurements were not accurate (Figure 2.4). These higher results could have been due to the reagent particles remaining buoyant in the sample and detected by the photometer light, giving a higher reading. I suggest that further testing with longer wait times to allow reagent particles to settle may improve measurement accuracy. For the Nutrient App, there was also no correlation between values obtained from the App and those from the laboratory, and nitrate concentrations measured on the App were vastly higher than those in the laboratory. As a result, I recommend avoiding the use of both devices for nitrate testing and treat existing results with extreme caution. The results from this study differ from those of Costa et al. (2020) who found good agreement between the Nutrient App and laboratory analyses because this study's data represent routine analyses by operators without long-standing training in the methods, as opposed to the App developers operating under more optimal conditions.

Beneficial Uses of Community Science Devices and Suggestions for Improvement

Some benefits of using community science devices for in-field testing over laboratory testing are a lessened need for prior experience or extensive training, a lower cost for materials, shorter testing times, and a reduced risk of sample degradation during transport. The Nutrient App is preferable to the YSI 9500 Photometer when considering these benefits. Testing with the App is more cost-efficient (approx. $1 per test), takes far less time (30 seconds per test), and is easier to transport to sampling sites. There is also the bonus of sharing results through the app's GPS function. Using the photometer for community science is also better than laboratory testing, but it does cost slightly more (approx. $3 per test) than the Nutrient App, each test takes a minimum of 10 minutes, and the photometer is less portable in the field. The constant cleaning of the photometer's testing tubes to prevent cross-contamination takes away time for sampling, and some of the reagents are not safe for the environment. The photometer could ideally be set up in a central, indoor, or sheltered location, but that risks sample degradation if samples are not well-sealed or kept cool during transport. As important as these considerations are to choosing which method to use, the most important one must be the degree of accuracy. Based on the results between the photometer and Nutrient App compared to the laboratory results, there are apparent differences in method accuracy for each measured compound (Table 2.1 & Figure 2.4). The Nutrient App smartphone application currently measures only phosphates and nitrates.

Though there are many benefits this app provides to users (noted above), it was determined that corrections to improve Nutrient App accuracy and reliability are needed. The Nutrient App had a moderate accuracy for phosphates, but more error was observed when compared to the phosphate results obtained from the Photometer. Despite the initial testing by its developers, this app needs modifications to improve its accuracy and account for possible errors by less experienced users. I suggest that adjustments should be made to the app's algorithm to account for human error, repeat measures, and more information on what to look for in measurement ranges could help improve accuracy. I also suggest that a more reactive test kit with a more distinctive colour range could be used instead of the current API nitrate test strips. The developers initially selected nitrate test strips (Costa et al., 2020) since they are convenient and easy to use for in-field testing and gave adequate results when they were tested. The liquid reagents used in the Nutrient App phosphate tests were far more accurate for low-level concentrations likely due to the greater range of colour between yellow, green, and dark blue.

The app could also improve its accuracy with a zoom function. Zooming into an image would make selecting the correct colour pixel easier without accidentally selecting an incorrect one. For instance, a person could have difficulty choosing the

Method Type	Nutrient Type	Slope	95% CI	Intercept	r^2	p-value
Photometer	Ammonia	1.117	0.621.62	-0.11	0.38	<0.001
Photometer	Phosphate	0.3343	0.350.45	-0.07	0.89	<0.001
Photometer	Nitrate	0.0573	-0.01–0.12	-0.02	0.07	0.072
Nutrient App	Phosphate	0.2932	0.04–0.55	-0.11	0.24	0.027
Nutrient App	Nitrate	-0.0061	-0.02–0.01	0.03	0.00	0.345

Table 2.1: Calculated statistics for Photometer and Nutrient App accuracy.
Statistical results compare the measurement accuracy of the YSI 9500 Photometer and Nutrient (Smartphone) App against the in-laboratory SmartChem method.

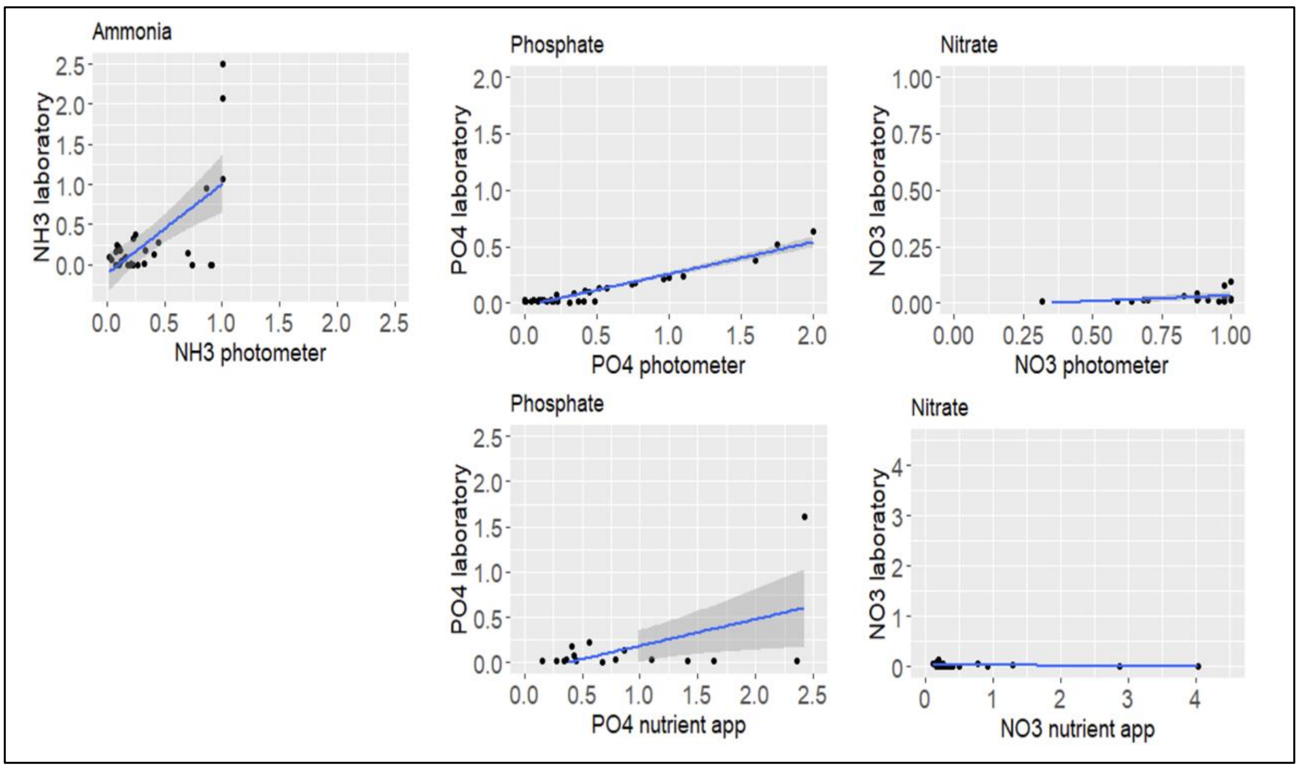

Figure 2.4: Nutrient concentration device measurement accuracy.
Concentrations of nutrients measured in a laboratory vs. concentrations measured using low-cost community science instruments (Photometer and Nutrient App). Trendlines provide a visual representation of the accuracy level: (i) Photometer ammonia has the best accuracy; (ii) phosphates for both methods have moderate accuracy (with some adjustment needed); (iii) nitrates for both methods are not close to laboratory results (actual results).

best spot on the image to measure due to a small phone screen size, larger fingers, or limited dexterity; a zooming function should reduce this issue. As previously suggested, when using the photometer, additional wait times should allow reagent particulates to settle in test tubes and prevent inaccurate measurements.

Nutrient Concentration Patterns between Average and Adverse Weather Years

Water sample data from 2019 and 2021 (Table 2.2; Figure 2.6-2.7) were analysed to compare nutrient concentrations between years with different climate conditions (precipitation frequency, evaporation rates, and average temperatures measured by GOC Environment and Climate Change Dataset). A source of error may have come from having two different researchers collect data (process of testing may be different, difference in experience, etc.) and all but one site was not the same between years. During the study period in 2019 and 2021 (April 29–September 20), the number of days of rainfall occurred evenly, with 26.8% during 2019 (30 of 112 days) and 27.7% in 2021 (31 of 112 days) (Figure 2.5). Even though these are essentially equal in duration, total average rainfall differed, with 249 mm falling in 2019 and 194 mm in 2021 (between April 29-September 20 for both years). It is important to note that much of the precipitation recorded by the Muenster recording site occurred in one day near the end of the 2021 study period (Aug. 31=62 mm). The average temperature ranges between the years (2019=7.95°C–20.89°C; 2021=8.9°C–23.0°C) were very similar but the number of times temperatures reached over 30.0°C greatly differed (2 days in 2019; 20 days in 2021). It is suspected that the combination of high temperature frequency and reduced amount of precipitation directly influenced the rates of evaporation and soil conditions, which led to the differences in nutrient loading into freshwater systems between these years. The data from this study shows overall nutrient concentrations were lower than those elsewhere in the province, such as the Qu’Appelle River Basin (Hosseini et al., 2018) and the South Saskatchewan River (Akomeah et al., 2015), but overall high phosphate and ammonia concentrations suggest a need for continued monitoring and management.

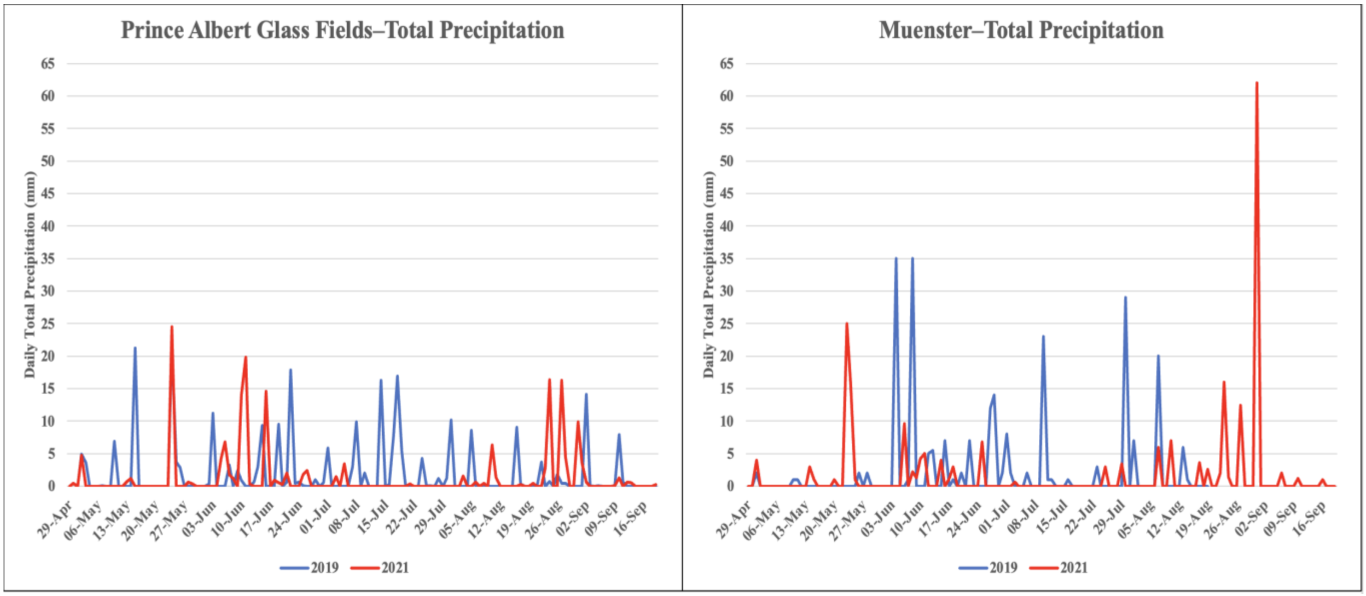

Figure 2.5: Precipitation Patterns.
The daily total precipitation in the study area during the 2019 and 2021 study periods was measured in millimetres. Data from two separate gauges were used to visualize the difference between the James Smith and Yellow Quill regions. Data were sourced from the GOC Environment and Climate Change Dataset (URL: https://climate-change.canada.ca/climate-data/#/daily-climate-data).

Differences in nutrient concentrations in the site that was the same between 2019 and 2021, the outlet of Nut Lake (N 52.3721, W -103.6947) were compared. Despite being lower than average ranges, precipitation appeared to be a key driver of nutrient concentrations in 2019 when other climate conditions (temperature, wind, sunlight exposure, atmospheric moisture) were within normal thresholds from May to September (Daily Average temperature range=10.5°C-17.8°C; Daily average precipitation range=45.6mm-73.6mm) (https://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnProv&lstProvince=SK&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=2973&dispBack=0). In this year, the Nut Lake Outlet had gradual increases in nutrient concentrations over time for ammonia and phosphate.

Sample Site	Year	Ammonia (NH_3) (measured by Photometer)	Ammonia (NH_3) (estimated value)	Phosphate (PO_4) (measured by Photometer)	Phosphate (PO_4) (estimated value)
Nut Lake South End	2019	0.71 ± 0.24 (17)	0.66	2.29± 1.46 (17)	0.56
Pond by 756	2019	0.56± 0.25 (17)	0.50	1.99± 0.76 (17)	0.48
Southeast End of Little Nut Lake	2019	0.48± 0.36 (17)	0.40	2.23± 0.87 (17)	0.55
Middle of Nut Lake	2019	0.91± 0.10 (16)	0.88	3.90± 0.26 (16)	1.04
Nut Lake Dam	2019	0.56± 0.26 (17)	0.50	0.96± 0.41 (17)	0.17
Nut Lake Outlet	2019	0.48± 0.15 (17)	0.41	0.58± 0.18 (17)	0.06
Nut Lake West End Inlet	2019	0.65± 0.15 (17)	0.59	1.46± 0.42 (17)	0.32
Wetland on 756	2019	0.77± 0.24 (17)	0.74	3.45± 0.57 (17)	0.90
Wetland on 35	2019	0.72± 0.14 (17)	0.68	1.28± 0.73 (17)	0.27
North Saskatchewan River	2021	0.17± 0.11 (11)	0.06	0.14± 0.15 (11)	<0.01
Pehanon	2021	0.51± 0.31 (11)	0.40	1.83± 0.88 (11)	0.43
Carrot River	2021	0.28± 0.24 (11)	0.28	1.04± 0.51 (11)	0.20
Goose Hunting Creek	2021	0.20± 0.12 (11)	0.11	0.36± 0.23 (11)	<0.01
Carps Lake Outlet	2021	0.24± 0.25 (10)	0.14	0.08± 0.09 (10)	<0.01
Nut Lake Outlet	2021	0.54± 0.28 (11)	0.48	0.36± 0.36(11)	<0.01
Little Nut Lake Inlet	2021	0.23± 0.17 (9)	0.12	0.59± 0.27(9)	0.07
Little Nut Lake Outlet	2021	0.55± 0.44 (10)	0.49	0.06± 0.15 (10)	<0.01
Duck Creek	2021	0.30± 0.22 (11)	0.19	0.36± 0.27 (11)	<0.01

Table 2.2: Mean nutrient concentrations (± S.D.) measured using a YSI9500 Photometer.
The average concentration of ammonia and phosphate concentrations in the sampling sites during the study period in 2019 and 2021. Nitrates were not included since they were unreliable based on the previous accuracy testing data.

Nutrient levels were expected to increase with rising temperatures and evaporation due to the drought-like conditions of 2021 but the presence of dams and associated in-reservoir processing can alter expected relationships by preventing the movement of nutrient-rich sediments from moving downstream (Dodds & Whiles, 2010). Nut Lake had high phosphate concentrations in 2019, as measured at multiple locations (Table 2.2) and Nut Lake Outlet concentrations were also high as water released by the dam moved downstream. This classifies Nut Lake as hypereutrophic (Smith et al. 1999) even after correcting for the overestimation of phosphate concentrations by the photometer. Yet in 2021, Nut Lake Outlet had 38% lower mean concentrations of phosphate ($F_{1,26} = 4.421$; $p = 0.045$) because drought-like conditions prevented the release of water from the dam upstream over a long period. Ammonia concentrations were similar in 2019 and 2021 ($F_{1, 26} = 0.632$; $p = 0.434$), which may owe to uptake by autotrophs within the reservoir and limited downstream release.

Overall, precipitation is a key factor in the movement of nutrients but also likely interacts with topography, abiotic features, and economic (agricultural) activities in the surrounding environment to dictate nutrient inputs and processing. During the 2019 study period, Saskatchewan experienced normal weather conditions, with average seasonal temperatures and more rain than in 2021. As noted above, there were instances of rapid increases in concentrations associated with precipitation in 2019. In 2019, nutrient concentrations were either stable or slightly increased from one period to the next; no dramatic increases in concentrations by precipitation were observed (Figure 2.6). Agricultural best management practices such as riparian buffers and precision fertilizer application rates could therefore prevent runoff during years with average seasonal temperatures and typical precipitation rates (Bosch et al. 2014).

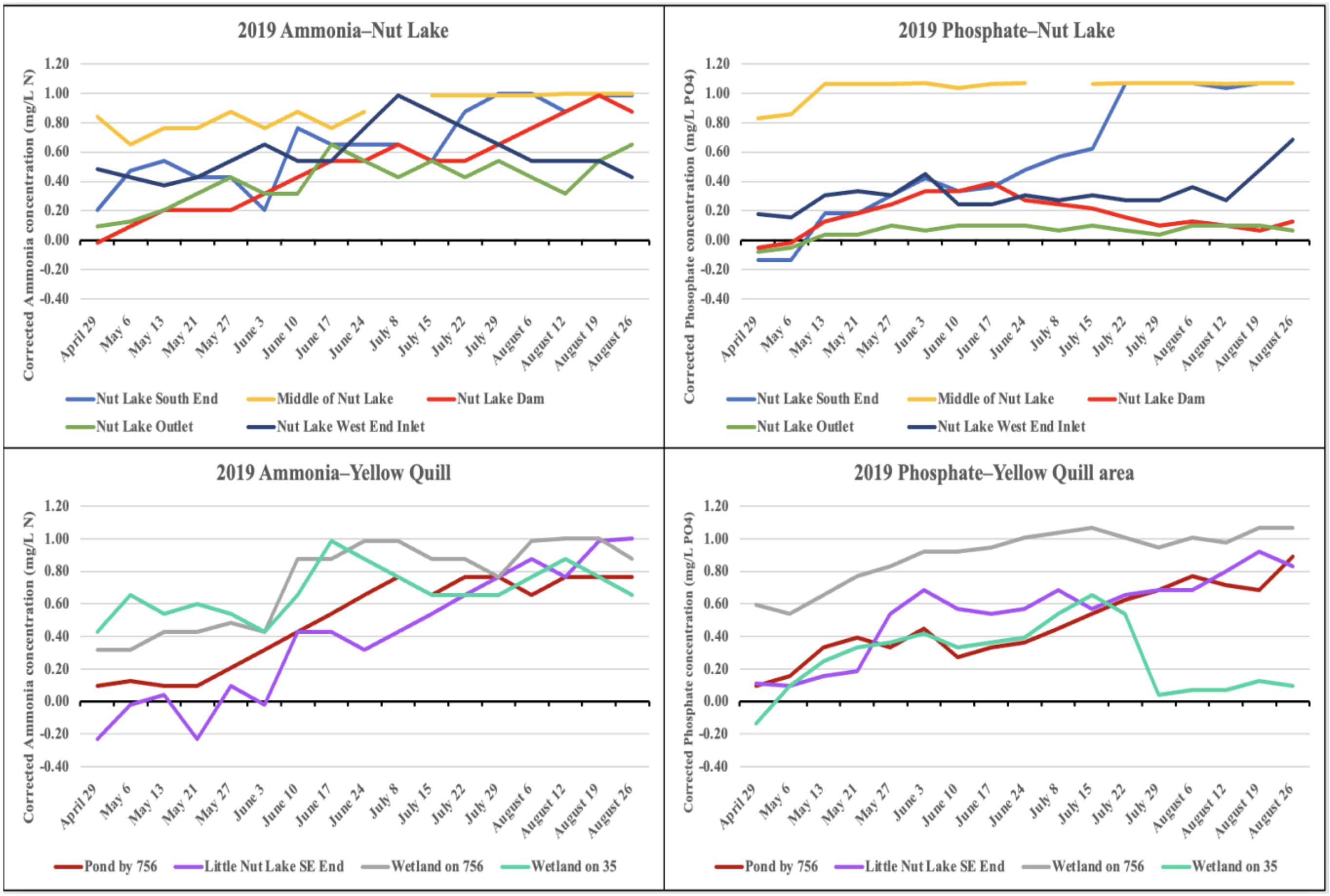

Figure 2.6: Nutrient Concentrations in 2019.
Concentrations of nutrients (ammonia, phosphate) from samples collected in 2019 outside the Yellow Quill First Nation (North of Kelvington, SK). Concentrations were measured using a YSI 9500 Photometer and corrected using best-fit equations relative to a SmartChem Analyser.

The 2021 sampling period was conducted during a drought year, with extreme conditions peaking in mid-summer and only two precipitation events occurring (Figure 2.5), both with less than average rainfall. Nutrient concentrations fluctuated but were inconsistent with a precipitation signal. After comparing the nutrient concentration and precipitation data (Figures 2.5, 2.7, 3.6; Table 3.3), I interpret that dry soil was the most common factor because of the high temperatures and lack of atmospheric moisture, limiting land runoff. Though this study did not measure soil contributions to nutrient levels in nearby lakes, this factor is mentioned by others as a stronger barrier to nutrient movement (Martin et al., 2021; Pan et al., 2019); this will require further investigation. Since ground saturation must occur before land runoff happens, the variability in measured concentrations during 2021 (Figure 2.7) was attributed to other factors, which are explained below. There were 32 observations of nutrient concentration increases and decreases in this year; I hypothesize four different factors, and their interactions, that influence these nutrient concentrations: 1) nutrient-enriched dust carried by the wind; 2) dilution or evaporation; 3) algal uptake; and 4) other causes, such as nearby road construction, livestock, and wildlife.

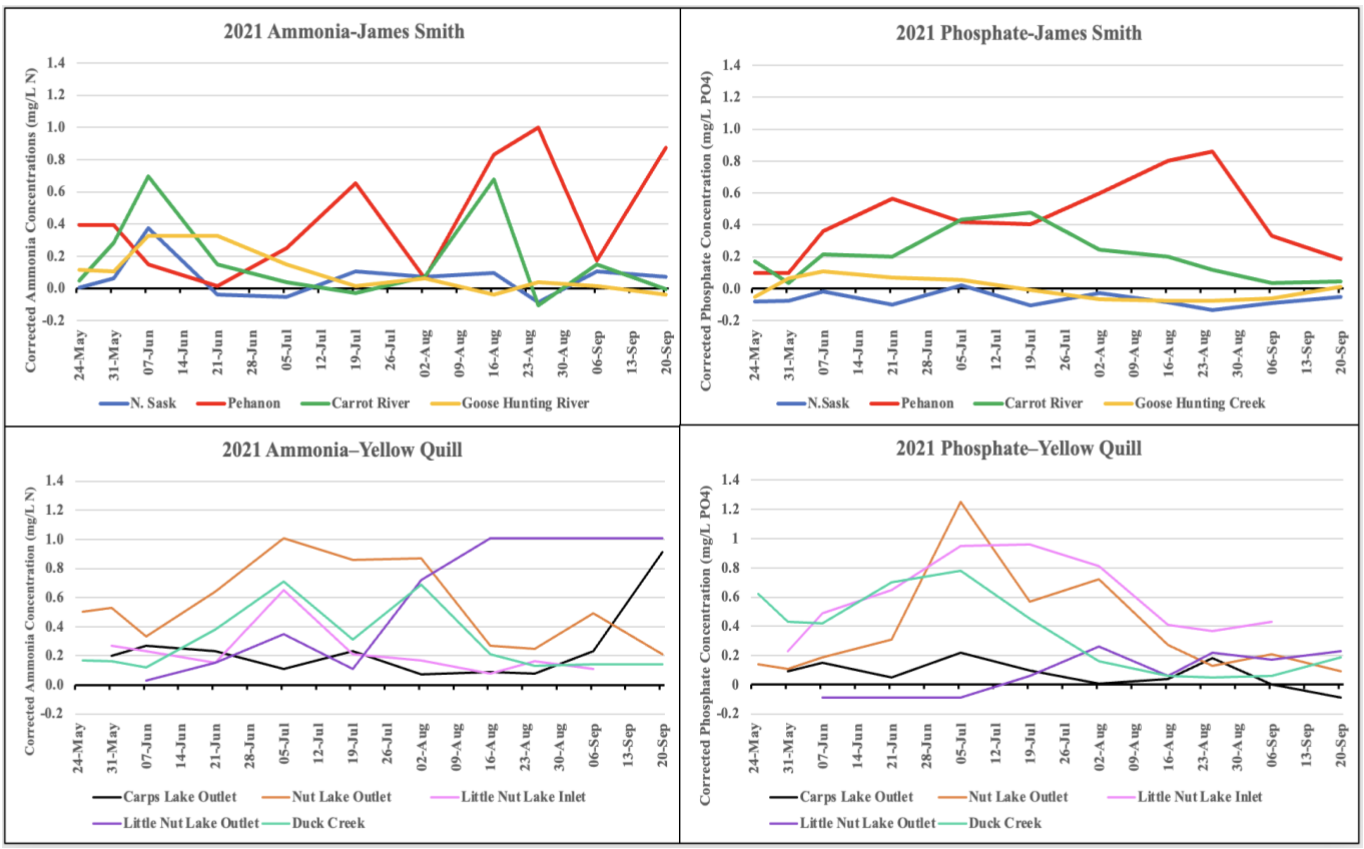

Figure 2.7: Nutrient Concentrations in 2021.
Concentrations of nutrients (ammonia, phosphate) from samples in 2021 outside the James Smith Cree Nation (West of Melfort, SK) and Yellow Quill First Nation Reserve (North of Kelvington, SK). Concentrations were measured using a YSI 9500 Photometer and corrected using best-fit equations relative to a SmartChem Analyser.

I interpret that the dry, hot weather in 2021 prevented the soil infiltration of added crop fertilizers and livestock wastes by reducing soil recharge and drying the ground surface, turning it into a fine dust that could be picked up by the wind and carried to another location. Therefore, when there are windy conditions and no precipitation, nutrient loading into freshwater bodies can happen through this wind-carried action. Research on industrial chemical dust settling on snowpacks and atmospheric contributions adds to the possibility that this process can occur during any season given the right conditions (Carling, Fernandez, & Johnson, 2012; Olsen et al, 2018).

Evaporation from standing waters (reservoirs and wetlands measured in 2021) was the second most common observation because of the high temperatures and minor amounts of rain in 2021. Long warm days in June and July likley led to gradual increases in ammonia concentrations in wetlands such as Duck Creek as their volume decreased. Dilution can also occur during intense rainfall events if runoff occurs over a low-nutrient landscape (Paerl et al. 2020; Celikkol et al. 2021).

When there is no correlation between precipitation or the other factors previously mentioned for nutrient decline, but algal growth is observed, it was suspected to be due to the uptake of those nutrients by algae (Reinl et al., 2021; Akomeah et al., 2020). There was no focus on specific algae species in this part of the study but algal biomass was recorded for another portion of this research project where algal growth was compared to nutrient concentration patterns. An example of nutrient decline by algal uptake happened at Pehanon on August 2nd, when ammonia concentrations dropped by more than half (0.6 to 0.1 mg/L) from the previous measurement two weeks prior. The total abundance of algae on August 9th showed a 72% increase since July 26th. Despite evaporation, nutrient concentrations continued to drop. I conclude that fast uptake by existing algae species caused the drop in ammonia during this period.

Other possible causes of nutrient loading in freshwater systems include runoff from nearby road construction, livestock wastes, and wildlife within a catchment. These factors were observed during the field sampling and could potentially impact results. Others have reported that construction materials, road treatments, and soil disruption from construction can affect algae bloom rates (Stoler et al., 2017; Al Quraishi, 2020). Chemicals used in road construction are less likely to directly influence concentrations of nutrients when protective measures are taken to reduce possible risk, such as plastic sheeting along the banks of a water source. Livestock (often cattle) and wildlife can directly introduce nutrients, mainly ammonia, from their waste. Animal inputs could create a spike in nutrients, especially when there are large aggregations, such as a cattle herd (Derlet et al 2010; 2012). Nut Lake Outlet and Duck Creek are two sites where animals were observed standing in and close to the water for almost half of the trips to the field. The former site gradually increased in ammonia (0.68 mg/L) over a month (June 7–July 5) when there was very little to no rain and rising temperatures.

2.4 Conclusions

Worldwide, agriculturists are being pushed for higher production, leading to increases in use of fertilizers to optimize crop yield (Weersink et al., 2019), placing a strain on the surrounding natural environment (Farkas, 2019; Bailey et al. 2020; Painter et al., 2021). This study focused on the accuracy of two tools to measure nutrients in the field in Canadian Prairie freshwater systems, affecting surface water quality. Though finding an effective solution to water management is far more complex than monitoring nutrient levels, this is one key aspect that needs to be understood and maintained to improve current surface water quality.

Spatial and temporal variation in nutrient concentrations in these Canadian Prairie freshwater systems, and periodic increases that exceeded eutrophication thresholds, emphasizes the need for continued monitoring. This monitoring should be a continuous process with some degree of flexibility to accommodate future changes in anthropogenic and climate pressures on the environment. Since the prairie climate fluctuates between normal and adverse conditions, past predictability is no longer viable for environmental management and planning (De Löe & Plummer, 2010). Monitoring tools need improvement to help capture these variations with higher precision and accuracy.

The data in this study show that precipitation is not always the main driver for nutrient concentrations, particularly in areas experiencing drought. Based on the patterns found, there are multiple interacting factors with varying influences on nutrients. During an abnormally hot prairie summer, leading influencers on nutrient concentrations could include evaporation, nutrient-enriched dust carried by the wind, algal uptake, and other causes, such as wastes from livestock. Past water management strategies that are '*one size fits all'* solutions no longer have the same impact they once did for a variety of reasons including increasing human pressures. With the rising complexity of factors impacting nutrient loading, there is a need to develop strategies best suited to tackle the combination of needs unique to each affected region.

The prairie climate is changing rapidly, giving researchers little time to gather and interpret data meant to inform policy- and decision-makers on climate action solutions. Field research projects can be challenging, costing time, money, and effort, especially when the research involves a large or remote region, and the research team is small. Community science methods can alleviate some of these challenges. Community science is becoming accepted as a suitable research method by both professionals and the public (Herman-Mercer et al., 2018; Wilderman et al., 2007), and as a viable means to gather more data in a shorter amount of time and over a more extensive study area. Issues arise when biased opinions on the validity of results collected by community scientists prevent the data from being accepted as evidence during policy and planning discussions. This adds a limitation to the use of community science; that is, device accuracy, but researchers are working to remove it by testing methods and providing detailed evidence on the benefits and success of these methods (Herman-Mercer et al., 2018; Wilson et al., 2018; Capdevila et al., 2020; Waldner et al., 2017; Gérin-Lajoie et al., 2018).

Continuous, long-term nutrient monitoring can be conducted through local community involvement in science methods while maintaining a professional relationship between communities and institutions. Collaborative strategies allow small communities and youth to participate in research that will benefit their community, gain experience, and may illicit some interest in scientific research as a career option. Relationships between the public and professional institutions can grow public trust in expert information and advice and encourage further community-based research in the future. For Indigenous Peoples, studies like this one act as a channel for cultural representation, where their voice and traditional perspectives are not only heard but valued and centred in the research process. Therefore, collaboration benefits all actors involved, creating level ground in responsibility, roles, jurisdiction, and discussion to achieve a shared goal.

This project emphasizes the need for researchers to take data accuracy seriously by thoroughly testing methods and making the necessary adjustments to optimize them to reduce potential errors (Mijares et al., 2018; Herman-Mercer et al., 2018). For the YSI 9500 Photometer and Nutrient App, adjustments are needed in the testing procedure, the digital algorithm, or a different form of the chemical reagents (i.e., liquid reagents instead of solid tablets). This paper provides in-field testing that can serve as input to developers on the limitations and accuracy of their device, along with some considerations on improvements. Overall, this study builds upon current literature emphasizing that community science methods are beneficial for long-term nutrient and water quality monitoring, and collaboration among diverse cultural, knowledge, and perspective (defined in Cultural Theory) groups is both invited, and necessary, for successful monitoring and management of on-reserve water sources.

CHAPTER 3 PREFACE

A Cultural Theory Story of Watershed Management: Part 2 Egalitarianism, Fatalism, and Hierarchy

Omar believes everyone deserves equitable access to basic needs and that those basic needs are provided in accordance with the law; these views align with the egalitarian way of life. He works as the manager for the Casper River Watershed Association (CRWA), which mainly assists crop producers and cattle farmers with testing nutrient levels in their water to prevent algal blooms that affect the health of their livestock. Lately, health authorities have been reporting frequent cases of water-related illnesses, and cyanotoxin exposures, in the Casper River Basin. Omar, the executive director, and other members of the CRWA want to help out by starting a community science cyanobacteria monitoring program. However, the association is a non-government organization (NGO) and they do not have enough funds to initiate new projects independently, or even buy equipment and reagents right now. Omar may be able to do these projects if he is able to partner with another organization who can share the financial costs and recruit volunteers from local communities. Omar first makes some calls to potential partner organizations. Without partnering with another organization, the project can't be initiated.

Dante manages the watershed organization for the Caribou Lake Basin, downstream from the Casper River Basin. He was called by Omar about an offer to partner in a monitoring project. Unfortunately, Dante had to refuse; his organization is also struggling with capacity building issues and experienced failures to acquire more financial support or establish partnerships. Due to these past failings, Dante's views are more fatalist, making him believe that partnering with the CRWA won't ensure the monitoring program will last or be successful. As the manager, he needs to be careful and conserve the funds his organization currently has for the projects where they are accountable to outside agencies. If their budget is blown, people will lose their jobs.

Aki is a Saulteaux woman and an Elder from Waaseyaa First Nation community. She has been experiencing poor water quality in the source waters of her community. And for the majority of her life, despite many fights in court to improve water for Indigenous peoples, there has been only minimal improvement. Her community has been placed under another DWA for the last few months since their treatment plant can't remove cyanotoxins and people in her community feel they are still getting sick from the water. Years before, there were opportunities within the watershed agencies for Indigenous Peoples to engage and help but there hasn't been any recently. Her nephews came home from school one day after a new environmental club was established where they learned how to use an app for water quality monitoring. They were so eager to do more, until they realized there was so much nitrogen in the water that their app couldn't spit out accurate information anymore. Then, they quit the environmental club. Eventually, Aki gave up on hoping for something to change and has accepted that there is little she can do to help with any of the water problems in the community. She was once hopeful when she believed there may be a chance to improve community water but has become disheartened over time with the recurrence of negative impacts on community health and well-being and the continued legal struggles over water.

Trudy works for the provincial government and has a hierarchical viewpoint. Trudy is aware of the health authority reports on cyanobacteria exposure in some local pets and livestock, and other exposures in remote and rural Indigenous communities, but since they are not within her jurisdiction (reserves are federal) and her job involves urban public policy, she takes no action. Additionally, she hasn't participated in any community-engagement projects for work, and has never experienced poor drinking water quality, suffered a water-borne illness, and has always been financially stable (raised in an upper-middle class family). Her lack of experience in these types of situations has made Trudy apathetic, and she does not entertain the thought of talking to or offering support to affected communities not within urban centres under provincial jurisdiction. Also, there has been quite a bit of inter-jurisdictional tensions between the provincial and federal governments; it has gotten to the point where government employees are sharing the feeling of "it's happening in their jurisdiction, they should deal with it themselves." Trudy just scrolls past the headlines onto the financial reporting, looks intently at the weather forecast, and checks her calendar against the notices of public open houses and meetings coming up this week.

This story presents the inter-jurisdictional tensions in watershed management and how the differences in experiences, current struggles, and personal interactions affect how individuals view the overall situation and act. The hierarchic agents (Trudy) may or may not be aware of their power and privileges. They stick within their well-defined and protected boundaries and mechanisms for interacting. They exert pressure on others to comply. In addition, they follow the rules with the belief that the rules apply to everyone to maintain the order in a system. Omar (representing egalitarianism) is in much the same position as Suzanne, wanting to make things fairer across the watershed; however, he encounters two fatalists and cannot build the partnerships and collaboration he needs because of their feelings of defeat. Both Dante and Aki (representing fatalism) feel powerless to invoke change and have retreated to positions of self-preservation, with the belief that chaos, futility and social exclusion are to be expected. This situation could be improved with more efforts by all individuals to communicate, create partnerships, and collaborate on environmental projects that will lead to positive social and environmental impacts. Government agents, like Trudy, could directly contact Indigenous community representatives regarding their water problems, create systems for reporting of policy breaches, see that communication opportunities like open houses and meetings are accessible, and implement suggestions into new draft policy. The federal and provincial governments could contact watershed organizations to discuss the projects that Indigenous communities, and watershed agencies want to do, and establish a partnership so those projects can be initiated. Organizations, like Omar's and Dante's, should remain open to potential partnerships with governments and other organizations, despite past fallouts in project planning. Furthermore, watershed organizations could promote their projects to local communities to encourage participation, starting with youth so a generation of collaborators develops. Partnerships among various authority groups, from stakeholders to government, can not only share resources for project success, but will provide more knowledge-sharing and cross-cultural learning. Stakeholder groups and members of affected communities, like Aki, could participate in these promoted projects, even if past experiences have made them reluctant. By participating, individuals not only support the progress of a project, but gain insight into the perspectives of other individuals and a clearer understanding of the overall problems, working constraints of collaborators, and gaps in knowledge and inclusion. With more participants involved in projects like these, more data and information can be gathered and shared, leading toward the development of creative solutions, decreasing the vulnerability of impacted regions, and promoting stronger resilience against possible future challenges.

Story as Analogy: Part 2

This preface provides insight into how the diversity of perspective groups interact within watershed management to influence public voice, and environmental empowerment and movements for monitoring for public health. The lack of both, due to under resourcing and anchoring on past failures results in inaction, project failures, and in this case, could precede a rapid production of algae blooms and increased risk of cyanotoxin exposure (Chapter 3). In order to document risks for the Indigenous communities given a lack of capacity and partnerships, in Chapter Three, I investigate the existence of cyanotoxins in Treaty 4 and 5 waterways, identify them, and produce a typology so communities can work on predicting which characteristics of a waterway may be contributing to algal bloom potential. The identified threats from the classification/typology will support the prioritizing of certain watershed components for remediation, which could prevent greater spread of cyanotoxin-producing bacteria. The greater analogy is that the opposing viewpoints among agencies responsible for public actions (i.e., government agencies at federal and provincial levels), could make greater use of community monitoring and partnerships with local organizations and local people (especially youth) if they can overcome the inertia between egalitarian, fatalist, and hierarchical forces. This work is currently being reformatted for submission to the Environmental Health Insight Journal for publication.

Image 1: Little Nut Lake Outlet with large algal bloom growth. Uncontrolled growth of an algal bloom occurs due to excessive nutrient loading from agricultural croplands and pastures surrounding the lake.

CHAPTER 3: NUTRIENT-ALGAL RELATIONSHIPS AND CYANOBACTERIA MONITORING

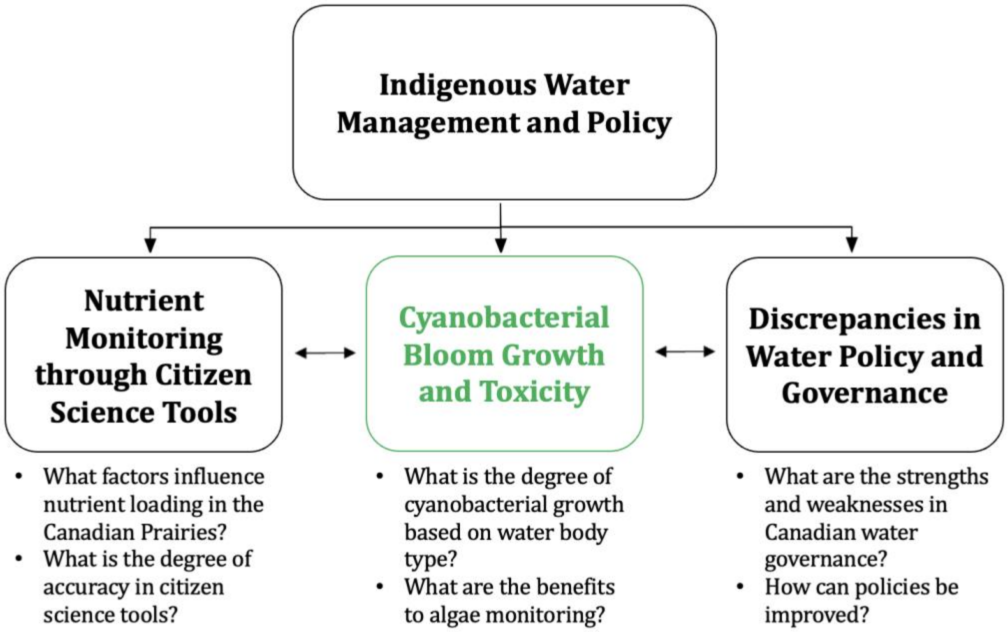

Figure 3.1: Graphical Abstract of Research Project; Cyanobacteria Monitoring
Graphical Abstract of Research Project. This study focuses on cyanobacterial growth in drinking water resources used by participating Indigenous communities and the impacts on community health and culture (in green) and fill in some of the knowledge gaps on interconnections between the environmental and social components to sustainable Indigenous watershed management.

3.1 Cyanobacteria Development and Impact on Human Health and Water Management

Often, discoloured water with odours or a green algal scum floating on the surface are perceived negatively because they can signify the potential for harmful algal blooms (HABs). In all environments, phototrophic species are the essential base trophic level needed for a healthy system, starting the energy transfer chain that determines the degree of survival and reproduction in higher trophic level species. Without external forces impacting them, most natural environments, and the biodiversity within them, are self-regulating and stable. The economic growth of Canadian Agriculture and a climate fluctuating between weather extremes are straining natural environments in multiple ways, one being excess nutrient loading into freshwater systems. Aquatic ecosystems are sensitive to shifts in nutrient loading (Aoki, 2003), especially in systems where toxin-producing cyanobacteria are present, impacting the biodiversity of higher trophic levels and the safety of water for consumption and recreation. With increased nutrient loading, the biomass of cyanobacteria is expected to increase, shifting algal blooms from healthy to toxic.

Current literature tells us there is a strong correlation between algal growth and excess nutrient loading (e.g. Paerl and Paul, 2011; McKindles et al., 2019). Kling et al. (2011) found rising concentrations of chlorophyll-a (a photosynthetic pigment) and essential nutrients for algal growth (nitrogen and phosphorus) in lake sediment cores dating back to the 1950s. Evidence like this indicates that the increasing growth of algal blooms correlates with the surrounding economic activities, such as mining, agriculture, and urban development. Over 50% of annual phosphorus inputs are from agriculture (Paerl, 2018) and nitrogen, a compound necessary to produce cyanotoxins (Levy, 2017; Ginger et al., 2017; Monchamp et al., 2014), is commonly sourced from crop fertilizers. Many crop and livestock producers in Saskatchewan have made efforts to reduce excessive nutrient inputs into water systems. Some employed approaches are fencing livestock away from water resources, establishing and maintaining riparian zones, and switching to alternative methods to fertilize their lands, such as zero-tillage or introducing natural nitrogen-fixing bacteria. From what was seen during field sampling, not everyone is following these practices, either by choice or financial restrictions. Additionally, the increasing occurrence and intensity of harsh weather conditions not previously considered may begin to have greater influence over nutrient loading as climate change strengthens.

When changing climate conditions are combined with economic pressures, conditions occur that are ideal for toxic species to survive and thrive. Some of the climate conditions that cyanobacteria flourish in include low-flushing rates, high water temperatures (15–30ºC), high nutrient inputs, and overly acidic or basic pH levels (for most cyanobacteria species) (Svrcek & Smith, 2004, Levy, 2017; O'Keeffe 2019; Paerl, 2017). Other environmental factors can influence the production and release of cyanobacterial toxins into water (Schmidt, Wilhelm, & Boyer, 2014; Romero et al., 2014). The ability of cyanobacteria to easily dominate a bloom is due to specialized features that enable them to outcompete harmless species, especially in climates that continue to shift in favour of cyanobacterial harmful algal blooms (cHABs), such as resistance to higher temperatures, extreme hyper- and hypoxic levels of dissolved oxygen (O'Keeffe, 2019; Paerl, 2017), and fluctuating pH levels for a few species (Levy, 2017). Other specialized traits also provide an advantage when competing with other taxa for nutrients (Paerl & Paul, 2011) and avoiding predators with toxins and (sometimes) their filamentous structure (Levy, 2017). The ability to store excess nutrients gives cyanobacteria an advantage in water systems with few suspended nutrients, essentially starving other algal species, which are an essential food source for planktonic consumers (Galloway et al. 2014).

Societal issues arise when these toxins reach consumers, especially in small rural areas, impacting community health. For decades, an increased frequency of cyanobacteria-dominated blooms has been observed around the globe, placing risk on human health, particularly in small communities dependent on surface waters for source water, recreation, and cultural needs (Codd, 1995; Paerl, 2018; Hanrahan, 2017; Lebel & Reed, 2010; Dunn et al., 2014). Cyanobacteria produce secondary metabolites known as "cyanotoxins," affecting different organs within the body (Papadimitriou et al., 2012; Svrcek & Smith, 2004). Based on which bodily structures they most commonly affect, these toxins are categorized into four families (dermatotoxins/endotoxins, hepatotoxins, neurotoxins, and cytotoxins) (Table 3.1; Svirčev et al., 2017). A person can experience chronic to acute symptoms of cyanotoxin exposure, depending on the toxin type and amount, the person's current state of health, and how often the exposure recurs. Acute effects happen more often but are easier to treat, such as fevers, skin and eye irritations and mild GI distress. Chronic impacts don't occur as often but are more challenging to treat and can be life-threatening, such as tumor growth, damage to structural tissues, hemorrhaging and tissue necrosis (Drobac et al., 2016; Koreivienė, 2014; Schmidt, Wilhelm, & Boyer, 2014). Cyanobacterial bloom contamination in rural water sources also impacts the mental and spiritual wellbeing of Indigenous Peoples living in reserve communities since it restricts their traditional lifestyles and ceremonial practices (McQueen et al., 2007; Fortin et al., 2010; Carmichael and Boyer, 2016).

Category	**Toxins**	**Impacted Systems/Organs**	**Common Symptoms**
Dermatotoxins/ Endotoxins	Lipopolysaccharide, Lyngbyatoxin, Aplysiatoxin	Skin, eyes, ears, gastrointestinal tract	Eye and ear irritation, sore throat, dermatitis, conjunctivitis, GI inflammation and distress, fever, septic shock (in high doses); tumor growth
Hepatotoxins	Microcystin, Nodularin	Liver, kidneys, spleen, adrenal glands, pancreas	Liver or kidney damage/ hemorrhaging/death, diabetes, chronic energy loss, abdominal pain, gastroenteritis, tumor growth
Neurotoxins	Anatoxin, Saxitoxin, β-N-methylamino-L-alanine (BMAA)	Nervous System	Paralysis of skeletal or respiratory muscles, neurodegeneration, dementia, hearing loss or tinnitus
Cytotoxins	Cylindrospermopsis	Any part	Cell damage/death

Table 3.1: Cyanotoxin Categories and Affected Body Systems
Cyanotoxins are organized into categories based on affected bodily systems and organs. Common symptoms for each toxins category are included.

3.2 Need for and Beneficial use of Algal Community Assessments and Monitoring

Monitoring of nutrients in source waters is needed so that awareness can be raised on potential threats to health, wellbeing, and cultural practices. Assessments of the abundance and taxonomic composition of algal species are equally important. Current literature has stated that there is a lack of algae monitoring in freshwater systems (O'Keeffe, 2019; Svirčev et al., 2017), including the identification and quantification of all present species. Assessments are often conducted after local health is negatively impacted after contact with contaminated water or when there is suspicion of a harmful algal bloom (HAB). Outbreaks like these can be pre-empted with the use of regular monitoring and assessments of algae in recreational and domestic water sources. There are multiple reasons why regular monitoring is beneficial, including climate change, growing industries in the surrounding area, data collection and ecological awareness, protection of local community health and capacity growth, and community participation in monitoring efforts (Shrubsole et al., 2016; Bradford et al., 2018; Lebel & Reed, 2010; Hanrahan, 2017).

Just like the differences in nutrient concentrations due to various factors (Chapter 2), alterations in weather and other external factors, such as temperature changes or degree of light exposure, can potentially impact algal growth or loss and may also influence the proportional difference between algal types, resulting in different toxicity levels. By continuously monitoring over multiple years, seasons, and weather conditions, the data from algae monitoring can provide information on shifting trends and correlations between growth, toxicity, the environment, and society. Depending on which methods are used to monitor freshwater systems for algal growth, monitoring can also be another avenue for community-based research, Indigenous and community participation, public awareness, informative adaptive planning, and decisive watershed management action. In partnered communities, anecdotal stories from community members built interest in the leadership about the frequency and composition of algal blooms, and concerns over traditional cultural practices which involved using reserve surface water for ceremony.

Financial support from the Federal Government has been made to remedy some problems of watershed safety (Lam et al., 2017; Arsenault et al., 2018) but had little success since investments have been insufficient to cover operational costs for widespread, continuous monitoring of water quality across watersheds. Assessing algal communities could also help focus educational campaigns to people living in watersheds with growing algal abundance, to prevent exposure during recreational or cultural uses of water, pets and livestock exposure, and downstream water supplies.

Monitoring and algal assessments are additional layers of protection to the overall health of communities; for Indigenous Peoples, protecting one's health includes spiritual health and cultural identity (Anderson et al., 2013; Fortin et al., 2010; Carmichael and Boyer, 2016). Algal assessments will help watershed managers and health officials determine what actions they need to take to ensure safe surface waters and protect user health. The emotional and mental wellbeing of individuals are also negatively impacted when some traditional practices and ceremonies are avoided to prevent exposure to contaminants. Water is a powerful spiritual component in Indigenous culture and to be unable to practice those traditions and teachings threatens Indigenous identity (Whyte et al., 2013).

Community-based monitoring programs are one way Indigenous Peoples can be involved in watershed management, adding their voice, views, and practices to the process for making decision on BMPs that protect water in their communities (Bradford et al., 2017; Arsenault et al., 2018). Earlier, we discussed the importance of community science in nutrient monitoring; the same would apply when monitoring algal blooms. By participating in the algae assessment process, Indigenous members will gain opportunity to share knowledge of algal species from firsthand experience and traditional stories, and gain knowledge and skills in future planning. This is particularly important for treatment facility operators and community representatives on effective water treatment practices for specific cyanobacteria species. Participating community members can 1) learn about western conceptions of the aquatic ecosystem at the microscopic level, along with how these species impact their daily lives, and 2) learn new skills and research techniques such as how to identify species and whether a species is harmful or not. Non-Indigenous project members can learn from Indigenous Peoples through their perspectives, knowledge, and environmental protection practices. Collaboration may also encourage youth to continue participating in community-based research projects or pursue careers in environmental protection and research (Aristeidou et al., 2021). Both Indigenous and non-Indigenous individuals will benefit and learn from one another while monitoring water through a mutual relationship based on respect, understanding, and a shared goal to protect the water resource (Simms et al., 2016; Arsenault et al., 2018; Bradford et al., 2017).

3.3 Study Purpose and Objectives

In this study, I measured the abundance of three common groups of autotrophs (cyanobacteria, diatoms, and harmless algae – including green, yellow, golden, and yellow-green) in assemblages from Canadian prairie lakes surrounding and in Indigenous territories. The purpose of this was to determine the frequency with which cyanobacteria dominates communities in freshwater systems in these dryland systems and to compare them to agricultural nutrient concentrations. This study provides insight into the necessity for algae monitoring in SWPPs and emphasizes the importance of algae monitoring and collaboration among diverse authority, knowledge, and perspective groups through community science methods as a long-term preventative action.

Specifically, the study aims to:

1. Identify algae species found in water resources that flow through Indigenous communities participating in this study.
2. Determine the composition of blooms and the total abundance of each group to determine dominance (cyanobacteria, harmless algae, diatoms).

3. Compare algal bloom biomass patterns to nutrient concentrations to determine the degree of correlation and determine if there is a method for cyanobacteria growth prediction.
4. Develop a simple categorical system visualizing the estimated cyanobacteria growth in different waterbody types.

3.4 Methods: Algal Bloom Sampling, Processing, and Identification

In 2021, water samples were collected (grab samples) from nine sites in the surrounding area of James Smith Cree Nation and Yellow Quill First Nation, including the North Saskatchewan River. Sampling occurred weekly from May 24th to August 25th, then bi-weekly in September. Due to Covid-19 restrictions implemented at the time of this research, all samples (n=79) were collected from sites outside reserve boundaries (refer to *Study Sites* in Chapter 2) and analysed at an off-campus laboratory setting. Microscopy methods were used to quantify the algal community composition and total abundance in water samples by identifying and counting individual algae cells with a compound and a dissection microscope in a standard-sized field of view. Concentrations of ammonia and phosphate were measured with a YSI 9500 photometer, corrected relative to measurements on a SmartChem Analyzer, and reported previously in Chapter 2.

For algal identifications, a vacuum filtration kit was used to filter 50 mL of lake water through a 0.45µm membrane filter; the filter was dried for 3 days at 65ºC in a portable incubator. Once filters were dried, a 1cm^2 piece from each sample was mounted onto a slide with a 70% glycerin mixture. Slides were examined for diatoms, harmless algae species, and cyanobacteria. Diatoms were included in the analysis as they are long-term indicators of particulate organic matter (POM) retention and processing (Heindel, 2021). Two keys for freshwater algae identification were used: A Key to the More Frequently Occurring Freshwater

Algae (Bellinger & Sigee, 2010) and the Canadian Algae Identification Field Guide (Serediak et al., 2011). Species were enumerated to estimate the total abundance of each category (diatoms, harmless algae, and cyanobacteria), bloom composition, and average cyanobacterial biomass at each study site. Cell densities were also calculated by multiplying the total number of cells counted in the 1 cm^2 aliquot by the total filter area (assuming an even distribution of cells across the surface of the filter), then dividing by the volume filtered. These densities were compared to trophic status thresholds (EPA 2003) to enable classification of these waterbodies according to eutrophication risk.

Based on the collected data on cyanobacteria abundance, I created a categorical system that attempts to explain the estimated differences in cyanobacteria growth throughout different parts of a water system. Water sampling sites were first characterized by waterbody type, either as a lake, outlet, river, or stream. The degree of cyanobacterial growth was determined by the calculated average and maximum cyanobacteria density (cells per Litre) over the study period (Table 3.2). Cyanobacteria estimates are categorized by waterbody type and any additional abiotic features that influences cyanobacteria biomass (e.g., light exposure, flow rate). The order of categories was determined by comparing the average cyanobacteria biomass data from each site to the WHO Guidance Values for health risks to cyanobacterial exposure (EPA, 2003).

3.5 Results

3.5.1 Algae Species Identification

Seventeen green algae, two golden and two yellow-green algae, twelve diatoms, and eleven cyanobacteria were identified within the water samples collected at nine sites (Table 3.2). Across all study sites, *Chlorella, Coelosphaerium, Mougeotia, Pediastrum*, and *Spirogyra* are the most common green algae species found. The presence of cyanobacteria is a greater concern because of their production of toxins potentially harmful to human and animal health. The most common cyanobacteria found in all study sites are *Anabaena, Microcystis, Gloeocapsa, Gomphosphaeria, Lyngbya,* and *Oscillatoria*. These species commonly produce anatoxins, microcystins, and saxitoxins (O'Keeffe, 2019; Schmidt, Wilhelm, & Boyer, 2014). Common symptoms induced by these toxins are oxidative stress on the liver, hepatic hemorrhaging, tumor development, gastrointestinal distress, and dermatitis (rashes and blistering).

Type	Genus	Sites Found
Diatom	Amphora	1, 2, 4–9
	Asterionella	7, 8
	Cyclotella	1–3, 8, 9
	Cymatopleura	1, 4, 7
	Cymbella	1, 8
	Fragilaria	4, 6, 7
	Gyrosigma	1–4, 7, 9
	Melosira	7
	Navicula	All sites
	Stauroneis	7
	Surirella	4, 5
	Synedra	1
Golden Algae (Harmless)	Synura	2, 4, 7–9
	Uroglena	6
Yellow-green Algae (Harmless)	Tribonema	4, 6, 8, 9
	Vaucheria	7

Type	Genus	Sites Found
Green Algae (Harmless)	Chlamydomonas	6
	Chlorella	All sites
	Closterium	5–9
	Coelosphaerium	All sites
	Eudorina	5, 7–9
	Gonium	5
	Hydrodictyon	1
	Microspora	1, 2, 4, 7
	Mougeotia	2–8
	Pandorina	5, 7
	Pediastrum	2–9
	Scenedesmus	5, 6, 8
	Selenastrum	2
	Spirogyra	2, 4–8
	Volvox	2, 8
	Westella	3–5, 7–9
	Zygnema	2, 4–6

Type	Genus	Sites Found	Toxins Produced
Cyanobacteria	Anabaena	1–5, 7–9	Microcystins, Saxitoxins, Cylindrospermopsins, Anatoxins, Lipopolysaccharide
	Aphanizomenon	1, 3, 6	Microcystins, Saxitoxins, Cylindrospermopsins, Anatoxins, Lipopolysaccharide
	Aphonacapsa	2	Microcystins, Lipopolysaccharide
	Chroococcus	1–, 5, 7, 9	Lipopolysaccharide
	Gloeocapsa	All sites	Lipopolysaccharide
	Gloeotrichia	5, 6, 8	Lipopolysaccharide
	Gomphosphaeria	1, 2, 4–9	Lipopolysaccharide
	Lyngbya	2–9	Saxitoxins, Lipopolysaccharide, Lyngbyatoxins
	Microcystis	All sites	Microcystins, Nodularian, Anatoxins, Lipopolysaccharide
	Oscillatoria	All sites	Microcystins, Saxitoxins, Anatoxins, Lipopolysaccharide, Aplysiatoxins
	Spirulina	4, 8	Lipopolysaccharide

Table 3.2: List of found diatoms, harmless algae, and cyanobacteria in sampled sites.
Potential toxins from cyanobacteria included. Refer to Table 2.2 for sites: bottom half of table from North Saskatchewan River to Duck Lake in numberical order.Refer to Table 3.1 for details on which bodily systems are impacted by cyanotoxins.

3.5.2 Algal Bloom Composition and Dominance

Algal bloom composition shifts over time due to various factors such as water temperature, precipitation, and wind movement across the water's surface, but the main factor to cyanobacterial growth is the availability of nutrients, mainly phosphates. The 2021 summer was abnormally hot in Western Canada, with a 7-day heat dome (June 27-July 3) that had temperatures ranging between 28-36ºC, exacerbating the already present drought-like conditions and less than average seasonal rainfall (Figure 2.5). The change in weather had substantial impacts on the movement of nutrients, and influenced the growth and toxicity patterns of algal blooms. It is beneficial to understand bloom development and monitor bloom composition (particularly the dominating species) since their growth will impact the ecosystem's health and residents in nearby locations.

Kling et al. (2011) stated that >90% of North American algae blooms are dominated by cyanobacteria by mid-late summer. This pattern was associated with algae bloom formation in lakes, often in lakes that are isolated, or the central watershed catch basin. In lakes that are part of a more extensive system, connected by streams, rivers, and wetlands, the mid-summer cHAB pattern often does not account for the growth and loss of algae at upstream locations. This study found that lake and lake outlets had cyanobacteria-dominated blooms that would start in mid-summer, then increase gradually, while streams and rivers showed varying dominance over time. It is important to note that the highest density of cyanobacteria (parts per Liter) mainly occurred in August to early-September for every study site.

Frequent shifts in bloom dominance between cyanobacteria and harmless algae species dominance was observed in some of the sampling sites (N. Sask. River, Pehanon, Carrot River, and Carps Lake Outlet) over the 2021 summer (Figures 3.4 & 3.5). Differences in algae development among sites are likely due to a unique combination of factors, such as the water system size, flow rate and retention time, occurrence of evaporation or precipitation, and how available nutrients were entering the systems. Each of these sites had differences in width, flow rate, and depth, so it is not clear why cyanobacteria-dominated blooms would appear one week and then disappear in the next. It is unknown if and how blooms form in these systems in years of greater precipitation and lower temperatures. This not only shows that continuous monitoring of nutrient concentrations in freshwater systems are needed, but the drivers to these frequent shifts should also be investigated further.

Figure 3.2: Algal Bloom Composition in James Smith Waterways
Algal bloom composition from study sites in the area outside the James Smith Cree Nation Reservation. Composition is indicated by the percentage of diatoms, harmless algae (includes golden, yellow-green, and green algae), and cyanobacteria species within the algal bloom at each site.

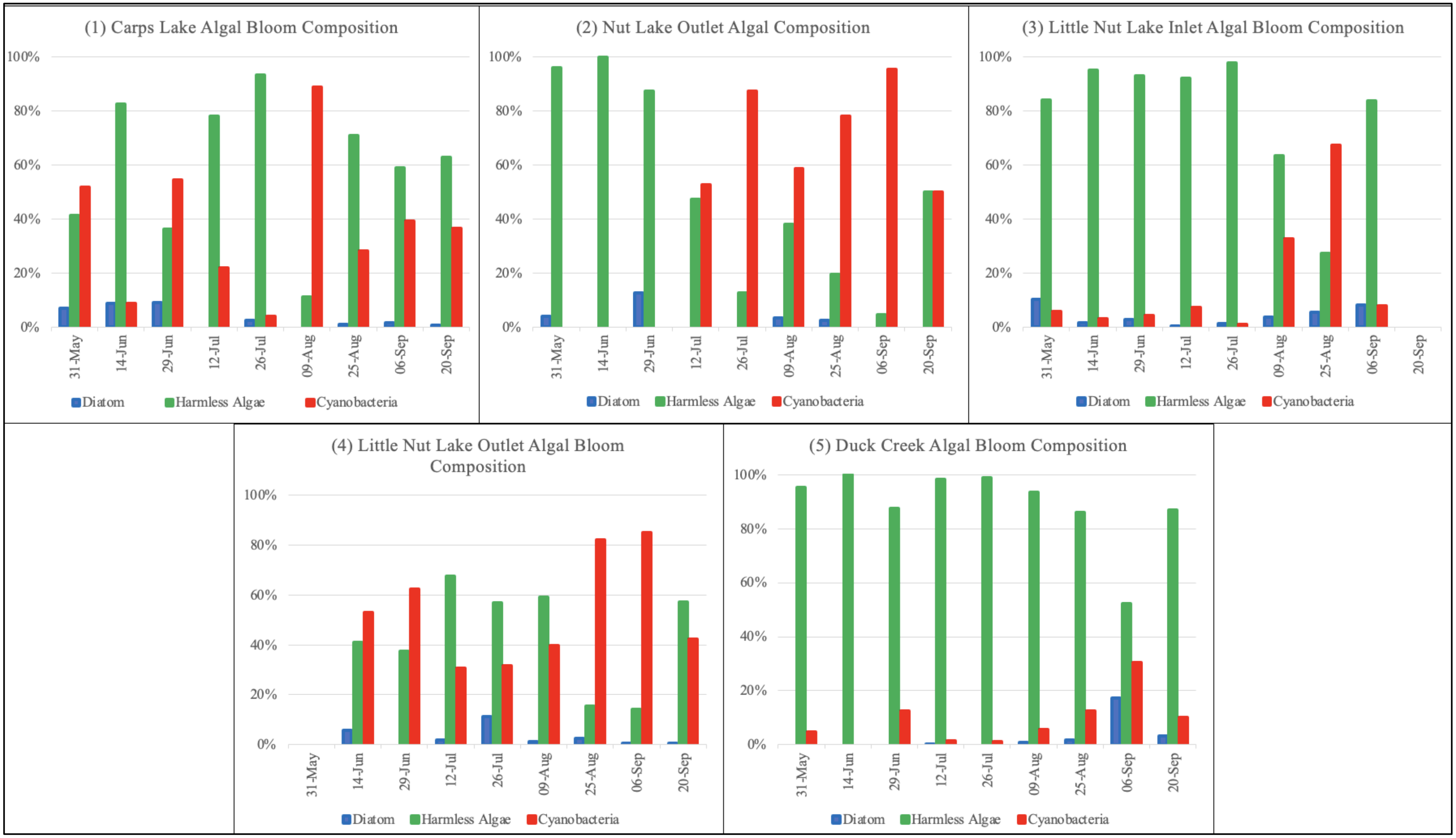

Figure 3.3: Algal Bloom Composition in Yellow Quill Waterways
Algal Bloom Composition from study sites in the area outside the Yellow Quill First Nation Reservation. Composition is indicated by the percentage of diatoms, harmless algae (includes golden, yellow-green, and green algae), and cyanobacteria species within the algal bloom at each site.

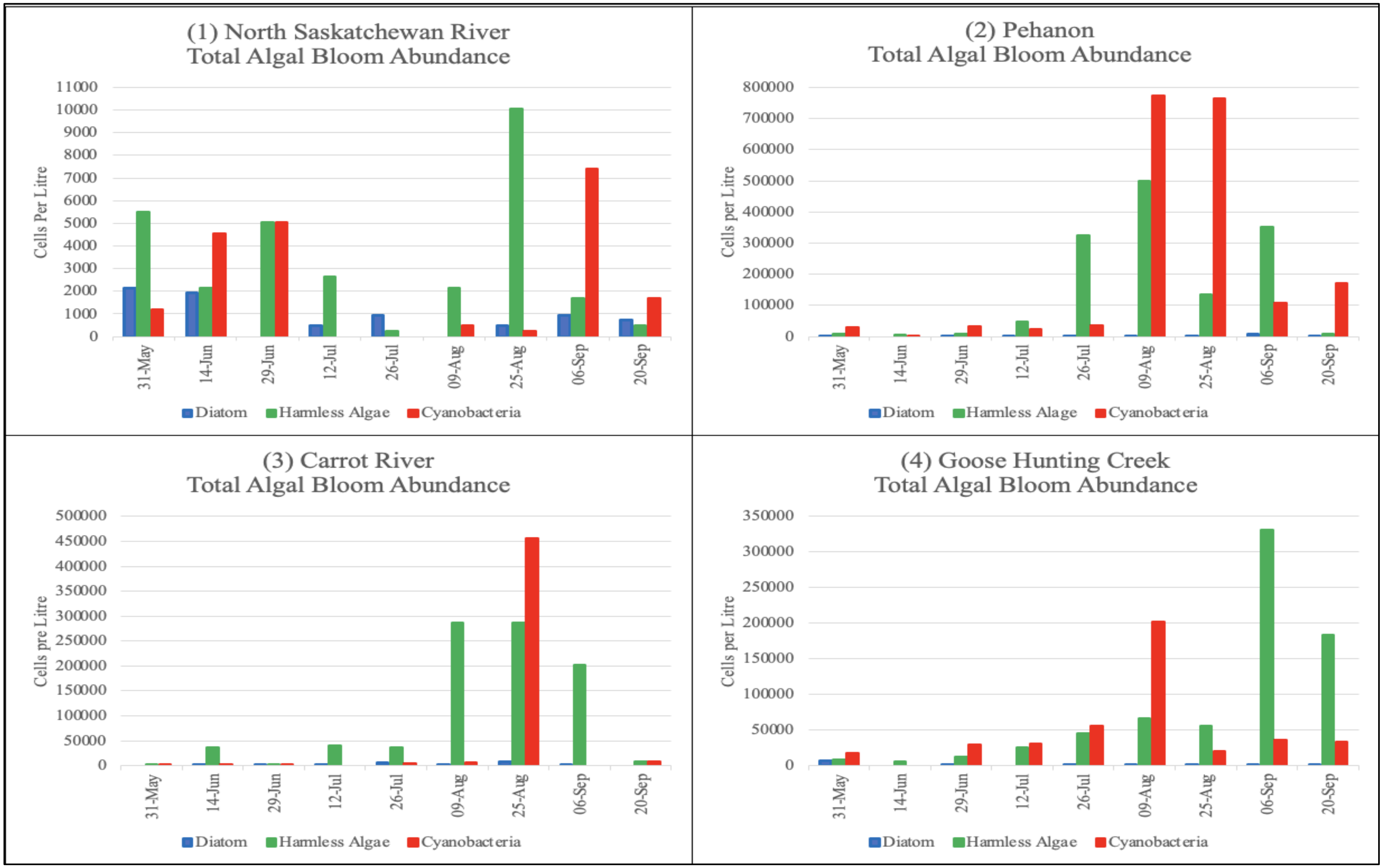

Figure 3.4: Total Algae Bloom Abundance in James Smith Waterways
Total abundance of 3 algae categories in blooms from study sites in the area outside the James Smith Cree Nation Reservation. These include diatoms, harmless algae (includes golden, yellow-green, and green algae), and cyanobacteria species within the algal bloom at each site. Graph for Carrot River I was adjusted to make bars more visible. The actual number of cyanobacteria for September 6 is 4,744, 358 parts per litre.

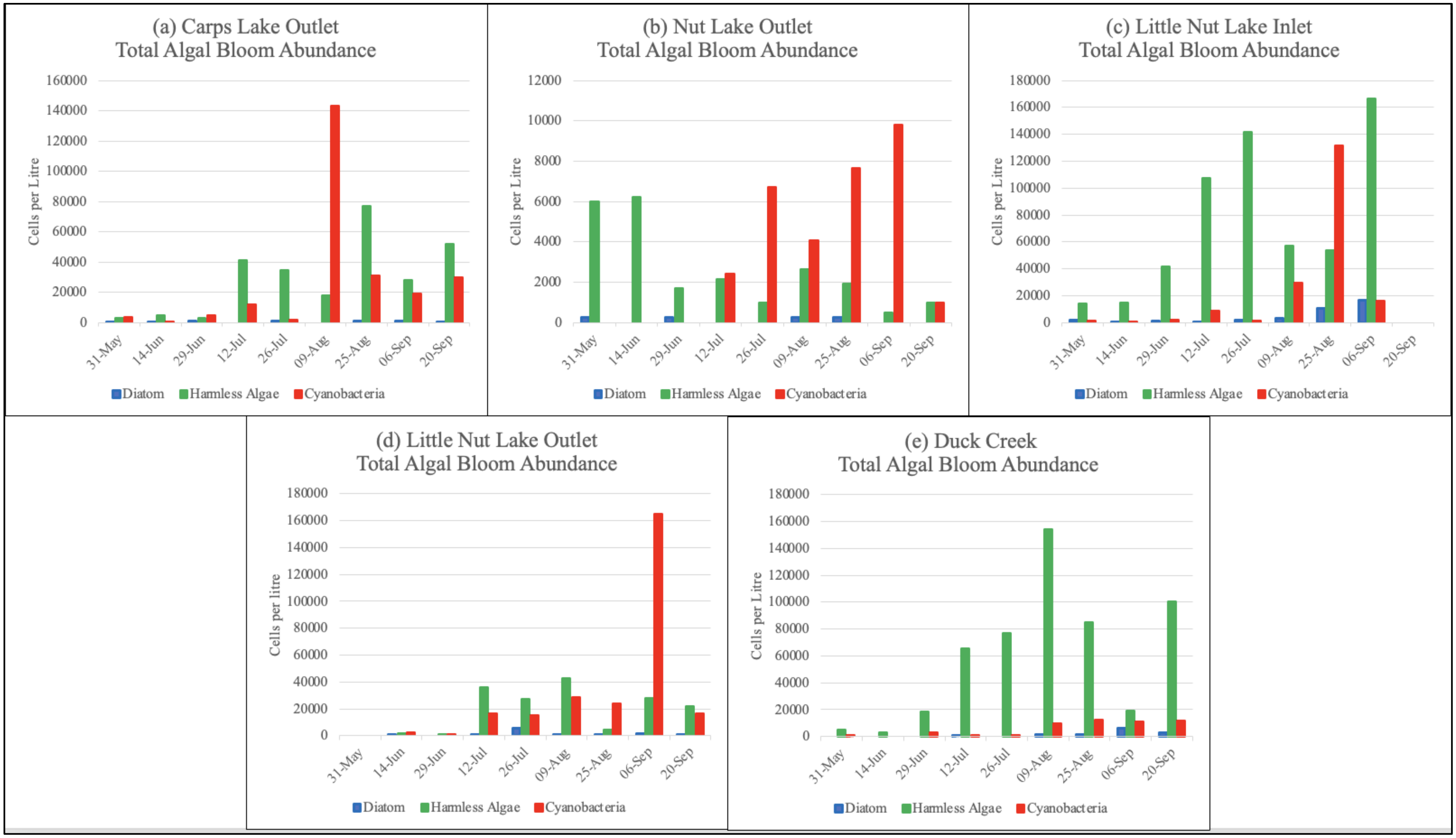

Figure 3.5: Total Algae Bloom Abundance in Yellow Quill Waterways

Total abundance of 3 algae categories in blooms from study sites in the area outside the Yellow Quill First Nation Reservation. Bloom includes diatoms, harmless algae (includes golden, yellow-green, and green algae), and cyanobacteria species within the algal bloom at each site.

Site	Combination	r^2 value
N. SK River	P vs A	0.039
	P vs Ph	0.1827
	P vs C	0.4428*
	A vs C	0.1411
	Ph vs C	0.0240
Pehanon	P vs A	0.1183
	P vs Ph	0.0209
	P vs C	0.0691
	A vs C	0.0742
	Ph vs C	0.4955*
Carrot River	P vs A	0.0040
	P vs Ph	0.1206
	P vs C	0.1395
	A vs C	0.0004
	Ph vs C	0.1541
GHC	P vs A	0.1877
	P vs Ph	0.0701
	P vs C	0.1464
	A vs C	0.0823
	Ph vs C	0.2770

Site	Combination	r^2 value
Carps Lake	P vs A	0.0207
	P vs Ph	0.0385
	P vs C	0.0135
	A vs C	0.0281
	Ph vs C	0.0838
Nut Lake	P vs A	0.0471
	P vs Ph	0.1102
	P vs C	0.3595
	A vs C	0.0023
	Ph vs C	0.0006
LNL Inlet	P vs A	0.1159
	P vs Ph	0.2041
	P vs C	0.0344
	A vs C	0.0502
	Ph vs C	0.0929
LNL Outlet	P vs A	0.1253
	P vs Ph	0.0190
	P vs C	0.8554*
	A vs C	0.2868
	Ph vs C	0.1101
Duck Creek	P vs A	0.1265
	P vs Ph	0.1067
	P vs C	0.1847
	A vs C	0.0316
	Ph vs C	0.6857*

Table 3.3: Table of r^2 values from simple correlation

r^2 values were calculated to find the degree of correlation among various combinations of variables (precipitation, ammonia/phosphate concentrations, and cyanobacteria abundance). P is precipitation; A is ammonia, Ph is phosphate; and C is cyanobacteria. An r^2 value above 0.4 and/or nearing 1.00 shows stronger correlation (signified by an asterisk*), and an r^2 value near 0.00 shows weak correlation. These values show that there is little to no correlation between all variables, except for some rare instances. (e.g., Cyanobacteria abundance correlates with phosphate concentrations at the Little Nut Lake Outlet site).

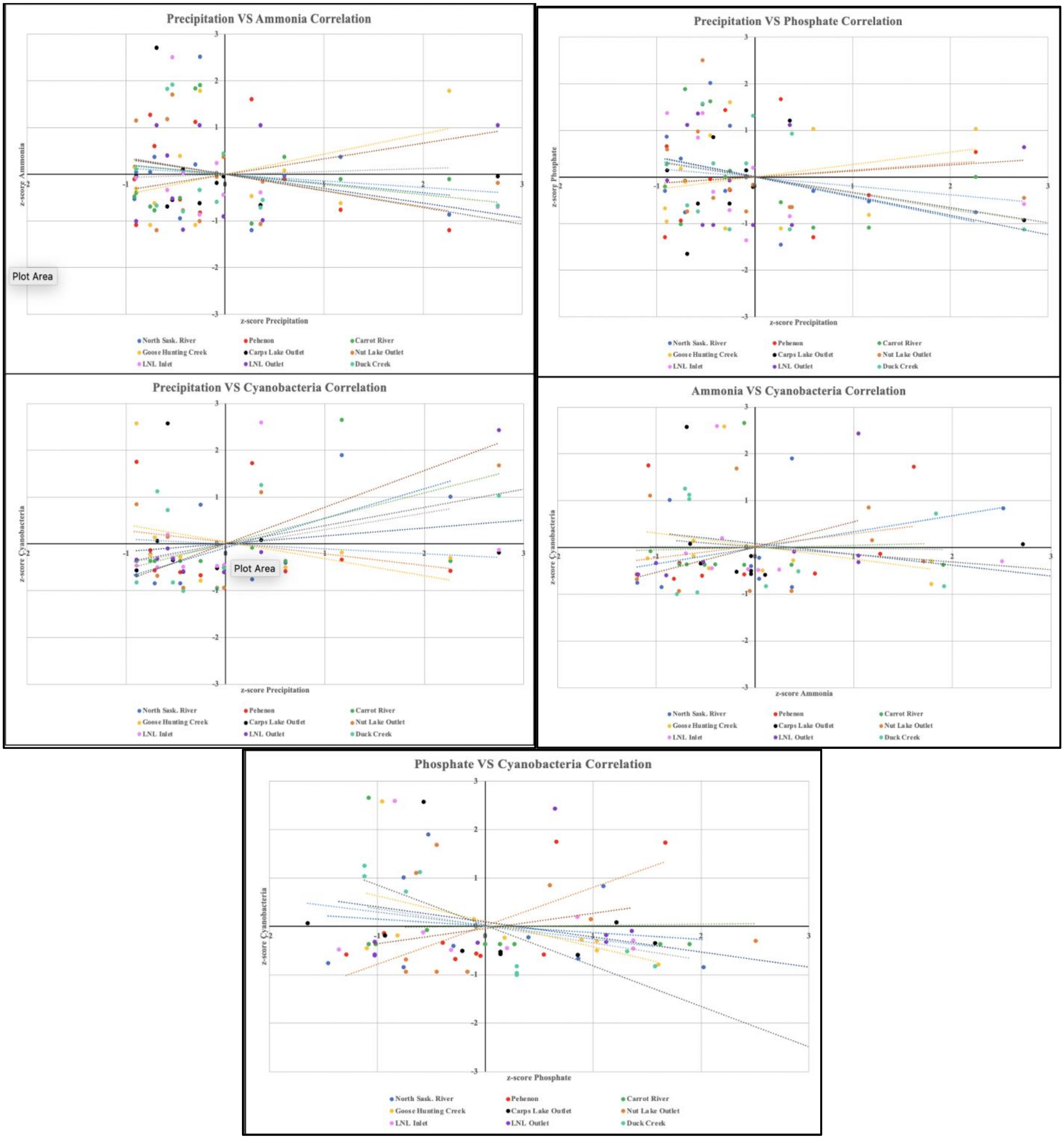

Figure 3.6: Simple Correlation of Nutrient and Algae Variables
Scatterplot graph of simple correlations among variables (precipitation, ammonia/phosphate concentrations, cyanobacteria abundance) for all 2021 water sampling sites. Low sloping trendline visualize the weak correlation between variables at each water sampling site.

3.5.3 Degree of Cyanobacterial Growth based on Waterbody Type

Algal blooms frequently occur in lakes but can also be found in other parts of a water system; even if an algae scum is not visible, it does not mean that an algae community is not present (Erratt et al., 2022). The appearance of a bloom helps to give a visual representation of the amount of algal growth, but it can also be determined through microscopy methods. Algae growth is expected to follow the pattern of nutrient concentrations as nutrient concentrations and availability are some of the limiting factors for growth, but the work presented in Chapters 2 and 3 note that this is not always the case. There is very little information on the quantification of algae communities in rivers and streams, nor is there much detail on categorization based on algal growth in different waterbodies other than lakes. More monitoring and development of long-term capacity is needed across watersheds by combining active monitoring with community records including local knowledge and experience. This may present opportunities to make better decision for local remediation.

Waterbody Type	Site	Width (m)	Mean Ammonia (mg/L N)	Mean Phosphate (mg/L PO4)	Mean Cyanobacteria Density (cells/L)	Max Cyanobacteria Density (cells/L)
Fast-moving River	Carrot River	8.86	0.18	0.20	579874	4744358
Fast-moving Rivers	Pehanon	6.70	0.44	0.43	214687	170746
Light-exposed Streams	Goose Hunting Creek	10.69	0.10	<0.01	47124	202030
Lake Outlet	Little Nut Lake Outlet	10.10	0.49	<0.01	33583	165015
Lake Outlet	Carps Lake Outlet*	7.90	0.14	<0.01	27012	142806
Shaded Stream	Little Nut Lake Inlet*	3.66	0.12	<0.01	21121	131582

Shaded Stream	Duck Creek	2.59	0.19	<0.01	5413	12179
Lake Outlet	Nut Lake Outlet	16.07	0.48	<0.01	3503	9792
Slow-moving Rivers	North Saskatchewan River	121.21	0.06	<0.01	2282	7403

Table 3.4: Comparison of Mean Nutrient Concentrations with Density of Cyanobacteria
Study sites are categorized by waterbody type. Mean ammonia and phosphate, and mean and maximum densities of cyanobacteria (cells per Litre) are given at each site for the entire study period. Sites that are indicated with a * are sites where flow had stopped or dried up, limiting algae growth.

Based on the collected data, algal growth throughout different parts of a water system can be ranked on a gradient scale (Table 3.5), with eutrophic lakes (shallow, total wind mixing, lots of nutrients) experiencing the most algae development and fast-moving (or large mountain sourced) rivers which experience the least. I compared the average biomass of cyanobacteria from each site to gauge how these water body types should be ordered, based on the WHO Guidance Values for health risks to cyanobacterial exposure (EPA, 2003) (Table 3.5).

Waterbody Type	**Degree of Algae Growth**	**Approx. cell count (cells/L)**	**Common Features impacting Algae Growth**
Fast-moving Rivers	Very High to High	>100,000	Low retention time, large surface area, continuous flow, depth ranges from shallow to deep
Sunlight exposed Streams	High to High-moderate	75,000-100,000	Small surface area, rarely covered by a riparian zone, shallow depth, warm water temperature
Eutrophic Lakes	High-moderate to Moderate	50,000-75,000	Catch basin, large surface area, lots of available nutrients
Shaded Streams	Moderate to Moderate-Low	25,000-50,000	Small surface area, commonly covered by a riparian zone, shallow depth, cool water temperature
Oligotrophic Lakes	Moderate-Low to Low	5,000-25,000	Catch basin, thermal stratification, few available nutrients till lake turnover, large surface area
Slow-moving Rivers or Outlets	Low to Very Low	<5,000	High retention time, large surface area, continuous flow, depth ranges from shallow to deep, high phosphate levels are common

Table 3.5: Expected Growth of Cyanobacteria Gradient Scale Based on Waterbody Type.

This table represents an expected order of fresh waterbody types of highest average cyanobacterial bloom growth to lowest during seasons with drought-like conditions. Approximate cell count is an estimation based on the WHO Guidance Values for health risks to cyanobacterial exposure (EPA, 2003).

3.6 Discussion

In the Canadian Prairies, freshwater systems are highly impacted by excessive agricultural nutrient inputs (Pick, 2016; Boyer, 2021). Management practices have been proposed, such as planting riparian species (i.e., sedges, rushes, grasses, trees) and putting up fencing along waterways, to reduce nutrient loading into nearby freshwater lakes and streams, but loading can still occur, as I have found from the previous study. For Indigenous Peoples, the concern is that excessive nutrient inputs fuel the growth and recurrence of toxic algae, which replaces native species that they have always been able to identify and adapt to. Algaecide treatment can also release large volumes of toxins (due to cyanobacterial cell death) into the water at one time, and affect other species (Crafton et al., 2018). With ineffective nutrient prevention and removal methods, the overall community health is impacted, from physical illnesses to spiritual, cultural, and mental harm. Harmless algae species are not a concern to human health, but they can create issues for livestock and other animals and to aesthetics. There is also the potential for algae to cause water to appear discoloured and have an unpleasant odour, limiting its use as people perceive the water to be unclean and potentially harmful.

No longer can communities comfortably predict the formation of algae blooms or their toxicity, as was done in the past because this work and other work have shown that uncertainty will continue to increase with the climate and unique abiotic features that either promote or limit the movement of land runoff (De Loë & Plummer, 2010; Akomeah, & Lindenschmidt, 2015). The unpredictability of toxic algae growth is why there needs to be continuous monitoring of the algal community within essential water sources. This study identified eleven toxic algae genera in sampled water used by participating Indigenous communities in Saskatchewan for source water, subsistence, cultural, and recreational use. Half of these cyanobacteria genera are commonly found in most freshwater systems throughout Canada (Winter et al., 2011), indicating that many Indigenous reserve communities are at risk of exposure to these algae species, which can be harmful to human health.

Based on the observations in this study, the physical features of a water body greatly influence the degree of cyanobacterial growth; for example, low gradient, high P streams were observed to have the highest cyanobacterial counts (Table 3.4). The influence of a waterbody's physical features has been particularly pronounced in years with abnormal climate, such as the drought-conditions experienced during the study period. These changes in algal development due to unique combinations of variables adds to the argument that continuous monitoring and algae assessments are needed (Cuvelier & Greenfield, 2016; McCullough & Farahbakhsh, 2015). Additionally, assessing algae blooms and monitoring their development will provide multiple benefits for both Indigenous and non-Indigenous communities by educating the public on what is in the water, how it impacts their overall health, and what actions need to be taken to fix the problem.

I propose the above gradient scale (Table 3.5) to be used as a reference for expected cyanobacterial growth, based on the waterbody type, to improve the efficiency of community-based monitoring methods and prioritize prevention and remediation efforts. Current academic literature tells us that algae growth is the highest in eutrophic lakes, followed by mesotrophic lakes, while oligotrophic lakes rarely experience algal blooms (Dodds & Whiles, 2010; Reinl et al., 2021). Lakes are ideal environments for cHAB development since they are the main catchment basins in a watershed, gathering most excess nutrients from the surrounding terrain and have a large surface area for optimal light exposure and increased surface water temperatures in which cyanobacteria can thrive (Reinl et al., 2021). Even if a drought occurs, as it did in 2021, lakes commonly have a large reserve of excess nutrients from a history of inputs (Dodds & Whiles, 2010). Thermal stratification will limit lake turnover in deep lakes, but not in shallow lakes. Therefore, eutrophic lakes will produce the largest and most toxic algal blooms. Mesotrophic lakes have nutrient levels between eutrophic and oligotrophic lakes, or they are transitioning due to eutrophication; thus, these are not separated into their own category in the gradient scale. On the other hand, lake outlets can have variable cyanobacterial growth. From the gathered data from these outlets, nutrient concentrations, bloom composition, and algae growth were lower than expected, and each studied outlet differed in nutrient concentrations and algae growth. I found that the flow rate and the type of lake (eutrophic/oligotrophic) determine the amount and toxicity of algae communities present in these outlets.

After lakes, slow-moving rivers, such as Pehanon or Carrot River, are next on the proposed cyanobacterial growth gradient scale. The wide surface area allows for the water to increase in temperature, and the slow movement of the water allows nutrients to be taken up by present algae species, adequate for cyanobacterial growth requirements. I suspect the 2021 heat dome played a role in keeping numbers down initially by lowering the water depth and temporarily slowing the streamflow further, limiting the replenishment of nutrients from upstream and surrounding agricultural sources, until sufficient precipitation returned, creating a noticeable increase in cyanobacterial biomass.

Next down on the gradient scale are sunlight-exposed streams, followed by shaded streams. Streams that are highly exposed to sunlight experienced earlier toxic bloom development, due to higher water temperatures and evaporation rates (increased nutrient to water ratio), and the quick consumption of available nutrients by cyanobacteria, whereas heavy rains decreased algae biomass by washing out the stream (Figure 2.5; Figure 3.4-3.5). For shaded streams, riparian zones and bank vegetation provide coverage and protect the health, diversity, and basic ecological functions within these waterbodies (Dodds & Whiles, 2010). These zones trap excessive nutrients and cool the water to a more livable range (for harmless algae species), keeping cyanobacterial growth very low. For example, Little Nut Lake Inlet and Duck Creek, both shaded streams (Figure 3.5) had nutrient concentrations similar to Goose Hunting Creek (light-exposed) (Figure 3.4) but Duck Creek had far less abundance (2-9 times less) of cyanobacteria. I interpret that this difference in cyanobacteria biomass and similarity in nutrient concentrations indicate that Goose Hunting Creek had more nutrients before sampling, and algae in the light-exposed stream would have quickly taken up all the available nutrients. This could explain why similar concentrations but a smaller algae biomass in the shaded streams were observed by the time of sampling. Lastly, fast-moving, or large mountain sourced, rivers will produce the least amount of cyanobacteria production, based on the gathered data. The North Saskatchewan River is a prime example of a river with steady streamflow that does not allow large growth of attached algae species and carries suspended species downstream. When comparing algae abundance to nutrient concentrations (Figure 2.7; Figure 3.4-3.5), both sets of numbers are minimal. Water flowing in large, fast rivers is expected to be more diluted compared to other rivers, likely because the large surface area catches more rainwater, and the fast movement carries available nutrients downstream faster than present algae can consume it.

The *Expected Growth of Cyanobacteria based on Waterbody Type* Gradient Scale (Table 3.5) could be used in part with source water planning and monitoring efforts for environmental monitors, researchers, and community members participating in monitoring efforts. By having a sense of the expected growth ranges for each waterbody type, those monitoring will know which source waters are at higher risk of cyanobacterial growth and should more easily identify when there are sudden changes in biomass. The gradient scale developed in this study accounts for the vulnerability of slow-moving prairie rivers and lake outlets and encourages more frequent monitoring of these sites. Future changes to climate and economic growth are expected to continue and influence algae growth if no action is taken; thus, this gradient scale shall remain flexible to revision based on future research findings. For now, this gradient scale for cyanobacteria growth is best suited in the Canadian Prairies. I suggest that the scale be used as a starting point for monitoring in other Canadian regions with different topographies, climates, and economic activities, then adjusted to fit those regions as needed. This scale should also work for normal climate years, but replication of this study should be conducted to confirm it.

The movement of excess agricultural nutrients and the frequent growth of toxic algae blooms were only part of a cyclic problem. Watershed managers must also consider the ineffectiveness of current watershed management on Indigenous lands, and strive to incorporate more collaborative discussions and Indigenous management practices. Canada has acknowledged its colonial past and how it has impacted First Nations Peoples, but this is not enough to solve the problem while remnants of this past remain in our governance and management system (Simms et al., 2016; Bakker and Cook, 2011). There needs to be further action taken to incorporate stakeholder and rightsholder participation in governance and management discussions and to foster community-based monitoring and environmental projects. Thus, decision makers must be aware of both the environmental factors and the political constraints contributing to this problem. By doing so, new creative solutions and practices can be developed and employed to improve water quality standards and the overall quality of living for Indigenous Peoples.

CHAPTER 4 PREFACE

A CT Story of Watershed Management: Part 3 Individualism and Hierarchical

Elu is a member of the Rolling Valley Cree Nation community. He is both the environmental monitor, and one of the reserve community's water treatment plant operators. The water treatment plant serves less than 300 people and draws water from a river that has several tributaries feeding it upstream. Elu wants the watershed management group to do a better job. Lately, he's been hearing stories from Elders and hunters and fisherpeople about the waters around the reserve being covered in brown and green masses, and they have been asking him whether it's safe to eat the fish. He has sent a few of the fish to the university lab in the city to find out, but the tests are going to cost hundreds of dollars out of his budget to complete. He knows that the environmental portfolio on the reserve does not receive enough funds to support this extra sampling, but he, as well as each person living on the reserve, knows that they are individually responsible to be stewards of the land and waters. They've all been taught that since they were very young. He just can't understand why others living in the watershed don't feel the same way. Why do the watershed managers not emphasize what each person can do to protect living kin and give each of them; fish, deer, moose, birds, a chance at a healthy life? His views on managing the watershed categorize Elu as an Individualist. The funds for the environmental monitoring are provided by the Federal Government and the amount Elu receives is smaller than other communities because they have less people, but not because their watershed is any different from the rest. Despite being in a smaller community, the allocated funds are still not enough to meet basic sampling needs to answer community questions about whether the fish and animals are okay to eat, the water is safe, and the ecosystem is healthy. Elu often makes hard decisions on what remediation efforts to start each year; plant in riparian areas? Clean up an old well site? Or buy monitoring supplies? The budget is not enough for Elu to hire more than one part-time monitoring helper. Elu asks the Community Council to borrow funds from other services. He doesn't want to borrow funds from other essential services because he knows they are also important to the community, so he does this very rarely. The community members are close with each other, so it upsets Elu when community members become sick from their recent hunting trips, or from fish they ate, or when he hears others express their distrust in the monitoring program. Elu wants there to be more community engagement with the government so his concerns over the community's ecosystem issues are heard. However, there is no clear information on how or to whom Elu should contact about these issues. Elu feels alone, but protects the interest of his community, and does what he can to keep his job. After all, he supports his family and his sisters' families too sometimes. He is admired among community members.

Ms. Mullins is a government employee, and like her supervisor and the regional director, her views align with the hierarchical perspective– operating within the policies and guidelines of her position which is funded by and accountable to taxpayers. Her job is to distribute annual financial allowances to various communities for the operation and maintenance of essential services. Elu's environmental monitor position is one of those services among 107 reserve communities in Ms. Mullins portfolio. To determine the amount of funds each community receives, Ms. Mullins uses the same decades-old formula, based on population and geographical area, which has not been adjusted to account for changing social and environmental circumstances. Ms. Mullins has not been in direct contact with community representatives or with essential service operators; she does not consider the unique conditions that impact the efficiency of service operations in each community. She gets the annual reports on the templates she created years ago, filed by the consultants hired by communities to make sure their reporting meets the requirements. Ms. Mullins never asks any clarifying questions because that raises suspicions about her department's work, and they have a perfect record of no complaints or access to information requests for the last decade. Additionally, Ms. Mullins does not have knowledge on how essential service operations are actually conducted on reserves or what is required to administer those services (i.e., methods, materials, labor, certification). As far as she knows, ecosystem monitoring programs like Elu's are receiving enough funds to keep the quality-of-service operations up to standard. No one, after all, has died.

Story as Analogy: Part 3

The continuing story shows how people with Individualism and Hierarchical perspectives can hold conflicting viewpoints on how to conduct management practices, which emerges from a lack of communication and transparency – as a result of the existence of the powerful and powerless. This breakdown contributes to the continuation of watershed management challenges still experienced by many Indigenous People. Elu's situation could be improved with a few alternative ways of organizing and intervening in the repetitive patterns; for instance, if the funding formula that Ms. Mullins has been using come under scrutiny by egalitarians, it may be refined to consider more than general entries, like complexity of tributary system, and surrounding land-use. Another example could be the fatalists expressing their dissatisfaction and defeat, working towards change in government. These ways of organizing being considered in the scope of watershed management, in conjunction with an in-person visit to communities, combine to redefine the real resourcing and financial need to determine a reasonable allocation of government funds.

Information on the funding formulae for watershed protection and management must be accessible for community environmental monitors. Programs that support emergency and long-term remediation issues could be created. Community members should not be expected to initiate all calls to the funding government authority, nor refer to consultants to ensure standards are met for every watershed management need. Liaisons such as technical service cooperatives, and service hubs for environmental and watershed management could be initiated.

At the individual level, part of Ms. Mullin's role should be to contact essential service managers, such as Elu, to discuss issues, operations, and the funds needed to address any water or environmental issues. Afterwards, both Ms. Mullins and Elu should keep in touch to stay up to date on the progress of addressing issues that require additional funds for material and labour resources. By keeping in contact with community members, the government can have a better understanding of the needs of communities and more details to better allocate funds. This method of collaboration is a great way to prevent negative impacts on health and wellbeing resulting from watershed management issues. It is better to address these issues now before they cost more to remediate in the future. This preface is an example of the interactions between two individuals with differing perspectives on watershed management and how political decision-making and policy design stemming from differences in knowledge, experiences, and personal viewpoints creates constraints on efficient watershed management in rural and Indigenous reserve communities (Chapter 4). This final results chapter presents a limited scope of the literature, and a SWOT-based review of that literature on prairie watershed management, Indigenous watershed management, and existing federal and provincial policy on watershed management. The chapter is intended to draw more from the social and political context to inform gaps in management knowledge and suggest revisions to existing policy so that the problems exemplified in the preface stories can be resolved.

CHAPTER 4: THE COMPLEXITY OF THE WATERSHED MANAGEMENT SYSTEM

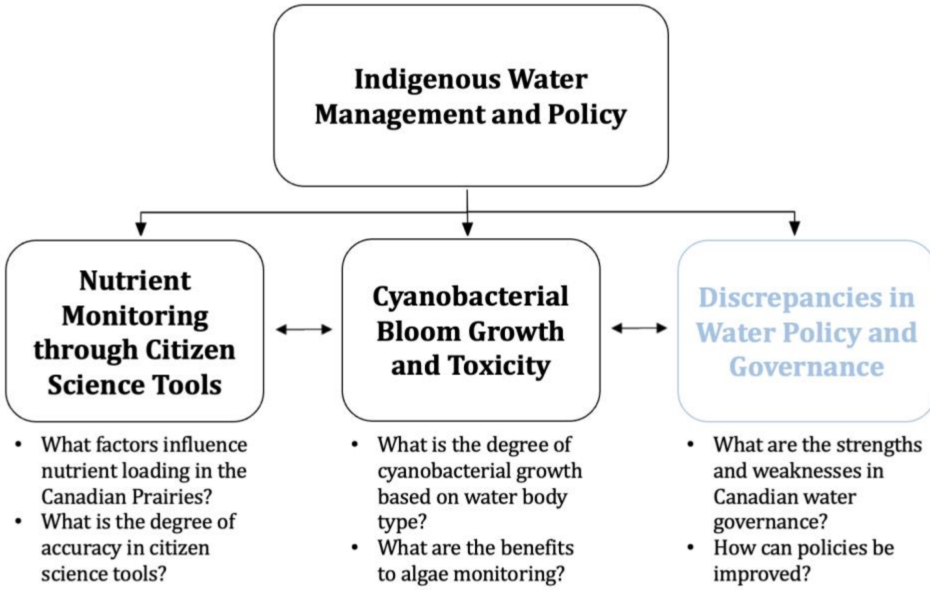

Figure 4.1: Graphical Abstract of Research Project; Canadian Water Management System and Policies. Chapter Four will build on the social component to sustainability regarding Indigenous water management challenges. This chapter will focus on Canadian water policies, their strengths and weaknesses, and areas in need of improvement (in blue).

*At this point, I would like to give a refresher on the definitions of governance, management, and policy, and how they differ. “Governance” is a system of how an organization, institution, industry, or government is operated, providing leadership and direction. It is the strategic actions taken by a committee or board to implement and manage various elements, which include setting goals, reasonable limitations, ethics, risk management, and accountability frameworks. “Management” means the methods and procedures that a management or executive team takes to oversee and allocate the necessary resources for daily operations of an organization. A “policy” is a structured framework for decision-making; this can take the form of a law, regulation, procedure, incentive, administration action, or a voluntary practice. Decisions on resource allocation and action planning are often made with the guidance of a policy. In summary, governance is how things are operated and where decisions are made, management oversees operations and follows through with the decision made at the governance level, and policies inform how decisions on operation are made.

4.1 Introduction to Watershed Management and Policies

Canada strives to be a fair and democratic nation, providing basic rights and freedoms for all citizens, and for many people, this is true. Poor surface water quality can be the result of contaminants entering freshwater systems from external point sources, such as industrial chemicals or biological water-borne infections, risking ecosystem disruption and threats to consumer health (Hossain et al., 2012; Warren et al., 2003). In the prairie region, the most common contaminants affecting surface waterbodies are from agricultural nutrient inputs, mainly nitrates and phosphates (Chapter 2), which facilitate worsening harmful algal blooms (Chapter 3) (Pick, 2016; Boyer, 2021). Many agriculturalists have taken action to reduce nutrient loading in freshwater systems, and better management practices have been developed to keep up with current scientific understanding (Bosch et al. 2014). However, many Indigenous reserve communities continue to describe changes to watershed dynamics (Patrick et al., 2019; Lam et al., 2017). This is despite a contention that water was never discussed or ceded in Treaties (Phare, 2009). The problem of changing watershed health on Indigenous lands is far more complex than in urban and non-Indigenous rural communities and goes beyond the environmental, social, and economic aspects (Yates et al., 2017). Politics, funding, and cultural sensitivity play a role in water management, but multiple jurisdictional issues have confused responsibilities among those involved in preserving and restoring water security for health and cultural sustainability on reserves.

Along with the discrepancies between jurisdictional and fiduciary responsibilities, there is poor inclusion of community-level stakeholders and knowledge keepers in watershed discussions and management planning (O'Keeffe, 2019). Current Canadian water policies implemented in the prairie regions provide general guidelines on overall management but are vague for management strategies involving Indigenous communities (Herman-Mercer et al., 2018; Wilderman et al., 2007; Bereskie, Rodriguez, & Sadiq, 2017). Policies that mention Indigenous involvement are not effective when the strategies are not put into action. One example is the *Environmental Management and Protection Act (2010)* which states it will not inhibit Indigenous Rights, but does not mention engagement with Indigenous communities or the protection of environments within Indigenous reserve boundaries. Another example is *Bill S-8: Safe Drinking Water for First Nations Act (2013)*, which includes legal enforcement of water quality standards on Indigenous lands, but takes away authority from Indigenous Peoples in overall watershed management. There is a need for more action to include Indigenous Peoples in discussions and policy revision to embrace Indigenous values and knowledge in management practices (Sinclair & Hutchison, 2013; Alcantara et al., 2020). As discussed in Chapters 2 and 3, changing climate is part if a suite of drivers of the environmental challenges in Indigenous waters; thus, solutions must involve continued, collaborative monitoring programs tp help with predictive capacities, engagement of Indigenous peoples in watershed planning, and the creation of adaptable plans with community members. The careful merging of western-styled methods and Indigenous knowledge is an avenue for unique solutions which will create action plans that are effective and satisfy the needs of all affected parties.

Within this chapter, I will discuss some of the history of Canadian watershed management, how it pertains to Indigenous water issues, and why this management system continues to struggle to advance solutions to water management. Through a SWOT document analysis, and interviews with Saskatchewan-based watershed agents and Indigenous members from participating communities, I analyzed current Canadian water policies and interpreted where policies have succeeded and could be improved.

4.1.1 Watershed Management in Canada

Canadian watershed management is broadly decentralized with various jurisdictions involved depending on the province or territory in which a reserve is located (Bereskie, Rodriguez, & Sadiq, 2017; Hrudey, 2011). Across the nation, watershed management is conducted through a three-tiered, top-to-bottom approach with federal, provincial/territorial, and municipal and regional jurisdictions, creating confusion on roles and responsibilities (Bereskie et al., 2017). Decisions on the design and implementation of water management policies are made at the federal level, while provincial and territorial governments set rules for water quality standards, regulations, monitoring, and enforcement, and municipalities or regional watershed groups run local monitoring, educational campaigns, remediation projects, and sometimes treatment and distribution systems (Bereskie et al., 2017; Robins, 2007). In certain contexts, some wider responsibilities are transferred to smaller governing authorities, such as municipalities, watershed organizations, or local Chief and Councils, who may not have to capacity to fulfill all tasks (Hrudey, 2011; Robins, 2007; Hutchcroft, 2001). Enforcement and policy regulations are further complicated when the issue involves separate jurisdictions between Indigenous governance and non-Indigenous management groups in the same watershed. On top of conflict over priorities for watershed management, the fragmentation between jurisdictions makes it difficult to establish unified water quality standards for recreational waterbodies, and source waters (Khan et al., 2003; Soumalia et al., 2019), or the subsequent legal enforcement mechanisms for those standards (Wuijts et al., 2018). Guidelines for watershed management, and water quality standards, at both the Federal and Provincial level are unclear and "voluntary," making it challenging to enforce health-based water treatment standards and determine who is accountable when issues arise (Lebel & Reed, 2011; Hanrahan, 2017; Bereskie, Rodriguez, & Sadiq, 2017).

Reinforced in the Canadian Charter of Rights and Freedoms and Section 35 of the Constitution Act (Waldner et al., 2017; Hanrahan, 2017), federal agencies and government officials are obligated to fulfill their responsibilities to Indigenous Peoples and their rights to clean water (Coulthard, 2007; Lebel & Reed, 2010). Fulfilling these responsibilities proves difficult when there is jurisdictional conflict. For instance, the Canadian Federal Government has jurisdiction for provision of services including surface and drinking water within Indigenous Reserve boundaries, but outside these boundaries agriculture and water management are under provincial government jurisdiction (Robins, 2007; Blomquist et al., 2007). Dunn et al. (2014) explains that within each jurisdiction, governing hierarchies are taking their own approaches to water management, failing to cooperate and discuss the impacts of economic activities and relaxed policies on water resources.

Not only are there conflicts between federal and provincial cooperation, but there is a lack of Indigenous representation in watershed management in general (Herman-Mercer et al., 2018; Wilderman et al., 2007). The Government of Canada has made statements on their intentions to improve existing water infrastructure in all Indigenous Reserves as part of their commitment to reconciliation (Bradford et al., 2018), but few policies mention working with Indigenous Peoples and their traditional knowledge in water management practices at the watershed level. The inclusion of Indigenous Peoples in discussions is needed for government authorities to understand the perspectives and concerns of impacted people, and how current management practices and policies limit their ability to sustain water resources to government standards

(Sinclair & Hutchison, 2013). Indigenous inclusion also aides in the development of action plans and community-based projects that center traditional knowledge, lifestyles, and belief systems (Sinclair & Hutchison, 2013, Wilson et al., 2018).

Current watershed management policies are better than previous ones, but even these new policies contain aspects that restrict stakeholders from reaching a consensus on effective resolutions and limit community input (Robins, 2007). This management structure is ill-suited to manage Indigenous water challenges as it allows misunderstandings or disregard of crucial risk and safety issues, a lack of overall leadership, and does not facilitate smooth coordination among all individuals involved, from federal officials to the individual consumer (Hrudey, 2011). Solutions that work for a non-Indigenous populace may not work for Indigenous communities (Page & Daniel, 2019; Thompson, Post, & McBean, 2017). Indigenous representation at the discussion table is vital to include communities and their ideas, beliefs and practices into solutions and future watershed management approaches (Reed et al., 2021; Sinclair & Hutchison, 2013).

4.1.2 History of Watershed Management: how it pertains to Indigenous waters

Canada's colonial history has put Indigenous Peoples at a disadvantage for natural resource management, including the protection and treatment of water meant for domestic, recreational, and ceremonial use (Bradford et al., 2017; Hanrahan, 2017; Wilson et al., 2018). Since the Indian Act was first written in 1876, watershed management movements have not incorporated Indigenous People meaningfully into the management process, and little support has been provided to Indigenous reserve communities in the form of adequate capital for environmental monitoring and restoration, water treatment, distribution, and wastewater removal (Patrick et al., 2019). Indigenous communities have developed distrust in government and external institutions; they have experienced recurring water-related illnesses, dissatisfaction with water quality and treatment resources, loss of cultural practices related to water, and ongoing colonialism that removed their independence to manage their resources until recently (Bradford et al., 2017; Wilson et al., 2018).

In addition to the challenges to accessing needed capital and stronger policy enforcement for water management, culturally embedded values and Indigenous traditional practices for water are not incorporated into federal management policies, or funding formulae (McCullough & Farahbakhsh, 2012; Murphy et al., 2015; Baijius & Patrick, 2019). Within some Indigenous cultures, water is an essential component to sustaining life, is conceived as a spiritual connection between all living things, and in some belief systems, is a sentient being (Linton, 2019). There is a shared belief among many Indigenous Peoples that water has a spirit, and contamination threatens its health and the survival of both the spirit and those reliant on the water (Lam et al., 2017).

Not only does poor watershed health affect physical and mental health, it also places limitations on cultural and community wellbeing that normally facilitate the traditional practices and social interactions important to Indigenous identity (Whyte et al., 2013; Hanrahan, 2017). Indigenous traditions and values are integral to cultural identity (Jilek, 1978; Waldram et al., 2006) and should be incorporated as part of watershed management systems since some westernized methods are not aligned with Indigenous cultures existing prior to colonization. For example, in some Indigenous communities, chemical treatment or bottling water kills the spirit within, rendering it ‘dead’ and unsuitable for cultural use and consumption (Page & Daniel, 2019; von der Porten, de Löe, & McGregor, 2016; Thompson, Post, & McBean, 2017). When faced with choosing between water treatment methods not aligned with their cultural practices or, using local resources without treatment in order to retain Indigenous identity, some will choose the latter (Dupont et al., 2014). Indeed, anecdotally, members of communities partnered in this work have told us that some Elders still collect water from local waterbodies over using their tap water, hunters and fishers will still dip their cups into waterbodies to get a drink while on the land, and others collect ice blocks from lakes in the winter to melt for ceremonies and making various teas, instead of using tap water.

Many agree that collaborative efforts with Indigenous communities are needed for effective and culturally aligned watershed management while developing respectful and trusting relationships (Simms et al., 2016; Arsenault et al., 2018; Bradford et al., 2017). There is a desire to increase community-based research and monitoring, but limitations to Indigenous participation or the weaving of knowledge systems have allowed this problem to persist (Wilson et al., 2018; Illsley, 2003; Shrubsole & Draper, 2007). To achieve sustainable watershed management, researchers stress the importance of balancing cultural awareness with political and economic constraints, and the resulting social impacts (Yates et al., 2017). By doing so, new solutions and practices can be developed and employed to improve watershed management and overall quality of life for Indigenous Peoples.

4.1.4 Statement on past solutions that failed to solve the issue

Watershed management challenges on Indigenous lands are complex. With many communities experiencing problems but having unique situational factors, a generalized, one-size-fits-all formula is not enough to resolve issues (McCullough & Farahbakhsh, 2012; Murphy et al., 2015; Baijius & Patrick, 2019). The Government of Canada has attempted a few solutions, such as financial investments, and minor adjustments to guidelines and water policies. These *solutions* have had little effect when considering the scale of this problem, especially when there is not a balance between the social, economic, and political aspects in the design (Harris et al., 2017). For instance, some solutions mainly focus on large-scale spending but not on community engagement in discussions on how that money is spent, or policies have set regulations, but technical wording limits strong enforcement (Dunn et al., 2014; Lebel & Reed, 2011; Bereskie, Rodriguez, & Sadiq, 2017).

The Federal Government has made financial investments to improve water security and quality on Indigenous lands with limited success. In 2003, $600 million was allocated to the 'First Nations Water Management Strategy,' which had the goal to address urgent water and wastewater issues by improving water and wastewater infrastructure and operating practices, increase operator training, and increase resources for monitoring and public engagement (Lebel & Reed, 2010). As ambitious as this strategy was, government funds were not sufficient to meet all these objectives. Since 2016, a total of $5.39 billion has been put towards water-related problems in Indigenous reserve communities (Galway, 2016; Bradford et al., 2018; Lam et al., 2017; O'Gorman & Penner, 2018). As much as these large-scale funds help in the short term, the finances do not solve the problem because aging infrastructure and growing contamination of water sources lead to additional costs allowing problems to persist (McCullough & Farahbakhsh, 2012; Murphy et al., 2015; Baijius & Patrick, 2019). Financial support does play an essential role in the solution to Indigenous water challenges, but political agreements between Indigenous leaders and governing authorities are also needed.

Government-implemented water policies and acts are necessary for effective watershed management to set guidelines on regulations, enforcement, and details on roles and responsibilities, jurisdictionally, and individually (Simms, 2014). Still, what has been written does not always reflect the action taken to meet those documented requirements. One of the most common requirements is that governments and external organizations must undertake 'prior consultation' with Indigenous communities; however, based on the experience of

Indigenous residents, this step is not always taken (Moore et al., 2017). For example, decisions on impact assessments of resource extraction activities, and land-use planning consider the watershed an economy as-a-whole instead of the minority interests of Indigenous residents (Beck, 2016; McCullough & Farahbakhsh, 2012). Without proper consultation, the distinctive set of conditions, concerns, monitoring needs, questions, and local knowledge of each community are not considered in policy and action planning, which may lead to further watershed management issues (Janzen et al., 2016; Fontaine, 2020; Hanrahan, 2017, Bradford et al., 2018).

There is also the issue of poor enforcement of regulations and standards in water management. Guidelines on enforcing policy regulations are generalized and loosely applied, often due to the vague terminology that could be misinterpreted, such as an "optional" protective measure and application of BMPs (Bereskie, Rodriguez, & Sadiq, 2017; Jalba et al., 2010). There are multiple water policies in central Saskatchewan written as guidelines for quality standards (Health Canada, 2021), and there are no clear frameworks in prairie provinces to enforce standards, ensure compliance and accountability, and guide discussions and the sharing of information among stakeholders (Bereskie et al., 2017; Walters et al., 2012), like there is in Ontario. To summarize, adequate meaningful engagement and decision power, financial support, and the fulfillment of policy requirements and standards are critical components to successfully reaching a resolution to persistent Indigenous watershed management challenges.

4.1.5 Barriers to Effective Watershed Management

Protecting water resources within reserve boundaries is a shared responsibility between the Federal Government and Indigenous Peoples, while the provincial or territorial government manages water resources outside reserve boundaries (Blomquist et al., 2007; de Loë & Kreatzwiser, 2007). Natural freshwater systems do not follow political and geographically-delineated jurisdictions; thus, determining who is responsible for water conditions when it flows into or out of reserve boundaries is difficult. Barriers to Indigenous watershed management are found in the political interactions between Indigenous communities and the federal and provincial/territorial governments through policy directives and conditional financing (Bradford et al., 2018; Hanrahan, 2017). In terms of legal foundations, Canadian watershed management structures are different between Indigenous and non-Indigenous populations, placing more protection on water resources outside of Indigenous reserve boundaries (Walters et al., 2012), such as the *Environmental Management and Protection Act (2010)* (Statutes of Saskatchewan, 2010). Some watershed management regulations do not even mention Indigenous water issues (Morrison et al., 2015). The crossover in jurisdictions creates conflict and confusion, especially when the protection and management of Canadian water is broken up among several provincial governments and watershed authorities (Lebel & Reed, 2011; Waters et al., 2012; Robin, 2007). The legislative foundation of Canadian watershed management remains rigid on what Indigenous Peoples can and cannot do to address issues, skews the degree of control over resource management, limits opportunities for creative solutions, and creates barriers for collaborative protection planning (Walters et al., 2012). For instance, Indigenous Peoples can participate in discussions and planning with the provincial government, but only if Indigenous communities "pass a by-law or law or band resolution agreeing to comply with provincial legislation" (Walters et al., 2012, pg. 2). Depending on the history between a provincial government and the Indigenous communities within that province, Indigenous Peoples may not comply with this prerequisite after past failures to meet Treaty agreements by provincial governments.

Another barrier to effective Indigenous watershed management is that water provision on Indigenous lands and solution planning are overly generalized (McCullough & Farahbakhsh, 2012; Murphy et al., 2015; Baijius & Patrick, 2019). Canada is a large country with many environmental, economic, and political players in water resource quality. Each Indigenous reserve community faces similar challenges, but the impacts on water quality may be caused by various combinations of factors (i.e., environmental, economic, social) and each community is unique in their cultural practices, beliefs, and local history regarding water, complicating preferences for how water is managed (Dunn et al., 2014).

4.2 Gaps in the Literature

4.2.1 Changing climate is affecting predictability

As climate continues to shift, predicting seasonal conditions and how they impact daily lives is becoming increasingly difficult. Additionally, weather extremes have been occurring more frequently and at much greater intensities, placing human populations at higher risk of experiencing largescale, adverse outcomes, such as excessive nutrient loading and toxic algal bloom growth (Levy, 2017; Patrick et al., 2019; McLeod et al, 2020). As climate continues to change, conditions also change, current Indigenous water quality issues are expected to worsen and new challenges may arise (Hosseini et al., 2017; Weber & Cutlac, 2017). Even though Indigenous watershed health and climate change reduction are discussed, there is little information on the key connections among environmental research, effective monitoring and predictive methods, and public policy.

4.2.2 Adaptability and inclusion of Indigenous voice for change

Canadian water policies, acts, and action plans have little mention of the importance of Indigenous participation in water policy planning or management discussions (Morrison et al., 2015). There have been few initiatives in establishing collaboration with Indigenous Peoples in watershed management (Alcantara et al., 2020). Within the literature, there is significant evidence that Indigenous Peoples experience water challenges more often than other cultural groups in Canada (Galway, 2016; Patrick et al., 2019; Lam et al., 2017; McLeod et al, 2020), and international agreements such as UNDRIP emphasize the need for embracing Indigenous perspectives in all decisions having or potentially having an impact on Indigenous communities (Sinclair & Hutchison, 2013; Diver et al., 2019; Alcantara et al., 2020). Few studies specifically look for the benefits and drawbacks of water policies for Indigenous communities and even less provide advice on how policy- and decision-makers can advance watershed management by embracing Indigenous perspectives and practices (Morrison et al., 2015; Dunn et al., 2014; Parsons & Fisher, 2020). This chapter covers the social and political analysis portion of the research project by examining how existing policies impact Indigenous communities for watershed management using a multimethod approach.

4.3 Research Purpose and Objectives

The purpose of this part of my study is to take a broad look at social and political components of the sustainability problems to complement the more natural sciences approaches of earlier chapters. I sought to determine the efficacy of watershed management policies on Indigenous communities in Treaties 4, 5, and 6, and provide decision-makers with information to improve management practices from the perspective of watershed agencies and Indigenous community members.

The objectives of this chapter are:

1. To determine the strengths and weaknesses in Canadian watershed management policies that are implemented in Central Saskatchewan or directly impact Indigenous Water Rights.
2. To determine the leading issues in watershed management based on the perspectives of watershed agents and Indigenous community members.
3. To provide evidence to policy- and decision-makers on the necessity for collaborative efforts with Indigenous communities for Indigenizing watershed management.

4.4 Methods

4.4.1 Document Analysis

To analyze Canadian water policy and management documents, a modified scoping review approach was taken (as per Grant and Booth, 2009) where I sought a preliminary assessment of the types of available watershed management guidelines and policies and academic critiques of those policies specific to watershed management in the Prairie provinces. I searched four databases (Scopus, Web of Knowledge, iPortal, Google Scholar) with the keywords: Canada, watershed management, prairies (Saskatchewan, Manitoba, Alberta), Indigenous (First Nation, Metis), and water. I additionally was provided with watershed management documents by community leadership who either found these in their records or were given the documents by Elders who had served previously on local watershed management boards as the guiding documents that were used by the board or committee. Finally, snowballing through citation searching also occurred. I included documents published in the last 20 years which specifically spoke to governance issues in the geographic areas of Treaty 4, 5 and 6. Though not comprehensive, the documents did provide key details on how watershed management operates as-a-whole in this region.

I decided to use the *Strengths, Weaknesses, Threats, and Opportunities* framework (SWOT; Robins, 2007). This method of analyzing documents has been used for identifying policy issues in environmental contexts such as urban planning, regional development strategies, circular economies, impact assessment, and resource extraction in the past (see for example, Falcone, 2019; Arfaee et al., 2015; Aspan et al., 2015; Benzaghta et al., 2021). The advantage of using SWOT for this purpose over full scoping or systematic reviewing is that SWOT focuses on the existing content of selected documents which are already located, which are also rich in regulations and prescriptions in policy documents, rather than scoping and systematic reviews which focus on seeking out a sample of manuscripts, then identifying gaps, and comparing findings (Marttunen et al., 2017). Using the SWOT analysis (Robins, 2007), I studied the 12 Canadian water policies and management strategies located during database searching, for the strengths and weaknesses of each policy, identifying opportunities for improvement, and assessing the threats the policy brings to meeting Indigenous rights and successful watershed management. Further details on individual Canadian water policies were obtained through peer-reviewed articles and open-access government documents to discover counter arguments and multiple perspectives on each document. A second document analysis involved looking at an additional set of documents specified by Indigenous leaders who were partnered on this project and held environment monitoring portfolios in their communities, to be of interest to this study. In those documents, no SWOT was conducted because it was deemed an imposition of a western evaluation system, so themes and conclusions from those documents were drawn in partnership with community coordinators.

4.4.2 Interviews

Qualitative interviews were conducted to gather perspectives from non-profit watershed agencies surrounding reserve lands, and Indigenous community members residing on reserve lands. Interviews were open-ended and semi-structured (Hammer & Wildavsky, 2018;

Roulston and Choi, 2018), and participation by interviewees was voluntary. Interview participants permitted the use of their responses through verbal consent following ethics certification protocols, and acknowledged that the researcher would not share the participant's private details. Interview questions were general and neutral to prevent unconsciously skewing a participant's response. Questions were formatted by the lead researcher (JP) and edited by the primary supervisor (LB) and Indigenous community representatives (MN, JB), and included topics such as decision-making procedures, perceptions on levels of community engagement, and what challenges or experiences did they experience? Ethics approval was granted by the University of Saskatchewan Behavioural Ethics Committee (BEH-2478).

Out of twenty contacted watershed agencies located in Treaty 4 and 6 Territories, eight participated in an interview with the lead researcher. Due to COVID-19 restrictions during the research period, interviews were conducted over the phone or via virtual ZOOM-mediated online calls. Each interview was audio recorded and transcribed to prevent any missing information, then underwent further analysis to discern themes around the impact of current practices on water quality in Indigenous reserve communities. Thematic coding proceeded via inductive analysis, and categorization into the SWOT framework (Guest et al., 2012) for the non-Indigenous managers' interviews.

Due to the pandemic restrictions during the time of this study, I was unable to conduct protocol (community blessing, exchange of gifts, in person feast, and in person data gathering) for community-based face-to-face interviews or group discussions with Indigenous community members. Transcriptions of past interviews with James Smith and Yellow Quill Community members on water-related emergency events were used as a secondary data source. These interviews were conducted in 2019 by researchers at the University of Saskatchewan during a broader water security project. Interviews were thematically analysed using induction similarly to the primary data from watershed agencies, and findings compared with those that were coded into the SWOT framework. Interview responses from both Indigenous community members, and watershed agents were used to compare organization/community values, goals, and practices through experienced challenges and successes in water management. Interviews were also used to determine which current water policies and strategies are working from their perspectives, if participants perceived that adaptations to strategies were needed, and if there were any barriers to improving current policies.

4.5 Results

4.5.1 Canadian Water Policy Document Analysis

4.5.1.1 General Quality of Water Policies Regarding Indigenous Watershed Management

Twelve acts, plans, and policies were found in databases, Canadian government archives and the library of acts for federal, provincial, and municipal watershed management that were relevant to the lands of Treaty 4, 5 and 6 in the Prairies (Appendix-B). Documents were either currently or previously implemented in watershed management and each has some degree of impact on Indigenous communities by virtue of geographic location, or hydrologic connectivity with Indigenous waterways and waterbodies. On consultation with Indigenous community members, these twelve policies and strategy documents were deemed relevant to their watershed management set-ups. In addition, I sought to find information through evaluations of these policies and strategies, but no published government documents could be found that offered the same assessment method of these strategies' effectiveness. Hence, assessing external validity of this SWOT against other evaluations of the policies and strategies was not possible (Ghazinoory et al., 2011). The SWOT assessment considered the interpretations and legal findings provided by an Indigenous researcher partner as a framework for evaluation. Some of the assessment criteria include, *Does the policy mention Indigenous Peoples, lands, water rights, or engagement; What are the goals and purpose of the policy; Are regulation and standard levels enforced appropriately and fairly; What is the policy's level of clarity;* and *Are their barriers to Sustainable Indigenous Watershed Management in the policy?*

The SWOT identified numerous weaknesses and few common strengths in the chosen documents (Appendix B-Table 1). I will begin with weaknesses which I broadly classified by concrete inclusion of requirement for Indigenous engagement/consultation in policy, and adequate capacity provisions in place (i.e., funding, training, support) to support alignment with Indigenous knowledge systems. Appendix-B also contains the list of Indigenous partner-recommended documents that were reviewed for this work and included Treaty documents themselves, as well as interpretations of those documents and legal decisions.

Requirement for Indigenous Engagement

Most documents either did not mention or lacked details on Indigenous engagement in watershed management (8/12, A-C, E-F, I-K), prior consultation with reserve communities (8/12, A-E, I-K), or how to prevent jurisdictional issues (6/12, A, E, F, J-L*). Bill S-8: Safe Drinking Water for First Nations Act* (K) is an example of all three of these weaknesses; this document emphasizes legal enforcement of water quality regulations and standards but does not recognize Indigenous authority and puts the majority of management power to the Federal Government, specifically the presiding INAC Minister (Bowden, 2011). Bill S-8 (K) is an example of an ineffective water management policy developed from a lack of Indigenous engagement and input through the design process, and violates both Treaty Rights and nine articles from UNDRIP (COO, 2013).

Capacity Issues for Aligning with Indigenization

Some documents were written in ways that seemed to conflict with Indigenous rights (5/12, A, E, I-K); for example, one act has a section that broadly explains the right to potable water but does not mention watershed management or source water protection rights on Indigenous lands (E). Some documents had obvious barriers to financial and capital support for effective watershed management and potable water provision (4/12, D, G, J, K) or did not mention surface or ground water quality standards on Indigenous lands (4/12, B, C, E, H). An example is *The Water Security Agency Act* (2005, E), which details guidelines for resource water protection, financing, crown ownership, water management and rights, and legal enforcement, but does not mention Indigenous reserve communities, their right to safe water, or guidelines on Indigenous water management strategies. In all twelve documents, there was no clear indication that Indigenous traditions, values, or practices relating to water were considered in the policy design as we may find through authorship notes, citations, acknowledgments, attribution statements, or in the introductions. Opposed to the weaknesses found in these documents, the most common strengths that I was able to classify included the document's purpose, inclusion of source water protection as a priority, and governance assignment (9/12, B-I, L). Though, these are only strengths when they are put into action.

Classification of Document

A key finding was that eight of the documents (B-E, G, H, I, L) specified that their policies were meant to be used as guidelines which meant that there was flexibility about meeting the policy depending on capacity and resourcing, and that there was no need for incentivization for doing more than the minimal enforceable limits. As guidelines though, there is debate about accountabilities being enforced. These guidelines covered different aspects of watershed management, from maintenance plans to enforcement of regulations (for non-Indigenous populations). Documents also shared a statement on federal obligations and how they intend to provide support (6/12, A, C, D, G, H, L), legal enforcement of policy regulations and authority responsibilities (4/12, C, G, I, K), and details on those responsibilities (2/12, C, L). One quarter (3/12, D, G, H) of the documents mentioned the protection of a source freshwater body and plan to increase capital specifically for water treatment (i.e., operator training, financing, upgrading infrastructure) and engagement between governments, experts, and stakeholders. Overall, each document had mixed effectiveness with Indigenous watershed management. Water policies governed by Indigenous authorities included more strengths and opportunities (INAC, 2008; Morrison et al., 2015), but those policies have only been recently implemented.

Being Informed by Indigenous Interpretations and Legal Findings

In addition to reviewing the government documents, community leadership recommended additional literature to review that supported Indigenization of water management. The seven documents, which included three Treaties themselves (Appendix-B, M-S), offered interpretations of the values, ways of life, and knowledge that was missing from the current policies. These included eight key points:

1) Water was never specifically discussed in Treaties except to delineate Treaty boundaries, or mentioned as a part of sacred lands which included “hunting territories, fishing territories, and gathering territories” (M-S)
2) An Elder specified that “The Commission said… All the creatures under the water, that too, I didn’t come to ask you for them. That will continue to be yours.” (P, Q)

3) The principle of kanâtisiwin - cleanliness - and Iyiniw miyikowisowina – clean pure water - two sacred cultural beliefs are not being met (P, Q)
4) The concept of *Sui generis* “of its own kind” means no or very little legal precedents have been established over water and land (containing water) that is more than a depth of a plough. Thus, issues of groundwater, mining, canals, and irrigation were not negotiated. (S, T)
5) Free, prior, and informed consent is needed for all negotiations and ensures meaningful and effective participation in decision-making. Duty to consult involves deep discussion of measures that might adversely impact potential or established treaty rights. (R, S, T)
6) Indigenous peoples as full partners in the natural resource and net-zero carbon economy and ensuring that Indigenous peoples have a seat at the table for decisions that may affect their communities (R)
7) Specific reserves were created to protect fishing rights, and thereby claims to clean, fresh water, are also protected in these reserves. Specific bands were assigned claim on the reserve lands based on their use of waters (S)
8) Three implications follow from the *sui generis* nature of the Indigenous interest in reserve lands. First, it is clear that traditional principles of the common law relating to property may not be helpful in the context of Indigenous interests in land. Second, reserve land does not fit neatly within the traditional rationale that underlies the process of compulsory takings in exchange for compensation in the amount of the market value. It is difficult to assign a price to compensate for a long-held gathering site, place of importance for hunting or fishing, or culturally important resting spot during travels. Third, the Indigenous interest in land will

generally have an important cultural component that reflects the relationship between a community and the land and the inherent and unique value in the land itself which is enjoyed by the community (S, T).

These documents and their main themes provide contrast to those employed by existing governments to direct watershed management. While the government-based documents dictate, in hierarchical and positivistic ways, what decisions should be based on (i.e., optimizing benefits to western settler societies, ownership, and economic use), the Indigenous-recommended literature presents values for water that seem missing from government management policies; that is, ability to use and reuse the resource in perpetuity, relationship building with elements from nature, cultural importance, subsistence value, food and water security, and sacredness.

4.5.1.2 Ineffective Water Policies for Indigenous Watershed Management

While it is a strength that this was the first bill presented to parliament on Indigenous water management, the document with the most weaknesses was Bill S-11 (written in 2010), also known as the "Safe Drinking Water for First Nations Act." It did not reach debate on the order table in the same year it was proposed (Appendix-B). This document only had one identifiable strength by meeting one of the seven goals set up in the First Nations Water Management Strategy (Morrison, et al., 2015; Bowden, 2011), which is "a set of integrated water quality management protocols with clearly defined roles and responsibilities consistent with national performance standards along with improvements in emergency response procedures" (GOC, 2010). Bill S-11's weaknesses included that it did not ensure prior consultation with Indigenous Peoples about their water resources, provided little clarity on who had legislative, administrative, and judicial control over Indigenous water resources, and had no support in transferring resource control to the user community. Additionally, the regulations within this bill may be identical to provincial legislative regimes, creating uneven sets of standards that differ among provinces and individual Indigenous communities (Bowden, 2011). In short, this bill would have set up Indigenous communities for failure to independently manage water resources and sanctioning as a result. Researchers also felt that it threatened Indigenous Rights to manage water supplies independently or in partnership with the government (Wilson et al., 2018; Bowden, 2011). Due to these failing components, this document was widely opposed by both Indigenous and non-Indigenous individuals, preventing it from implementation, though it offered an opportunity from groups to start discussing what such a bill might look like, and to revise this first draft for further resubmission.

Out of the currently implemented watershed management documents in Canada, Bill S-8 followed on from Bill S-11, addressing its failings and offered some improvement. This Act provided new strengths in that it clarified enforcement of water quality regulations and standards for drinking water; however, the enforcement included rural Indigenous communities who may not have had capacity for management. It also created the opportunity to combine provincial and federal regulations for more effective management strategies and plans. Unfortunately, Bill S-8 has also been ineffective for Indigenous watershed management (Bowden, 2011). Bill S-8 fails to recognize Indigenous authority over water management on traditional lands, only drinking water treatment and provision. This bill is weak as an Indigenous water management policy as it gives control of watershed management to the Federal Government, Provincial subsidiaries, and non-Indigenous authorities (Morrison et al., 2015) and does not engage with Indigenous representatives. Legal scholars note that Bill S-8 violates nine articles in the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP), one of which is the right of Indigenous Peoples to manage their natural resources used for basic sustenance and cultural purposes (COO, 2013). Another weakness of Bill S-8 is that it does not ensure that additional resources will be provided to rural Indigenous communities for resources to meet the act's water regulations. Even though the policy has the Federal Government as the leading authority, liability is placed on the community leaders and water facility operators and the lack of financial and capacity support threatens them with financial and criminal penalties when those regulations are not met (Morrison et al., 2015). Despite the many issues, Bill S-8 was still implemented. Both Bill S-11 and S-8 are broad water management documents meant to be a format for collaboration between Indigenous Peoples and the Federal Government. These documents, however, create multiple barriers and limitations to effective collaboration with Indigenous Peoples, perspectives, and practices. There are opportunities for improvement, mainly through engagement with Indigenous partners, equitable enforcement and liability of regulations, and clearly defined roles and responsibilities of all authority figures.

4.5.1.3 Most Effective Water Policies for Indigenous Watershed Management

From the analysed documents, two stood out for their robust strengths that benefit Indigenous watershed management: the *First Nations Water and Wastewater Action Plan* (2006-2012) and *Bill C-15* (2020) (Appendix B-Table 1). The First Nations Water and Wastewater Action Plan (FNWWAP) was a temporary action plan led by Aboriginal Affairs and Northern Development Canada (AANDC) in collaboration with Health Canada (Morrison et al., 2015). Its primary purpose was to provide the necessary financial support to bring water management, treatment, and provision standards to the same level as non-Indigenous communities. This statement is further strengthened by the action of investing nearly $3.1 billion to create monitoring and awareness programs on source water protection, upgrade infrastructure, cover the cost of operation and maintenance, training, and certification of operators, and bring drinking water quality to safety standards (GOC, 2014). This action plan incorporated all impacted stakeholders and knowledge-keepers and had an integrative and coordinated leadership structure. A weakness to this action plan is that efforts were limited to improving drinking water and wastewater standards to the level experienced by non-Indigenous populations of similar size and location, without instruction or capacity to transfer skills and authority for watershed management. From what has been learned in financial and risk assessments, rural and remote communities with a small populace tend to be at higher risk for poor water quality (Hanrahan, 2017; Walder et al., 2017). It is possible that these communities will not have the capacity to independently advocate for source water protection, support these upgraded systems, and maintain quality standards in the long term, which could result in continuous poor water conditions in the future, threatening health (Wilson et al., 2018).

Bill C-15, *An Act Respecting the United Nations Declaration on the Rights of Indigenous Peoples*, is an initiative by the Provincial Government of British Columbia (GOC, 2021) and was implemented in June 2021. This act is not implemented in the prairie provinces, but was included for its alignment to Indigenous Rights; this way, I provide an example why it could be beneficial for provincial governments to learn from each other's governance strategies. The greatest strength of this act is that it has proven to be a powerful structure for Indigenous watershed management by clearly stating its purpose, objectives, and goals, and a summary of UNDRIP is included as a refresher for readers. Bill C-15 clearly explains how to implement actions and set timelines for consistent reporting (every two years) to ensure continued efforts to reduce the frequency and severity of any issues that may arise (GOC, 2021). It is detail-oriented, evidenced by its provision of explanations on what each clause means, its purpose, and the necessary actions to implement it. It is suggested in Bill C-15 that implementation should be shared among federal, provincial/territorial, and municipal governments; this could prove problematic if barriers to cross-jurisdictional coordination, such as differences in values, opinions, and poor communication among parties, are not resolved. Thus, the suggestion to implement multi-level collaboration is a strength if all parties commit to work together or a weakness if they do not. It does, however, provide opportunity to advance Indigenous sovereignty on watershed management and does not threaten the rights, values, and lifestyle of Indigenous communities.

4.6 Interview Responses

All interviews underwent inductive thematic coding until saturation (Guest et al., 2020) to discern themes around the impact of current practices on water quality in Indigenous reserve communities till thematic saturation has been reached (Figure 4.2). Interview data are presented next in two parts: Part 1 with Watershed Agency Managers/Agents and Part 2 with Indigenous Community members.

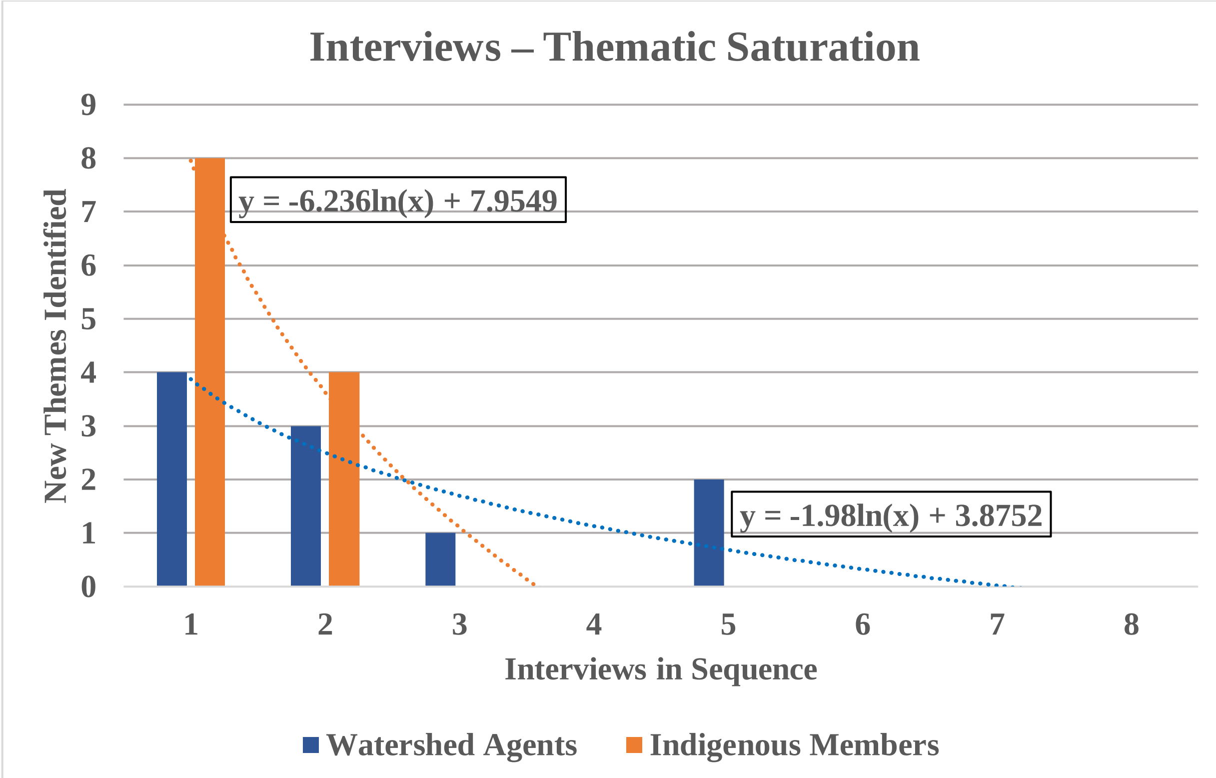

Figure 4.2: Interview Thematic Saturation

4.6.1 Watershed Agency Responses

Eight participants, representing seven agencies across a variety of governance levels (rural municipality, sub watershed organizations, watershed groups, Indigenous communities), participated in interviews conducted during February to March 2020 and June to July 2021. The watershed agents participating in an interview were equal number of men and women. Interviews ranged from 17 to 43 minutes in length and were transcribed and verified by participants. Half of the interviews with watershed agents were conducted by a former graduate student (Dr. Kelechi Nwanekezie, PhD) who was working as a research assistant at the University of Saskatchewan in 2020, and the other half were conducted by me in 2021. Six themes emerged: (1) Barriers to Nutrient Management and Monitoring; (2) Views on Policy Design and Suggestions for Policy Revision; (3) Resource and Capacity Challenges; (4) Inter-jurisdictional Collaboration among

Agencies; (5) Indigenous Representation among Agencies; and (6) Citizen science and Community Engagement.

Theme 1: Barriers to Nutrient Management and Monitoring

Participants stated that nutrient management and monitoring is the most common area of discussion for prairie watershed agencies because of the environmental impacts on rural populations. Participants stated that regions with abundant agricultural activity have a higher risk of excessive nutrient loading in freshwater systems; thus, most interviewed agencies indicated they are interested in monitoring or managing the movement of agricultural nutrients. Most participants said their agency assists producers in implementing "Beneficial (Best) management practices" or collaborate with partner organizations on projects to reduce nutrient inputs (INT-1-5 and 7):

> We try to collaborate with producers to help them implement best management practices that will improve water quality, such as fencing off sensitive riparian areas…restrict access to water and having water systems that pump out of the creek or sensitive riparian areas to troughs that are away (INT-4).

Only two participants stated they directly monitor nutrient concentrations, focusing on nitrogen and phosphorus-based compounds (INT-1 and 2); however, for one agency it was not clear whether these efforts were mandated, or out of personal interest:

> I'm involved in a very large drainage project. I'm personally doing a lot of water testing for nitrogen and phosphorus to monitor it…trying to get a baseline and then monitor it throughout the drainage to see if it changes (INT-1).

> We do look at nitrogen and phosphorus. Those would be our two focuses actually because of the eutrophication and the nutrient loading …we look more at nutrient loading into the wetlands as a whole, but also protecting the wetlands from cattle and overgrazing (INT-2).

The remaining agencies either focused on conducting general water quality testing (often for household use) or placed more effort on providing information on nutrient loading impacts to the public, rather than preventing them upstream:

> We also do a lot of water quality monitoring, and work with the city and the wastewater treatment plant to do water sampling and ensure that the treatment plant is not having a negative impact on water quality downstream of it…then we do a lot of education work. Newsletters, talking about what residents can do on their own to ensure that their practices aren't having a negative impact on water quality (INT-4).

Based on participant responses, the monitoring and prevention strategies of nutrient loading in freshwater systems is prioritized in the Canadian prairie region. Each participant stated their agency does what they can to mitigate excessive agricultural nutrient loading, either through water testing (INT-1, 2, 4-6), collaborating with producers and landowners (INT-1-5, 7), or public awareness and education (INT-1, 5, 6, 8). Participants have also mentioned that agencies would like to do more but are limited in the number of projects and programs they wish to implement due to various reasons (further details in following themes).

Theme 2: Views on Policy Design and Suggestions for Policy Revision

All agency interview participants shared concerns over policy design and how regulations are enforced for various reasons and gave their suggestions on possible revisions to improve policy efficiency. Participants explained that decisions over policy design and project planning are carried out by different individuals in each agency, depending on the agency's purpose and who provides their funding/employment. Participants provided various descriptions of who makes decisions within their organization; some said that decision-makers were individuals, such as executive directors or agency managers, while other respondents said decisions are made by groups, such as an elected Board of Directors, a City or Town Council, a government department, or user groups. Some participants were unsure who made final decisions on water testing and environmental projects within their agency:

> I don't know that anybody's in charge of water quality…Water quality decisions, I mean in the province of Saskatchewan, the Water Security Agency is…basically in charge of all things water. Saskatoon is a big water user. Well, our watershed and, I guess, water quality…is something managed by them, and probably the Ministry of Environment, maybe Public Health, I'm not sure (INT-5).

Participants were concerned that the variation in decision-makers made it difficult to collaborate with other agencies with a different decision-making process. One agent said they felt that decision-makers with the same background leads to unconsciously biased decisions on what the agency should do without considering other ideas:

> Our watershed is governed by a Board of Directors… rural municipalities have the ability to nominate either landowners …or residents within our watershed to sit on our board…many of them have an agricultural background…we don't necessarily have professionals in the fields of water quality or water management… I think sort of a lack of knowledge and understanding, maybe, and I wouldn't point it at our Board of Directors. Just as a whole across our watershed (INT- 7).

Another agent interviewed (INT-6) believed water quality concerns stem from the perception of user groups advocating, as discussed among Board Members. Additionally, the level of engagement with user groups influences whether those concerns will be addressed. When asked about how decisions were made, all participants agreed that changes are needed and that there should be more effort by non-profit agencies in water management. Some participants believe their agency could do more in terms of public awareness and to addressing nutrient problems, further work on Source Water Planning, and improve the sharing of water quality data:

> I think there definitely needs to be more awareness and I think we definitely need to do more about nutrient problems (INT-2).

> …some local community members, often landowners or peoples who are kind of interested…we did some shoreline planting projects…that's not something we've done a lot of, although I've been looking at incorporating more of that (INT-7).

> I think both citizen science and the sharing of data should be something that should be high on the priority list (INT-8).

In terms of enforcement, the watershed agencies I spoke to do not have a direct role in enforcing regulations but either assist in regulation enforcement or collect the data/evidence for those who do.

Theme 3: Resource and Capacity Challenges

Resource and capacity challenges are common among agencies, particularly non-profit agencies, limiting the number of projects each agency can do:

> We haven't received funding to the extent to make meaningful impact…but I think that's something that could be grown or improved on (INT-6).

This statement shows that funding is an issue shared between watershed agencies to address the problem of nutrient loading in freshwater systems and other watershed-related concerns. As explained in Chapter 2, when there is a limited budget to work with, needed resources are removed or downsized, minimizing the efficacy of efforts done by watershed agencies. Interviewed participants said their agencies had to limit the number of projects and programs they want to do due to lack of adequate funding, sources, and labour:

> Within our organization, unfortunately, everything comes down to money. There are certain projects and certain things we'd love to look into, but we just can't because we are a non-profit charity. We don't have huge amount of money to spend (INT-1).

The role of each watershed agency is restricted to a narrow field of focus, such as only environmental monitoring, working with a select group of people, or putting most of their efforts into public awareness and education. Therefore, agencies try to mediate these challenges by collaborating with outside organizations, authorities, and public volunteers.

Theme 4: Inter-jurisdictional Collaboration among Agencies

When asked about project planning and partnerships, participants explained that collaboration between different stakeholder groups is common among non-profit agencies due to the lack of capital preventing them from working independently. Therefore, collaboration is necessary for watershed agencies to operate and achieve their goals. “So, non-profits, you got to partner with everybody” is how one participant explained it (INT-3). Much like the variation of decision-makers, agencies collaborate with a broad range of organizations and user groups, creating a network that connects multiple levels of authority and power. For example, some groups working with watershed agencies include federal and provincial government departments, academic institutions, other watershed agencies, stewardships and conservation organizations, and volunteers from user groups.

Some participants have indicated that most project funding is provided by government organizations and large commercial groups, which often gave them a decisive decision-making role. Labour roles are often fulfilled by collaborating with other agencies and community volunteers. The type of partners that agencies collaborate with will often determine the degree of success toward achieving a project goal, but there are sometimes trade-offs in terms of control over a project. Some agencies may be employed by, or have signed a contract with, a larger organization with more jurisdictional or financial power on a few selected tasks, such as water quality testing for an urban or rural municipality or provincial health agency. For instance, one participant explained there is more of a focus on water quality monitoring but not enough programing for public awareness:

> …the biggest decisions on water quality are being made by the city…and its water treatment plant because they use the water …for domestic supply…that water treatment plant probably supplies water to 75% of the residents in the watershed…I’d like more involvement with the general public…to present information to landowners (and urban residents) that show how, maybe, they are impacting water quality…and what they can do to improve water quality for downstream users (INT-4).

There is not much collaboration in cases like these, as the partner organization with more financial or jurisdictional power will have more control over the direction of projects and agency responsibilities.

Based on some responses, participants felt a better connection with organizations and groups at the municipal and lower authority level. Mutual collaboration among groups is possibly due to both parties having more shared values and perspectives and are focused more on a goal that benefits local communities and the environment. One participant (INT-5) said that the level of collaboration an agency must have stems from the perception and concerns of their user group. For smaller concerns that an agency has the "capacity to support" are "taken into discussion with our Board of Directors," while more concerns that require more resources to resolve are transferred to the appropriate government partner. From the responses of participants, that non-profit agencies tend to work better with organizations closer to their authority level in the management system, with communities that are within their watershed, and with those who are interested in and support the agency goals and values.

Theme 5: Indigenous Engagement and Collaboration among Agencies

Interview participants stated that Indigenous representation is an area of interest in recent years for watershed agencies, but based on responses, there has been little engagement in terms of implementation and administration. Even though they are in the early stages, half of the interviewed agencies have stated they are engaged with Indigenous communities (or in the beginning stages) through restoration projects, source water planning, or educational programs (INT-3, 5-7) but are finding it difficult to keep engagement up:

> We've always lacked representation by the First Nations in our watershed. Our bylaws do state that there is a spot for First Nations representation on our

> Board…It's the biggest thing that we're lacking…We're in the initial discussion phases for some wetland restoration projects with the First Nations reserves in our watershed…It's been tough with COVID…we're trying to get something put together here but I don't know whether we can pull it off (INT-3).

Two other agencies are in the beginning stages of community engagement with Indigenous Peoples in projects (INT-3 and 7). One agent (INT-3) said they tried to start a project with Indigenous youth, but the COVID-19 pandemic prevented that. There was no confirmation that this project would be tried again later. Agencies that are not currently engaged with Indigenous communities say they find it difficult to engage when reserve lands are not within their mandated watershed boundaries or are unsure how to start that relationship:

> We don't have a First Nations or Indigenous reservation in our watershed…we've been talking about one of our target goals this year is to be more involved with the Indigenous communities that we haven't in the past (INT-2).
>
> We try various methods to discuss personally with leaders in the Indigenous community…we find it very difficult…the First Nations and Métis communities have so much on their plate (INT-8).

Participant #8 expressed their agency's understanding that Indigenous communities already have so many responsibilities that asking them to take on another one might be putting an unwanted burden on them. Though, that may not be true since some connections between agencies and communities are made through a third-party organization at the request of communities. It might be possible that agencies are afraid to accidentally make a wrong impression and cause damage to future opportunities to work with Indigenous communities, as these agencies have expressed their interest in working with Indigenous Peoples within and outside their watershed.

Theme 6: Community science and community engagement

Based on interview responses, there is little community science and community engagement with watershed agencies despite their support of the practice. Agencies mainly work with environmental and conservation organizations, other watershed agencies, academic institutions, and agricultural producers and landowners. Capacity challenges are why community science methods have rarely been used on non-profit agencies. As explained before, capacity building and sufficient funding are needed to provide the resources for project that employs community science. Without it, agencies cut back on projects and methods that incorporate public engagement or remove them altogether. A couple of agents have said their agencies strongly focus on monitoring or implementing best management practices, leaving community science and community engagement to the side until sufficient funding and resources are attainable. There is a shared agreement among interviewed agents that there needs to be further action to employ community science methods and educational programs, including data sharing with the public and impacted communities.

> I think we could develop quite a bit in the efficiency of citizen science sampling…volunteers have been well trained and provide comprehensive data. I feel there hasn't been enough support and training of volunteers…it would require more investment… there's a lot of opportunity with citizen science…that isn't being utilized to its full extent (INT-6).

This same respondent mentioned they had positive experiences working with volunteers and that the volunteers provided "comprehensive data." This sentiment was echoed by another respondent who said that community science was better in the past:

> They've been lacking in accepting citizen science. At one point 20 years ago, they made stewardship groups, and they help them study the lakes, and helping in doing water quality testing. There were a number around the province, but that went by the wayside. There was a person in executive at the time who didn't believe in citizen science and don't believe that they could take the sample properly enough to be credible. It was actually disheartening because that was almost at the same time, we started a watershed planning within the province and a big call for more water quality data and the sharing of that data (INT-8).

Some agencies have said they are doing public awareness, but there is only so much that can be conveyed in booklets, posters, and lectures. Community and citizen science and community engagement allow the public to interact with the science and play a role in the research progress, making them excited to do and learn more. Still, some agencies found it hard to get people engaged. This is not fully understood, but it often comes down to individuals' lack of interest or volunteer experience. Youth engagement is an avenue providing children and teens with an interactive experience, garnering interest and positive response to research and environmental projects. Two agents indicated that their agency is currently engaged with the public volunteers using citizen science kits (INT-1 and 5) or had positive experiences working with volunteers (INT-6). Agents felt that if capacity building and public interest improve, citizen science and community engagement are likely to be a standard methodology for future watershed agency projects.

4.6.2 Indigenous Community Representative Members Perceptions on Management in the Watershed

Interviews with Indigenous community members were conducted to better understand their views on watershed and nutrient management in Treaties 4, 5, and 6 and how that management impacts their water quality, health, and culture. Following traditional protocol including gift and tobacco giving and a community blessing with an Elder, interviews with Indigenous community members were planned to be in person, either privately or with a group sharing circle. The COVID-19 pandemic health and safety restrictions prevented this from happening as I did not want to impose risks on communities, and due to community regulations, I was also unable to enter reservation boundaries. Past interview data was collected by three research colleagues in 2019 and 2020, focused on water security and flood management (Kurt Belcher, Lori Bradford, and Lalita Bharadwaj). These transcribed interviews with Indigenous participants were believed to provide similar perspectives on the challenges on water quality and management. Using the results from the SWOT analysis and prior literature review, nine topic areas were used to extract information from secondary sources (transcripts): funding and capital issues, information sharing, community involvement, government assistance, cross-jurisdictional issues, prevention planning, double-standards, risks to water quality, and impacts on health and culture. Secondary data were derived from 37 participants interviewed, individually, in sharing circles, or “across the table” conversations, and groups ranged from two to 25 individuals. Based on the responses from these interviews and earlier themes, five new themes emerged: (1) Challenges to Building Funding and Resource Capacity; (2) Lack of Involvement and Information Sharing with Indigenous Peoples; (3) Degree of Government Assistance and Cross-jurisdictional Issues; (4) Water Contamination Sources threatening Community Health; (5) Extended Negative Impacts on Indigenous Health and Culture; (6) Double Standards experienced by Indigenous Communities in Watershed Management.

Theme 1: Challenges to Building Funding and Resource Capacity

Participants stated that insufficient funds and capital (social, economic, human resources) are ongoing challenges for Indigenous communities to provide training, infrastructure maintenance, and proper operation of any environmental services, including water monitoring. Indigenous interview participants explained that this is an issue that impacts that whole community, from degrading road conditions to cutbacks on services, such as mental health. One participant explained that funds from Indian Affairs Canada (INFA) does not cover all necessary operational costs for on reserve services; there is annual funding of around $700,000 meant for all reserve services, but despite the community’s growing population and rising inflation, “the budget stays the same” (INT-11). With a limited budget, communities try to live with the aging infrastructure like buildings, roads, and culverts, making repairs with whatever materials they have and spending the budget only on priority items, leaving less for other services. Regarding health programs, the Federal Government provides a “steady flow of money” for mandatory health programs for communicable diseases (spread from person to person) (INT-36). Participants said that this funding does not support environmental-related health issues, such as algae blooms or inorganic chemical exposure.

Indigenous interview participants said that limited finances and resources also burden their communities before, during, and after emergency events. One example that a majority of participants returned to frequently was the 2012 flooding event in Central Saskatchewan that impacted the communities participating in this study. Budgets do go up during emergencies, but participants have said that the Federal Government (INAC) would not provide the additional funding until there has been an official "state of emergency" declared by the reservation Chief and Council (INT-11), after which they are provided around 30% of the total costs (INT-10). Participants did mention that the Provincial Government also helps support Indigenous communities with health-related funds during emergencies but rarely covers post-emergency costs, including environmental restoration or monitoring. One participant mentioned the Emergency Management Assistance Program (EMAP), which is a partnership between First Nations communities and provincial/territorial governments for the purpose of emergency preparedness, response, and recovery (INT-10). It was mainly through this program some financial assistance was received, but Indigenous communities must submit expenditures to receive reimbursement, and some things are not reimbursed:

> We have to track down all our expenditures from transportation to meals that we provide. We have to track them down and overtime hours of our staff, everything has to be recorded and submitted to the Provincial Government, which reimburses us somehow. But not everything is reimbursable. (INT-36).

Even before the 2012 flooding, participants noted that the lack of funds for watershed monitoring and badly needed reserve infrastructure maintenance contributed to the difficulties experienced during the emergency. In one community, the roads had not been upgraded in the last few decades, making them difficult to traverse even during ideal weather. When the previously damaged and worn-down roads were flooded, it prevented essential services from reaching homes, such as water delivery, garbage and waste removal, medical transport to appointments in nearby urban centers, and bus services for students:

> Essential services for sure, like water and sewage trucks, they're going to be impacted because of the impassable roads. Ambulances and firetrucks can't access these flooded areas. That was one of the major reasons why we called an emergency (INT-8).

Participants reported that flooded roads and expanded wetlands stranded some of the community's most at-risk residents with chronic health issues, making it difficult for community volunteers to evacuate them or deliver medicine. One community set aside $10,000 from personal funds for an emergency budget because INAC does not provide emergency funding ahead of time (INT-10 and 11). Participants said that a small budget would easily be used up in one emergency event. Should a community experience multiple emergencies, it could borrow funds from other services not as crucial at the time but are still needed (respondent did not specify which services or how much is borrowed) (INT-36). If the reserve's water and environmental operations are part of those services, the lack of monitoring of source water, and potential spillover to source waters from nearby wetlands could impact the community's source water. These responses present the capacity-building challenges are felt in all areas and can potentially worsen other challenges in the community.

Participants suggested that there should at least be more financial assistance for communities at higher risk of water-borne contaminations through surface source waters by improving up- and downstream communications, investing in better water treatment methods, upgrading aging water management infrastructure like dams and floodgates, and increasing monitoring for effective source water protection planning. They noted that overall, it is difficult for Indigenous communities to receive enough funding and capital for daily operations and emergency events, let alone participate in wider watershed efforts. Additionally, there is the added confusion with the various organizations and government departments that are involved in financial support. Elders expressed their confusion about who they were receiving funds from and how those funds were being allocated. That confusion enhanced the conflicting nature of whether it was safe to share information between Indigenous reserve communities and external organizations since different jurisdictions seem to be at odds with Indigenous planning mechanisms.

Theme 2: Lack of Involvement and Information Sharing with Indigenous Peoples

Most Indigenous participants said there is a lack of information sharing between their communities and external organizations and governments. Some participants also believe there is poor communication between organizations and government departments:

> They (INAC and Health Canada) don't know what is going on with each other, and they work for the federal government. Those are the kind of barriers that happen, especially at the grassroots level with a lot of reserves (INT- 11).

Some participants (INT-9-11, 16, 36) said a lack of transparency is why there is little engagement in discussions on external activities impacting their lands, resources, and traditional practices. The lack of Indigenous involvement is distressing to participants, as they feel that collaborative work will be beneficial to their communities and reduce racial bias amongst groups. Indigenous participants want opportunities to share information and knowledge with external collaborators and governments:

> Yeah, but Elders knowledge on stuff like this are going to be instrumental when it comes to dealing with questions like that. In my time, I see a lot of changes, especially in weather patterns…it's real. It's going to affect future generations for sure (INT-20).

Some individuals say they would like to know more about water movement and what "proactive measures" they can take to prevent future overland flooding, nutrient run-off, and contamination of water sources (INT-18). Other participants would like "more direct help from…representatives from all levels of government" through in-person visits and discussions with residents (INT-20).

Theme 3: Degree of Government Assistance and Cross-Jurisdictional Issues

Interview participants discussed the varying degree of assistance Indigenous communities received from government and the conflicts between jurisdictions that limits that assistance. Indigenous participants have noticed these issues and how it impacts their ability to provide all essential services or prepare for possible unexpected events, such as watershed disruptions and severe weather resulting from climate change. One of the most common cross-jurisdictional issues participants mentioned was the lack of engagement with Indigenous leaders and residents on the environment by governments and external organizations (INT 8, 9-11, 18, 20, 30). One participant said they would like to have a scheduled visit to the community from government officials:

> They should be here, representatives from all levels of government, every time something happens…they have to come and see it firsthand and what we are going through but they never actually came (INT-9).

Participants who had been in local governance said that a lack of commitment and failed promises adds to the distrust in external government involvement, making it difficult for future attempts to involve Indigenous Peoples in government-related programs and management (INT-6-9, 11, 20-22, 30, 36). Government assistance during water emergencies was also lacking, as explained in the previous section on financial and capital building challenges. After an emergency is declared, the respective Federal government agency for the affected community would begin following set guidelines for the emergency circumstances, which takes too much time. Indigenous participants that experienced the flooding in 2012 said it took two weeks after the emergency event ended before the community received financial support (INT-11). Due to the slow response by the government, participants said that community residents had to take up the role of evacuating and providing support services because they did not have the time to wait.

Participants made it clear that Indigenous Peoples had many negative experiences with the Canadian government, but some individual government departments, agencies, and programs have established a good relationship with Indigenous communities. Interestingly, participants said most of their positive relationships are with some divisions of the Provincial Government, and federally, with Health Canada. Participants said that Health Canada provides sufficient support for daily health needs and has a good rapport with the communities:

> Our health program is totally separate from what the band office is getting from Indian Affairs or Indigenous Canada, right…Our funds are coming directly to the health program, and they are coming from Health Canada…We get support from different government agencies, as well as non-profit organizations…the Provincial Health Government, Provincial Government Agency…the Red Cross…So both ways, we get enough funding (for normal health program services) (INT-36).

Participants mentioned the Emergency Management Assistance Program (EMAP) as being the most accessible for emergency support. The EMAP program's direct partnership between Indigenous Peoples and the Provincial/Territorial Government is perceived by participants as the reason why it was successful as an emergency measure. They said that the EMAP processes emphasize the benefits of collaborating with Indigenous Peoples to create plans, programs, and policies that better support their rights, establish more representative roles, and provide resources needed for improving infrastructure and essential services to prevent or prepare for emergency events. They did not know though, whether algae blooms, nutrient run-off, or other contamination event would represent a big enough 'emergency' to qualify for emergency support. In their views, yes, the contamination of their source and culturally important waters would be enough to constitute an emergency, but not if they went strictly by government guidelines.

Theme 4: Water Contamination Sources threatening Community Health

Even though the interview questions were originally directed towards flooding and post-emergency outcomes on reserves, responses from participants provided information on possible risks to water quality from poor management and point sources. Some of the risks that participants observed include high precipitation and climate change, land flooding, illegal trenching of farmlands diverting water and excessive nutrients onto Indigenous lands, inorganic chemical spillage, and damaged water and wastewater infrastructure. Participants agree there is not much that can be done about climate change at the municipal or watershed level but plans and policy revisions can help prevent or alleviate the impact of the other potential risks to water quality. For instance, broken or leaking cisterns prevent proper water storage and allow contaminants to enter groundwater. This can result in algae/bacteria growth, and algae spilling from flooded wetlands, causing users to either use or consume untreated water and eat wildlife who have been in that water, or spend more personal funds on safer foods, bottled water, or cistern replacement:

> I got the environmental health officers from the Tribal Council to come up, help assess the cisterns…got back the report, 31 of them were condemned...I get a quote every year to replace those 31 cisterns…it's $3700 a cistern…That's just for the material. You need another $80,000 just to install (INT-10).

Participates revealed that septic tanks are also aging and leaking, becoming a source for nutrient runoff, and leading to other potential health risks (i.e., E. coli), from leakage of cisterns into local waterbodies, and source water supplies. The potential loss of a cistern, or concerns about existing septic tanks influenced community wellbeing, and perceptions of environmental health.

Previously mentioned, one participant said that money may be borrowed from programs and services to cover emergency costs (INT-36); if resource management budgets are siphoned for other priority needs, there are even less finances for environmental officers and treatment operators to work with, putting a higher risk of contaminant exposure. Participants also said they experienced "an increase of cancer clients in the community" (INT-36). These cancer cases may not be directly related to watershed management on-the-whole, or the flooding events, but some participants perceived it possible that some cancer cases are related to repeated environmental and/or cyanotoxin exposure (INT-7), presenting a threat to both short- and long-term health, cultural appreciation for their waterbodies, and the protection of traditional practices.

Theme 5: Extended Negative Impacts on Indigenous Health and Culture

Participants stated that unclean surface waters affect the traditional practices that are valuable to Indigenous lifestyle and identity, such as hunting, fishing, and gathering medicinal plants. Participants said contaminants in watersheds also impact the health of wildlife, limiting the traditional foods used in ceremonies or daily consumption, thus harming the overall health and cultural practices of Indigenous Peoples (refer to Chapter 3). Interview participants explained that the mental health of community members is not solely impacted by poor water quality, but also by the recurrence of preventable emergencies that removes people from their homes and traditional lifestyle:

> Number one is their mental health. They're greatly affected because whenever somebody is evacuated, your mind is still within the community, within your house, (wondering) what is happening with my pets and so on…their sleeping pattern will be greatly affected…they lose weight…they are deprived of their traditional food, those kind of things (INT-36).

With worsening water quality and limitations on traditional and cultural practices due to physical health risks, participants expect to see further decline in the mental health of community members. A few participants, who had previously evacuated during an emergency, said they felt emotionally distressed when they were away from their homes, especially for long periods and multiple times:

> The evacuations that happened, the impacts to the people…How do you ask an already distressed person, how much more distressed they've been put under…But that's how it is…year after year after year (INT-10).

> I got evacuated about three, four times, I guess. The longest time was just about two weeks and that was hard. We were away from our homes. (INT-21).

Evacuations are harder on those with a strong connection to the place, the land, and the traditional practices connected to it. Participants said it was particularly tough for Elders and children who were separated since they are used to the *close-knit family structure* in Indigenous households. One respondent (INT-28) recalled an evacuated Elder who felt isolated in their hotel room and was unable to leave because of health problems. It is clear in the responses from Indigenous participants that the physical, mental, and spiritual health of community members are constantly being harmed by contaminants in natural water or food sources, limitations to traditional practices, and a disconnection from family and home during evacuations.

Theme 6: Double Standards experienced by Indigenous Communities in Watershed Management

The responses from Indigenous participants detailed that there is a perceived difference in watershed health standards between Indigenous and non-Indigenous populations. For instance, participants expressed their dissatisfaction with their living conditions and how they were treated as second-class citizens by external organizations and governments compared to non-Indigenous populations:

> Our houses do not have the same categories of houses being built in urban areas, and I resent that. We are treated like a totally different class of people. If you are going to look at the building code in the city right now, I guess they are implementing the air exchangers, but here anything that is built will be occupied by anybody. Maybe what you see in your place, and if you go into some houses here, you might say this is not habitable and that is true. No exaggeration (INT- 36).

Participants argued that the difference in living standards is a challenge to many parts of daily life for Indigenous reserve residents, including skewed financial assistance, lower health care access, education, and limited media attention preventing external populations from fully understanding Indigenous conditions. Interview participants felt that a lack of awareness interfered with external organizations understanding their plight and engaging with them. Some other examples include the governments' limited support and slow response during emergencies, living standards on reserve lands being lower than non-Indigenous urban and rural centres, and unreasonable expectations for involvement in local social, political, or environmental movements with external organizations. The participants noted that double standards Indigenous people live with also influenced their ability to effectively get involved in management and planning external to their reserve communities, prepare for emergencies, and prevent future communal health risks. Further information on the double standards of Indigenous water quality can be found in Appendix-A.

4.7 Discussion

This study provides qualitative results showing that in the case of watershed management in Treaty 4, 5 and 6, there is a lack of action or policy to protect Indigenous rights, prioritize their concerns, increase data quality and quantity, and encourage new methods of environmental research and management methods, which aligns with findings of other researchers (Black & McBean, 2017; Sardarli, 2013; Patrick, 2018; Bradford et al., 2018; Arsenault, 2018; Robins, 2007). The SWOT analysis found that water policies are generalized and lacking information on the purpose, procedures, protocols for Indigenous engagement; others who evaluated political promises and federal obligations to Indigenous communities found similar results (Dunn et al., 2014). When SWOT results are examined alongside key Indigenous documents on Treaty interpretation, and interview responses, these written promises have not been fulfilled, policies remain restrictive or unenforced, and the outcome of both prevents adequate growth of needed capital. These results again align with others, for instance, some previously used policy strategies were described as "little more than a statement of good intentions" but "largely ignored" continuing problems (Saunder & Wenig, 2007, pg. 126).

Interview participants described only minimal inclusion of Indigenous representation in political and social discussions, which, noted by others, impedes the Indigenous right to self-determination (Fontaine, 2020), and results in failures to respect protocol (Hanrahan, 2017, Bradford et al., 2018). Participants felt that including Indigenous Peoples and their practices in watershed management is necessary to strengthen watershed health, cultural identity, spirituality, and the professional relationships between Indigenous communities, the Canadian Government, and external organizations and institutions. Others have reported similar needs (Waldram et al., 2006; Simms et al., 2016; Bradford et al., 2017; Arsenault et al., 2018). In these results, the lack of community engagement, continuing disputes over the inequitable treatment of water sources, and tensions between Indigenous communities and the Canadian Government are apparent (Patrick, 2011; Galway, 2016; Hanrahan, 2017).

This study echoes conclusions of others that there has not been enough action to embrace more Indigenous engagement, knowledge-sharing, and Indigenous management practices (Arseneault et al., 2018) in Canadian Watershed Management. Since the 1970s, there has been an increasing expectation for community-level stakeholders to take part in the decision-making process (Illsley, 2003; Shrubsole & Draper, 2007), but there remains the long-standing challenge of capacity building in water management, which is part a larger socio-political dimension identified by others (Lebel & Reed, 2010; Arsenault et al., 2018) and as explained by interview participants. At the municipal and institutional level (i.e., universities, agencies, and non-profit organizations), this, and other studies show the beneficial nature of blending Indigenous and western environmental practices in discussions and community-based research and monitoring, such as sharing knowledge and skills to achieve a mutual goal (Wilson et al., 2018; Gérin-Lajoie et al., 2018; Patrick et al., 2019). With broader knowledge sharing, management systems can better adapt to changing circumstances and challenges in the future (Dupont et al., 2014; Bradford et al., 2018), however, in these three Treaty Areas, there was a lack of evidence to show that adaptation was occurring for watershed management in general, and more specifically for nutrient management.

This study is meant to provide information on the current status of water policies in Treaties 4, 5, and 6 around nutrient management, based on an analysis of existing polices and interview responses of individuals involved or directly impacted. The further purpose was to relay the evidence gathered in this study to policy- and decision-makers to potentially initiate action toward an improved water management system benefiting both Indigenous and non-Indigenous Peoples. Results provide further evidence that there needs to be more harmonization between governing hierarchies in terms of jurisdiction, responsibilities, and decision-making authority at the Federal and Provincial levels, and there is opportunity requirement, given UNDRIP, for Indigenous watershed management policies to emerge from communities. This way the goals, values, and priorities of everyone involved are aligned and integrated to increase the likelihood for successful social outcomes (Bradford et al., 2018). However, after a troubling history between Indigenous Peoples and both federal and provincial governments, sharing of Traditional Knowledge may be limited due to distrust in governments and institutions from past negative experiences (Arsenault et al., 2018). Much like this study, there is little information in the literature on how to approach this problem, but the interviews and SWOT in this study did demonstrate that poor watershed management and a lack of meaningful engagement with Indigenous communities remains unresolved.

Interdisciplinary Approach

By conducting this study simultaneously with the nutrient and algae bloom monitoring studies (CH. 2 and 3), I gained real time observation of some obvious impacts, which helped to build my areas of focus for the SWOT. This strengthened my study approach as I was able to find evidence on the strong interconnection between social and political actions and the lack thereof, with environmental and economic challenges. This distal interdisciplinary approach supported more holistic findings on the overall system of watershed management and its performance.

This study had some limitations. For some watershed management policies, I did not have access to the official documentation due to delays in the access to information requests and the pandemic, and was restricted to including assessments done by other researchers. Other than one watershed management policy implemented in British Columbia, this study focused water policies on Treaty 4, 5, and 6 in Saskatchewan, and did not analyze water policies in other provinces and territories. Currently, water management and enforcement standards vary between provinces and between Indigenous and non-Indigenous boundaries (Dunn et al., 2014). With the differences between the policies in Saskatchewan (B, C, E) and British Columbia (L), I note that there appears to be a difference in values and goals toward Indigenous engagement and further analysis on watershed management based on province. Future research could analyze the water policies, acts, and regulations in different Canadian provinces for strength, weaknesses, and how each province can learn from each other’s successes and mistakes. This study helped to build further understanding of the continuing social implications in watershed management, so that more targeted social sustainable strategies can be implemented to improve both environmental and community health on Indigenous lands and bring attention to possible directions toward future research on Canadian watershed management and policy.

CHAPTER 5 PREFACE

During the winter of 2023, Health Canada received a report on public health issues and the suspected causes of illnesses by province for the past year. Surprisingly, there was an unusually higher number of reported water-borne illnesses and infections than in the previous decades in the Canadian prairies. This aligned with veterinary reporting on illnesses in cattle herds as well. Many cases of human illness were recorded as severe or requiring hospitalization, and the province reported 25 waterborne illness deaths, each from a different sub-watershed area. This information prompted Health Canada to conduct an inquest. Through a suggestion by one of the department's agents, and with agreement by the overseeing judge, Health Canada hosted a series of open house meetings and invited various stakeholder and rights-holder groups for a thorough understanding of 'what is happening on the ground' through the viewpoints and experiences of those affected and involved. Proposed discussion topics were included in the invitations so potential participants would know what the meetings would be focused on, but remained general to account for changes in discussion due to new information. One such meeting was held in the banquet hall of the Roseberry Hotel in Regina, Saskatchewan.

Individuals from diverse representative groups attended the meeting. Ms. Mullins from the Federal Government and Trudy from the provincial government showed up (Hierarchical). In addition, NGO agents Suzanne and Omar were there (Egalitarianism), and Dante (Fatalism) came too. Brett, the canola and cattle farmer (Individualism) and Elu, the environmental monitor of Rolling Valley Cree Nation (Individualist) also decided to attend. Aki (Fatalism) was personally invited to be one of the Indigenous representatives at the meeting and was asked to provide an opening blessing or prayer. At first, she was unsure due to the disappointment she experienced trying to work with the government in the past, but her daughter encouraged her to go and joined her there. A local newspaper organization, *The Country Times*, was also invited to record the meeting's discussions and share some of that information with the general public. The editor of *The Country Times*, Jeff, decided to send one of the student interns, Jessica. Jessica didn't have any knowledge of the proposed discussion topics, but she was eager to prove to Jeff she can be a valued journalist. She was mostly watching from the sidelines (Autonomous).

After the facilitator said a quick thank you to everyone that could attend, and a brief overview of the meeting and its purpose, Aki's prayer occurred. Then, the meeting progressed with some questions probing what participants know and feel about water quality in their region, followed by a discussion of the perceived causes of water quality issues. After two hours of vigorous discussion, the majority of participants were in agreeance that nutrient movement and cyanobacterial growth are concerning problems, but the lack of information-sharing meant these issues continued with no one taking leadership on fixing the problems. Since each participant experiences water quality management differently, the group determined that a National Water Data Network would be most beneficial so all could share information and that information would be accessible to all authority levels, local to federal. Further discussion revolved around what information should be included and the group came up with a list:

1. Nutrient concentrations in natural waterbodies to monitor if levels are within normal ranges, or to help find external point sources.
2. Quality of water entering treatment plants and after treatment to indicate treatment efficiency.
3. Algae bloom assessments to determine if waterbodies are safe for recreation or a water advisory is needed.
4. Local, Traditional, and Treaty knowledge, as well as pictures and stories recorded and uploaded to a GIS database. The database was to be designed with academics and watershed groups so stories could be connected to place.

People at the meeting felt that this data network would create transparency among authority levels, and provide data to researchers, watershed agents, and public groups that want to see the collection of information to help them make decisions. Since this network is planned to be a continuous method of water quality monitoring, data will show trends that will indicate to NGOs and government agents if strategies are successful and where they are/are not working. The network will be set up so agencies and academic institutions contributing can directly input data so there is faster response to concerning results. Participants agreed that the inputting of data can be done any time at the discretion of the agency or institute but no later than 4 months since the last data log date is a reasonable requirement. There would be opportunity for youth to be trained and involved. The people also agreed that data results outside normal ranges should be reported no later than a week after the data was collected to protect public health.

However, to gather data, some NGOs and service operations said they need assistance to remove capacity issues and improve funds needed to establish and enhance water monitoring programs. These points were brought up so that eventually, at a future meeting, the groups could work together to design strategies to improve communication and partnerships among NGOs, and local communities (volunteer researchers). They also thought they needed a new policy to allocate government funds appropriately for better maintenance of flood infrastructure, water and wastewater operations and NGO and community-based environmental projects. Participants decided that further discussions were needed; Health Canada representatives agreed and said they would book a meeting space and inform participants of the date for the next meeting.

Story as Analogy: Part 4

This story is an example of how diverse groups can collaborate to create a “clumsy solution” (Thompson, 2008). This form of solution design is not commonly used as it strays away from the *elegant solutions* designed through processes that exclude people holding perspectives other than those in dominant groups or the resource-rich (Thompson, 2008; Offermans, 2010). A clumsy solution is one that satisfies at least some of the needs of each perspective group. What is meant by that is some groups may get exactly what they need from the solution, while others may not but still receive some sort of alternate benefit. In this example, the majority of people were experiencing problems in information and data-sharing. By creating a data network, most groups will benefit. For instance, Elu and other environmental monitors can share data and prove to funding agencies when budgets aren’t enough to cover costs or when local watershed conditions create costs above what is expected (e.g., increased blooms means going through more filters, and more expensive filters). Crop and livestock producers, like Brett, can check if nearby water sources upstream and downstream are impacted by his and others’ agricultural activities or his stock are experiencing illness from local waterbodies where they may drink. Government employees that distribute funds, like Ms. Mullins, will have a clearer understanding of the water quality needs in communities, whether for better infrastructure for flood control, or remediation programs, or for capacity building on monitoring programs. Watershed groups can contact government agents if the numbers are not satisfactory to discuss adjustments to a budget to improve water quality, public health, and safety. Trudy and other provincial government agents can use the data to inform local communities of water quality concerns, even concerns that are not within their jurisdiction, such as Provincial or National Parks where people will go to camp, fish, and enjoy water recreational activities. They can also report federally on their progress on the Sustainable Development Goals, such as Goal 6, Water and Sanitation, or Goal 14, Life

Below Water. Omar, Dante, and other NGO agents who have been wanting environmental monitoring programs are now supported to initiate one in their watershed to contribute to the network without also having to manage a complex database; once the next meeting on resolving capacity issues happens, NGOs are expected to start these programs. Suzanne, who is also an NGO agent, wanted to establish more BMPs on agricultural lands. Despite not getting that result from this meeting, she will be able to find the data network useful since she will have access to data that will indicate where BMPs are really needed and which are working. Since the data network is planned to be open access to the public, Indigenous Peoples will be able to use the information in research with academic institutions and be able to see if upstream waterbodies will put their communities at risk, and where their knowledge is being taken up to prevent losses of cultural activities, and remediate different waterbodies. Plus, with more environmental monitoring, it is expected that more community members will be invited to participate, providing voice, knowledge, and representation.

CHAPTER 5: DISCUSSIONS, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Summary of Results

5.1.1 Interpretations on the differences in Nutrients, Cyanobacterial Dominance, and Watershed Management Policies

To advance progress on Indigenous water challenges, a major improvement would be if the watershed management system was observed as a whole, instead of focusing in on the parts bounded by political jurisdictions or disciplinary boundaries. Research on individual components, or sub-watershed phenomena has been conducted extensively, but rarely have studies stepped back to see how they connect across the whole watershed, or socio-ecological system. It is within these overlapping areas among the political, social, and environmental components to sustainable watershed management that barriers emerge constraining effective watershed management and progress on Indigenous watershed management challenges. This research project was focused on understanding the environmental (Chapters 2 and 3), social (Chapters 3 and 4), and political (Chapters 2 and 4) components of sustainable watershed management in Treaty Areas 4, 5 and 6, and to identify key connections between them that influence Indigenous watershed management challenges. Based on the data gathered in these three studies, there is evidence on the unbalanced and dysfunctional nature of watershed management in watersheds containing a reserve community (all land involved as data sites in this study is Treaty land, and thereby Indigenous land).

It has been well documented that Indigenous communities are often subjected to unequal water quality standards, limited financial and resource capacity, and little government support in water access and management compared to non-Indigenous populations (Arsenault et al., 2018; Bereskie et al., 2017). The present watershed management systems in Treaty 4, 5, and 6 are rudimentary and have a difficult time adjusting to changing environmental and societal needs.

Without significant change toward a more adaptable system, Indigenous water challenges are expected to worsen (Simms et al., 2016). Therefore, it is important to take an interdisciplinary approach to studying both the components and the whole of watershed management in watersheds with reserves to find where the system succeeds and fails. The results found in this thesis emphasize the asymmetric balance in power and control in decision-making, the allocation of resources, and the degree of responsibility among various levels of jurisdiction and government, often leaving subsidiary stakeholders and Indigenous communities with the least amount of leverage but most affected.

Watershed management as a process has multiple components which are physical, social, economic, cultural, spiritual, and political in nature, making it complex and difficult to fully understand. There are, however, obvious differences between settler-Canadian and Indigenous watershed management priorities and perspectives on success. First, water management activities on Indigenous lands are held to different standards than external communities, and funders provide less capital than is needed for appropriate source protection, and remediation of issues such as blooms. Enforcement of water quality standards in local waterbodies are not as robust to prevent contaminations and community illness, especially when these issues arise from upstream sources, outside of reserve boundaries, bringing jurisdictional conflict. In addition, the dramatic changes to climate (excessive precipitation, drought, or storms) are placing Indigenous communities at an even higher risk than before by negatively impacting water quality more frequently, reducing the ability to predict harmful outcomes, and making it harder to effectively maintain healthy watershed (de Loë & Plummer, 2010). This is evident in the results from Chapter 2 and 3, showing there is no strong correlation between climate conditions, nutrient concentrations, and cyanobacteria growth/dominance during abnormal climate years (Table 3.3; Figure 3.6).

Second, watershed monitoring capacity and tools, and collaborative community engagement are underfunded in Indigenous communities. Communities in this study stated that there is interest in increasing community participation in monitoring programs and environmental research. But resources are limited, as are collaborative and pan-watershed opportunities to apply these methods. Other barriers to community engagement in water monitoring are often caused by societal and political disagreements, biased opinion, and distrust from a colonial history, continuing issues, and defaulted government promises (Blomquist et al., 2007, Robins, 2007; Dunn et al., 2014; *Indigenous Interview Responses*). There has been more effort to engage communities in environmental monitoring and research in recent years, but collaboration between Indigenous communities and the Government of Canada in political discussions trails behind the progress other nations have made with Indigenous engagement (for example, New Zealand, Scandinavia, and Australia) (Hill et al. 2012; David-Chavez and Gavin, 2018).

Third, current Canadian watershed management policies are not adequate to resolve Indigenous water issues because of their rigid structure, and poor adaptability to environmental and societal changes (Walters et al., 2012). Information and guidelines in Canadian water policies are generalized for settler populations and lack discussion of Indigenous-specific water values and concerns (McCullough & Farahbakhsh, 2012; Murphy et al., 2015; Baijius & Patrick, 2019). In policies that do mention Indigenous communities, the formulae to determine funding and methods for “management” do not account for the unique environmental, social, economic situations, and cultural conditions of each reserve community and the dynamics of those with respect to the overall watershed (Herman-Mercer et al., 2018; Wilderman et al., 2007). My analysis found that most watershed management policies lack inclusion of the knowledge and worldviews important to Indigenous culture, do not account for differences between Nations, and overall, lack the primacy of the significance of the land and water to the people. The few policies that were well-suited to effective Indigenous watershed management were those developed or governed by an Indigenous authority, and centered cultural perspectives, adaptability, and sustainable practices.

Indigenous watershed management policies have rarely been implemented at scales beyond reserve boundaries, but since provincial jurisdictions have had more experience with wider scales of watershed management, there may be opportunities for shared knowledge to ensure better inclusion of regional factors from experienced organizations as well as Indigenous communities. What is still needed is some platform for each provincial- and federal-level watershed management policy to be shared and adapted with inclusion of perspectives in a variety of regions to learn from others and adjust policies if required. The differences between Canadian and Indigenous watershed management priorities and policies are one reason why water challenges persist in Indigenous reserve communities; there is a need to further fill in the knowledge gaps, align values and goals, meet the specifications of UNDRIP, and share power across transboundary watersheds to improve current policies and future decision-making procedures.

5.1.2 Lack of correlation between Nutrient Concentrations and Algal Growth

Based on the results gathered in the studies described in Chapters 2 and 3, the movement of nutrients do not always correlate to precipitation and cyanobacterial growth, and algal bloom toxicity does not correlate to changes in nutrient concentrations in freshwater systems. This information emphasizes the importance of monitoring nutrients (and sources of nutrient input to the system) and algae separately, especially as climate continues to change and previous predictions are no longer relevant. These observations are particularly important for Indigenous and rural communities in agricultural regions since they are at higher risk of worsening water quality and related social, cultural, and health impacts. For instance, Indigenous community members and past studies have observed a trend of more frequent algae bloom growth and toxicity (Galway, 2016; Patrick et al., 2019; Lam et al., 2017; McLeod et al, 2020). The weak correlation between precipitation patterns, nutrient concentrations, and algae growth in the data indicate that predictive methods in freshwater systems elsewhere may not apply effectively in prairie systems where biological and geochemical drivers may differ.

Not only do nutrients and algae need to be monitored separately, but also, continuously and across watershed geography to account for conditional changes in climate, human activity, and economic growth. The purpose of continuous monitoring is to identify shifts in patterns over time and be a stronger preventative method to protecting human health. Data from both Chapters 2 and 3 also present the increasing complexity of researching and monitoring freshwater nutrient concentrations and cyanobacterial algal blooms as multiple factors (e.g., weather conditions, surrounding terrestrial environment, cyanobacteria survival techniques) influence both and these factors are not always the same for each watershed and waterbody. Since there are many factors that can influence nutrients and algae, we can expect that concentrations of each will differ between regions with various combinations of impeding or assistive factors (Liu et al 2013). Therefore, static management frameworks and overly generalized solutions are no longer suitable to monitor and manage freshwater systems across the nation and could potentially make water challenges worse for many affected communities.

It is vital to keep records of these changes as human society is coming closer to the 2030 climate deadline agreed on in the Paris Agreement (UNEP, 2022). Recently inadequate prediction methods and expected deterioration of water quality are why I propose researchers should continue to study the shifting patterns of nutrient concentrations and algae growth in these new conditions and to, potentially, develop new gradient scales (suggested in Chapter 3) or predictive methods that can be altered with new information. Monitoring freshwater resources helps to gain a clearer understanding of nutrient movement and algal growth in a changing climate to design better predictive methods, and archive data on spatial and temporal changes for future research, especially now that we are at an inflection point in climatic history (Bloom, 2020).

5.1.3 Support for Capacity Building in Water Management on Indigenous Reserves

The research presented here emphasizes the need for long-term, continuous monitoring of both nutrient concentrations and algae in upstream and within-reserve Indigenous waters, and social and political conditions across the watershed, though to do so requires solutions to capacity issues that both non-Indigenous watershed agencies and Indigenous communities struggle with. The unequal allocation of funds and resources for sufficient environmental monitoring is a prominent issue. Often, Indigenous communities and watershed agencies must partner with others, figure out funding themselves, or cut back on restoration projects or watershed monitoring, limiting what they can do to maintain watershed health. Community science methods can be used to support capacity issues (personnel, travel costs, community input), but this method only works to a certain extent. Based on my analysis of the literature on Indigenous water challenges and the responses from interview participants (Chapter 4), funding is the primary barrier to capacity-building.

In some examples of Canadian watershed management, the method of allocation of financial resources is determined through a calculated formula (e.g., Ontario, see Plummer et al., 2011). However, this formula is set up as a one-size-fits-all solution that does not consider conditional factors that influence an Indigenous community or watershed agency's capacity to achieve their goals and fulfill necessary responsibilities (McCullough & Farahbakhsh, 2012; Murphy et al., 2015; Baijius & Patrick, 2019). Tying in with the financial issues to capacity-building in Indigenous water management, there has not been enough effort in terms of sharing information and understanding ways of knowing. This is another primary reason why Indigenous watershed challenges continue. The transfer of information among stakeholders and rights-holders is vital to filling in knowledge gaps with decision-makers (Baird et al., 2014). The exchange of knowledge and data allows for open-minded consideration of each Indigenous community's perspectives, values, and challenges. This will make the process of resource allocation more robust and improve political discussions toward creative and sustainable solutions with a higher likelihood for success. In short, both information sharing practices among Indigenous and non-Indigenous organizations, as well as capacity issues in Indigenous water management limit success in reducing water challenges. Further actions, such as information campaigns, mandated Indigenous collaboration for funding applications and grant allocations, and improvements in engagement practices could be taken to relieve these capacity issues and improve water management practices and prevention methods. In addition, my specific project demonstrated that community science, and Indigenous representation in political and decision-making discussions is possible, and desirable.

5.1.4 Further emphasis long-term, adaptable design and Indigenous practices in Canadian Watershed Management

With the uncertainty of predicting climate change effects, we cannot confidently identify potential environmental and social outcomes from water management practices. Various combinations of drivers to water-related issues persist in different regions across the country, relegating some management practices, water policies and generalized plans unsuitable in all cases to reduce impacts. It is recommended that watershed management in Treaties 4, 5, and 6 territories shift to a more inclusive and adaptive structure and be periodically reviewed to identify areas of success and make necessary adjustments to work with changing environmental and social dynamics. Water policies, acts, and plans should have stronger enforcement on nutrient input hotpots, and more funding for preventative measures and reporting, so that risks to community water values decrease. Watershed management strategies must also account for the unique conditional factors found in an affected regions, watersheds, or communities, including the cultural, economic, and environmental components to Indigenous watershed management (Dunn et al., 2014). It is not enough, given UNDRIP, and various Treaty agreements and interpretations to only measure economic and environmental impacts; that is, impacts to social and cultural dynamics in communities are also important.

The interviews in this study showed that community members believe that watershed management on Indigenous lands require improvements in many areas, primarily in community representation in political discussions, fair access to funding, support in capacity-building for adequate source water protection and watershed monitoring, and better collaboration between Indigenous communities, external organizations, institutions, and governments. The most significant step toward improving this as mentioned by study participants is to recognize and centralise Indigenous Traditional Knowledge, practices and cultural values in policy designs and management practices. The cultural practices and values of Indigenous Peoples differ between Nations, but they emphasize responsibility as stewards to respect and care for the land, which aligns with the values of sustainable management and environmental protection (Hall et al., 2022). Therefore, the incorporation of Indigenous practices, knowledge, and values in watershed management is beneficial for both Indigenous and non-Indigenous communities.

Community input through collaboration is an ideal way to prioritize concerns and ways of knowing at a regional scale (Arsenault et al., 2018). Indigenous practices and values in watershed management are important for retaining cultural identity and lifestyles, and Indigenous knowledge helps external populations to understand these values, the history of the land, and the perspective of communities experiencing water challenges. By increasing the knowledge set among collaborative groups, policymakers and water authorities can reduce biased decision-making, strengthen relationships, and make watershed management flexible and adaptive over the long-term. A recommendation from my work is to put in place activities to build engagement quality and frequency in watersheds that have Indigenous reserves within the overall boundary. Once sufficient actions are made, we can expect improvements to future responses to water challenges, equalize accessibility to clean source and recreational water, and better cultural health and maintain traditional practices, identity, and the spiritual relationship important to Indigenous Peoples.

5.2 Cultural Theory and Connection to Sustainability

From assessing freshwater nutrient concentrations to the analysis of Canadian watershed management policies, this research project presents evidence on the necessity of multi-level collaboration and knowledge-sharing to achieve a sustainable watershed management system. Earlier in this thesis, I presented the framework and foundations of Cultural Theory (see Section 1.3), and provided chapter prefaces, which provides context on how this framework helps us to understand why there are gaps in knowledge and implementation of strategies to mitigate problems based in certain pillars of sustainability in the context of watershed management in Treaties 4, 5, and 6 Territories. In this section, I will expand on the merits of using a Cultural Theory framework to guide transformation in watershed management in these territories.

The ideology of Cultural Theory, which views a specified subject matter though a holistic perspective, and accounts for key components, how they connect, and how culture plays a role

(Serrat, 2017), benefits us by seeking to understand the relationships between individuals, environments, institutions, and everyday activities. CT theorists pay close attention to power dynamics in everyday lives and help shed light on how social and material conditions frame our experiences. Previously mentioned in Chapter 1, the five CT classical societal behaviours are based on one's perspective on degree of shared power and the degree of competition. The ways of life according to Cultural Theory are *Hierarchy, Individualism, Egalitarianism, Fatalism,* and *Autonomous.*

In the context of watershed management, I modified this so that the degree of power reflects the amount of control (political discussions, policy design, action planning, etc.) and degree of competition is replaced with the perceived fair number of policy regulations (Figure 1.2). It is important to note that each person's perception of a fair number of policies is subjective to their own experiences and views on the subject matter. Hierarchy includes those who are perceived as having greater power and control over the system (i.e., federal/provincial/territorial governments, Saskatchewan Water Security Agency, policy and decision makers, scientists). Individualists are people and businesses that value maintaining their basic essentials; they want to be included in the political discussions but want less policy restrictions that impact their ability to be self-reliant and productive and financially stable (e.g., private businesses, landowners and farmers who do not use BMPs, small communities that work hard for equitable access to available resources). Egalitarians are those who want things to be equal or shared in terms of control and stakeholder participation but also to have policies for the protection of the watershed environment and those directly impacted (e.g., Health Canada, non-profit NGOs, farmers, and landowners who do use BMPs). The environment can be considered an egalitarian in watershed management; though it may not consciously make decisions and participate in the management process, natural processes shift to maintain healthy equilibrium of ecosystems. Fatalists are those who believe that there is little they can do to improve a situation (e.g., some impacted Indigenous community members, NGOs with restricted budgets, those without voice). In this study, interview participants shared fatalistic thoughts and frustration with not being able to change things – including watershed managers and Indigenous water managers. People who are Autonomous are those who are not directly involved in the watershed management process or don't have an opinion on the subject (e.g., some external organizations and the public, UNDRIP).

Often, these differences in perspective create conflict between groups, which can make it difficult to develop effective practices, tools, and policies in contexts such as watershed management. Cultural Theorists suggest it is through collaborative methods among these opposing groups that mutual goals, creative solutions, and fair decisions can be achieved (Horndeski &Koontz, 2020). The ideology in Cultural Theory recognizes the value of various backgrounds, opinions, beliefs, and knowledge and that they contribute to a better understanding of the subject matter and the development of sustainable practices through collaboration (Koehler, 2018). Serrat (2017) states that the benefit of Cultural Theory brings "attentions to the needs (common to all people) and makes possible a focus on the whole and the parts, on contexts and contents, and values and value systems, and on strategic relationships between key variables…it yields conceptual insights and practical benefits and allows informed choices and intelligent decisions…to deal better with complexity and fragmentation–the emphasis is on systems rather than on parts of systems." Therefore, Cultural Theory reaffirms the beneficial use of collaborative methods to bring together a variety of perspectives and knowledge sets to better understand the environmental, economic, and social components and their key connections in watershed management.

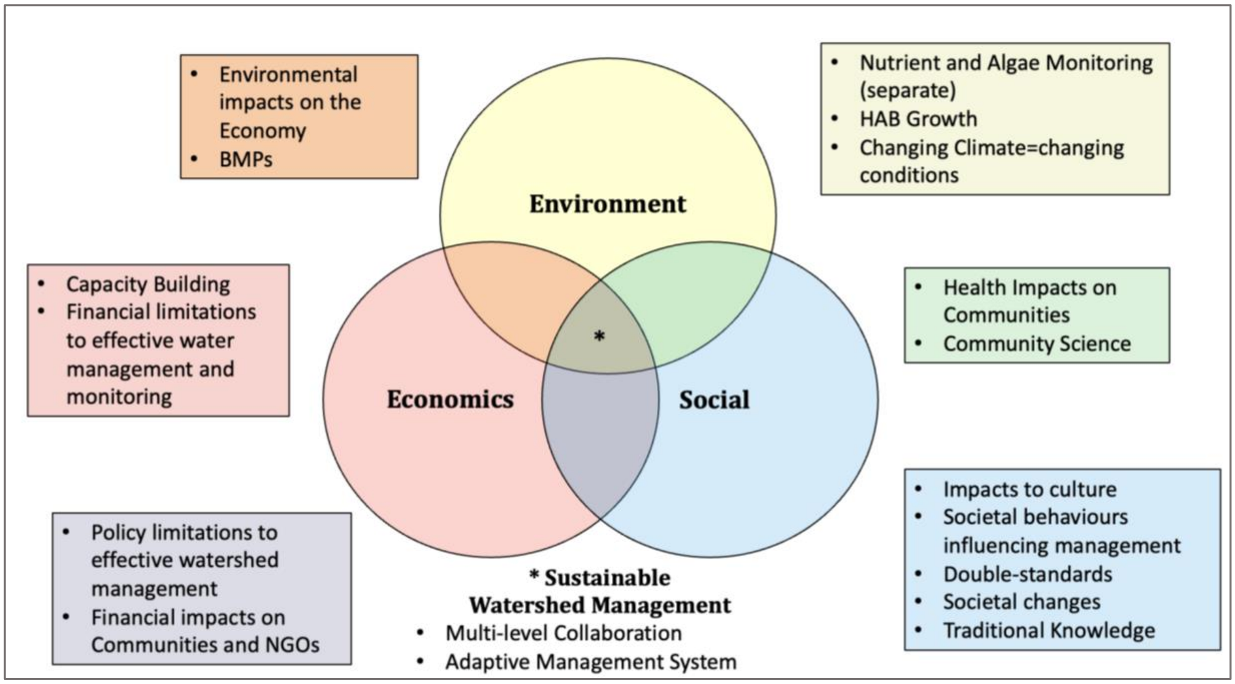

Figure 5.1: Revised Sustainable Watershed Management Venn Diagram.
A visual representation of the environmental, economic, and social components and their interconnections to a sustainable management system. Sustainability Venn Diagram revised with the addition of this research project's results. Colour-coordinated boxes reference where results are best situated.

By comparing the descriptions of each way of life (or perspective group) in Cultural Theory to the results gathered in this thesis project and how those results fit into the pillars of sustainability (Figure 1.1), I can merge the *Cultural Theory's 5 Categories of Social Solidarity and Perspectives in Watershed Management* Chart (Figure 1.2) with the Sustainable Watershed Management Venn Diagram (Figure 5.1). This merging gives a clearer understanding of which components of watershed management would be of interest to each perspective group, and aligned with their way of organizing, as defined in Cultural Theory (Figure 5.2). Offerman (2010, p.14) stated that "a nation in which the different ways of life are present is less vulnerable to being surprised and will have a wider repertoire to draw from in responding to novel and surprising situations." The results from this thesis project emphasizes this point by providing contextual evidence and on how these ways of life interact and influence the efficiency of watershed management.

Figure 5.2 shows the blending of Cultural Theory perspectives in relation to the pillars of sustainability, based on the responses of interview participants in the third study. Responses were organized into the CT categories based on how they were worded; Table 5.1 was used as the basis for categorization. Table 5.1 is adapted from Schwartz and Thompson (1990, Table 5.1 on page 66) and lists thirteen characteristics of the five ways of organizing. Transcripts were coded against these thirteen characteristics, and the proportion of statements coded in each transcript, by word count and classification, was deemed to belong by majority to each of the five ways of organizing. In each generated CT category statement list, similar or identical responses were merged, and then responses were organized once more into the three pillars of sustainability, based on the main subject of each response. The axis indicates how many of those responses (percentage) are environmental, economic, or social, thereby allowing for radial graphing.

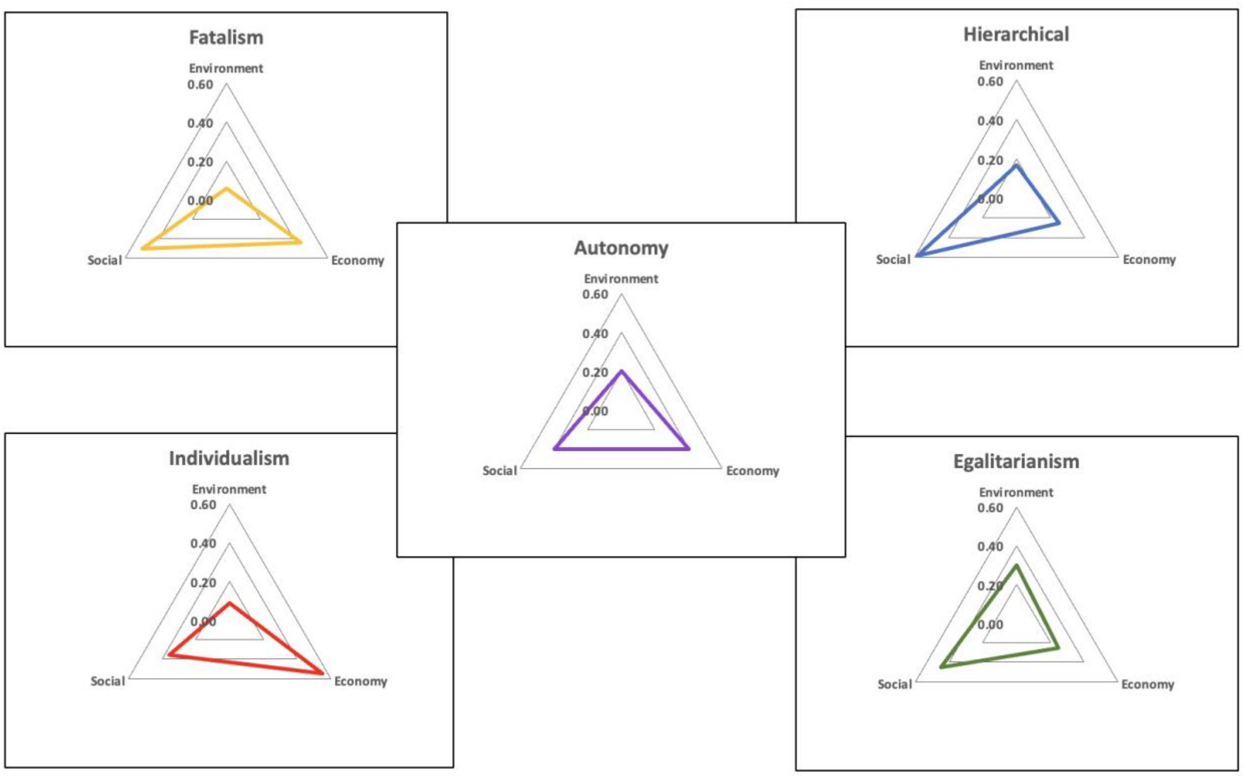

Figure 5.2: Pillars of Sustainability among Cultural Theory Ways of Life.
Radial graphs showing that each way of life is most concerned with only one or two of the sustainability pillars based on the responses from Watershed agents and Indigenous Community Members in Study 3.

	Individualism	Hierarchical	Autonomy	Egalitarian	Fatalism
Myth of nature	Benign	Perverse and tolerant	Resilient	Fragile/ Ephemeral	Capricious
Perception of time	Short term	Short or long term	Eternity/Now	Long term	Illusion
Ideal scale	Appropriate	Large	Nested	Small	Illusion
Engineering esthetic	Appropriate	High Tech	Depends	Frugal	Denial
Energy future	Business as usual	Middle of the road	Diverse	Low growth	Atomized
Desired system properties	Exploitability	Controllability	Resilience	Sustainability	Copability
Salient risks	Threats to market functions	Loss of the public trust	Ignorance	Catastrophic, irreversible and inequitable developments	Life, the Universe, and everything in it
Risk handling style	Acceptance and deflection	Rejection and absorption	Contemplation	Rejection and deflection	Acceptance and absorption
Model of consent	Implicit Consent	Hypothetical consent	Live and let live	Direct consent	Non consent
Latent strategy	Preservation of the individual's freedom	Secure internal structure of authority	Transcendence	Survival of the collective	Survival of the individual
Commitment to institutions	Only if profitable	Correct procedures and discriminated status. Loyalty.	Commitment to experience and observe without judgment. Zen.	Collective moral fervor. Voice.	None. Trust no one
Decision Making heuristic	Pros and Cons	Heuristics and Biases	Choiceless awareness	Gut feelings	Adapt to other's choices – ad hoc
Behavioural Strategy	+ Grip	+ Grip	0 Zero	- Grip	- Grip

Table 5.1: Cultural Theory Ways of Life Categorization Table for Coding adapted from Schwartz and Thompson (1990, Table 5.1. p. 66).

From the findings on the interviews with watershed management in this research project, I have found additional information that helps to explain the interconnections between excessive nutrient loading and toxic algal bloom growth in the sample areas on Treaty 4, 5, and 6 lands, their impacts on communities and ecosystems (environment), and importance of continuous monitoring via community science as a management practice.

Through this mixed methods approach, I have also uncovered some limitations to independent water management, research, and monitoring by communities and NGOs (economic), and the impacts to health, culture, and traditional lifestyle of affected Indigenous communities (social). Previously, our understanding of the social component to watershed management has been understudied, leaving the sustainability of the system unbalanced (Figure.

1.1). This research project builds on the social knowledge gaps in Canadian Watershed Management (Figure 1.1) and strongly suggests that sustainability will be achieved through collaboration and partnerships among various groups while we continue to measure and report on environmental and economic effects. By implementing collaborative methods, such as community science and more inclusive discussions with individuals from Indigenous Peoples to the Federal Government, we can build towards a sustainable system.

5.3 Conclusion

This thesis research project produced three key findings that provided evidence of the need for balanced structure of watershed management, nutrient monitoring, and the political constraints that leads to the continuation of water challenges in many Indigenous Reserve Communities. First, the data from Chapter 2 and 3 showed there is a need for continuous monitoring of nutrient movement and algal bloom growth within a watershed. The nutrient concentration data (Table 2.2, Figure 2.7 2.8) found particularly high nutrient hotspots upstream of communities that did not align with precipitation patterns, and changes in nutrient concentration that were influenced by additional, unmeasured drivers. Some of these drivers are due to evolving environmental, economic, and societal changes, and political constraints, which may render former predictive methods invalid. In addition to the unpredictability of nutrient loading in freshwater systems, this research identified 12 cyanobacteria species that are harmful to human health, and their growth did not correlate with nutrient concentration patterns. Secondly, both the YSI 9500 Photometer and the GWF Nutrient (Smartphone) App need further adjustments to improve measurement accuracy, mainly nitrates (Table 2.1 & Figure 2.5), and ease of use for in-field data collection. Lastly, the current structure of watershed management in Canada is ineffective and inequitable, mainly impacting Indigenous communities and watershed

NGOs. Issues are present due to little engagement and knowledge sharing among stakeholders, organizations, and governments (cross-jurisdictional conflict) and policies, acts, and management strategies have hardly changed in recent decades regarding Indigenous water rights, community engagement, and the balancing of power dynamics.

There were some limitations within this research project that may have impacted the holistic understanding of the watershed management system. Only two community science tools were tested (Chapter 2); more tools could have been tested, but the study did not have enough time or resources to do so independently. Both the Photometer and the Nutrient App had a limited capacity to accurately measure nutrient concentrations (refer to Chapter 2 results). Another limitation that likely impacted this research is the biased opinions on the validity of community science and the limited access to government-shared data. This prevented me from obtaining more information that would have given me a more detailed picture of the components. The COVID-19 pandemic restrictions prevented me from conducting interviews with Indigenous communities directly, causing me to refer to secondary data on a similar topic (emergency flooding response and impacts on Indigenous communities). During the document analysis of Canadian watershed policies, I did not have access to the hardcopy of some documents; therefore, assessments and descriptions of these policies from peer-reviewed studies were used as a secondary source. Additionally, I did not have the resources to do a thorough analysis since I was not able to find water policies beyond the ones in my research (refer to Chapter 4). My personal limited knowledge of watershed politics may be considered a limitation that influences my interpretations of watershed management documents. Though, restricted knowledge of water politics could also be beneficial as I have an outsider's perspective that is not skewed by political biases.

The watershed management issues in Treaty 4, 5, and 6 represent a wicked problem; Cultural Theory effectively frames sustainable watershed management as it dictates that a clumsy solution that includes all players with voice is needed to address these continuing issues. Interactions among CT's perspective groups (Figure 5.2) vary between sub-contexts, but in the whole of Sustainable Watershed Management, all are necessary for a balanced and resilient system. The example scenarios in chapters 2-4 (Figure 2.7, 3.6, 4.2) presented context of how differing perspectives of individuals involved can promote or hinder outcomes beneficial to social and environmental wellbeing. In Chapter 2, there is evidence that the current structure of water policies does not fully restrict agricultural nutrient movement by not making certain preventative measures a requirement, giving hierarchy and individualist groups greater control. Chapter 3 emphasized the complexity and tensions among the jurisdiction hierarchy, and how differences in experience, knowledge, and personal interactions affect one's views on the overall subject. Chapter 4 echoes the conclusions of other researchers, on the lack in communication, policy reform, and information transparency allowing the continuation of Indigenous water challenges. The application of Cultural Theory in Canadian Watershed Management requires uniform collaboration efforts among diverse authority hierarchies to achieve holistic understanding and balanced power dynamics to fill in gaps and address weaknesses. Should the Canadian watershed management system remain in its current structure, political constraints will continue to lead to a lack of enforcement, fair accountability, and requirement of appropriate BMPs and treatment methods. From there, nutrient loading and algae bloom toxicity is expected to increase, resulting in negative impacts on the health and culture on communities with little to no access to potable water resources and proper water treatment.

5.4 Recommendations

Along with the data gathered in this research project, I recommend the following actions be taken to increase the efficiency of the Canadian watershed management system in the three prairie Treaty areas covered here, and to move towards resolving recurring watershed challenges impacting Indigenous communities. For communities, locate which organization within your Treaty area have nutrient management responsibilities and actively participate in community-based research and monitoring. Engage wherever possible, in collaborative discussions and planning that involves Indigenous land and water resources and contribute to the sharing of knowledge and data among multiple communities, NGOs, and governments. Thus, your community will play a greater role in the watershed management process. Provide questions and share concerns that can help direct partner institutions toward further research, which may lead to new and innovative solutions and strategies. I also recommend community leaders promote a career in watershed management, environmental remediation, and resource politics to members to further the community's self-determination of water resources on traditional lands.

The actions that I recommend to watershed management organizations in Treaty 4, 5, and 6 start with learning about biases and inclusivity in watershed management. To improve capacity building issues, these organizations should advocate for more resources from the provincial government and further their partnership agreements to share available resources. Watershed organizations should engage meaningfully with Indigenous communities, often through community-based research and monitoring programs. Watershed management organizations should negotiate for a bigger role in collaborative watershed management and planning in order to better reach out to communities and share information/knowledge/concerns with governments.

Provincial and territorial governments should develop new or revise current water strategies to be flexible and adaptive, and create specified action plans that account for the unique combination of driving factors impacting watersheds within their province. After a specified amount of time, provincial/territorial governments should share the successes of these new or revised strategies and action plans with other provinces and territories so they can consider them for their own water policies. This method is another way to optimize inter-provincial collaboration and cross-border watershed management practices. Organize more opportunities for engagement with Indigenous communities, stakeholders, and NGOs to discuss water policy development. Not only is collaborative engagement a way to encourage knowledge-sharing, but also helps to identify areas that are lacking with the aid of various perspectives of those involved. In addition to knowledge sharing, provincial/territorial governments should share data with researchers for thorough studies with robust results and with community representatives to reinforce community-based action plans, strategies, and environmental monitoring.

The first recommended action the Federal Government should take is to revise current federal watershed management policies; previous "one-size-fits-all" strategies and generalized policies and acts may work for some but not for others. These policies should be flexible and adaptive, consideration of equitable access to information and resources in watershed planning, and increased funding and resources to different ministries (i.e., Environment Climate Change Canada, Health Canada, Indigenous Services Canada) for watershed management practices that are of federal interest (i.e., interprovincial agreements). The Federal Government should compose a stronger commitment statement to resolving Indigenous water challenges by emphasizing the importance of respecting and protecting Indigenous water rights in all watershed management policies and establish a time frame in which to meet the strategies within the document. Community-engaged research and monitoring programs, making BMPs required to protect downstream communities, and collaborative discussions with regional Indigenous and watershed NGO representatives are some methods suggested to be used to maintain this commitment. The Federal Government must be more transparent in watershed management information and data sharing, providing better access to communities, watershed organizations, and academic and research institutions. The last recommendation is that the Federal Government provide a greater portion of control over watershed management to NGOs and stakeholder groups for more independence in the management and monitoring of water resources reserved for community use.

Academics working within this area of study are recommended to establish and maintain partnerships with Indigenous communities and stakeholder groups, and to apply community-based research methods wherever possible. By including community-based methods on one's research, academics can maintain a mutual, reciprocal partnership aimed at achieving a common objective. Also, academics using these methods provide opportunities for knowledge and data sharing, self-determination, and cross-cultural learning; this should create stronger bonds between academics (and institutions) and community members resulting in growing respect and consideration of multiple ways of knowing.

Based on the findings in this research project, there are some options for future research. Firstly, there should be further studies to test community science tool accuracy on various devices. Not only would the results provide evidence of the viability of this method for data collection but could lead toward advancements in portable research devices. Along with the testing of quantitative data, studies on the accuracy of community-science-gathered qualitative data should be conducted to illustrate its validity for the purpose of research triangulation. Nutrient and algae monitoring in regional freshwater systems should be continuously conducted to observe any changes in the data that could indicate shifts in dominant drivers to nutrient movement and loading within a watershed, and to identify any emergent threats from toxic algae. By doing so, predictive methods can be adjusted to account for observed changes to improve these methods and aid researchers, communities, and policymakers in the preparing for potential water quality challenges. I do not suggest more studies on the watershed management system, but

I do suggest more political action on improving the Canadian watershed management system since there has been more than a sufficient number of studies that agree on the need for change from a rigid and reticent system to an adaptive, decolonized, and engaging one.

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APPENDIX-A

Walkerton, Ontario

In spring 2000, surface water contaminated with E. coli infected well water used by the community of Walkerton, Ontario, leading to one of Canada's worst water-borne outbreaks (O'Connor, 2002). The population of Walkerton was 5,000 people, and the outbreak resulted in 2,300 cases of infection and seven deaths (Salvadori et al., 2009). Symptoms of the outbreak appeared in mid-May, but the Public Utilities Commission (PUC) did not notify health authorities, insisting the water remained safe to consume (Salvadori et al., 2009). A boil water advisory was implemented after the contamination had been confirmed by a third-party medical health officer a week after the first reported symptoms, remaining in place until December of that year. Within that short window between initial contamination and public notification of the contamination, many individuals became very sick. Due to the lack of transparency by the PUC and the impact on the health of nearly half of the town's residents, a criminal investigation and public inquiry began, and a class-action lawsuit financially compensated all residents directly and indirectly impacted by the outbreak (O'Connor, 2001). This outbreak resulted from the privatization of water testing, cutbacks to water treatment and water testing, and the ignorance to evidence from microbiological monitoring and warnings from hydrologists years prior (Hrudey, 2011). This outbreak emphasizes the importance of continued monitoring water sources, acceptance of expert advice and physical evidence, and proactive information sharing. Even though this outbreak took a little over a year to resolve, it was short compared to water-borne outbreaks experienced in other communities, especially Indigenous reserve communities.

Shoal Lake 40, Ontario

In 1997, the Indigenous community of Shoal Lake 40, near the Manitoba-Ontario border, was placed under a boil water advisory because the quality of locally extracted water sources did not meet health and safety standards (Cecco, 2021). This community of around 300 residents lived under a drinking water advisory for 24 years until the construction of a new water treatment plant in 2019 (Petz, 2021). The treatment plant was a long-awaited solution, but it should have never taken this long to solve the drinking water problems within the community. Since Shoal Lake is remotely located, chlorine pumps were used to gather river water for non-consumptive purposes (i.e., washing clothes and cleaning dishes), and drinking water had to be truck-delivered by barge or an ice bridge. The cost of truck-delivered water significantly reduced the community's ability to save funds for a water treatment plant. The Federal Government did have plans to install a treatment plant before, but those plans were cancelled due to the hefty construction price (Greene & Paul, 2011).

For years, Shoal Lake residents made many calls for change and better access to potable water (Cecco, 2021). It was mainly due to the development of the "Freedom Road" (a 24-kilometre road connecting to the Trans-Can Highway) that the plans for a Shoal Lake water treatment plant were revived, and construction began in late 2020 (Petz, 2021; Cecco, 2021; *Shoal Lake 40 First Nation breaks ground for water treatment system*, 2019). The water-related difficulties that Shoal Lake residents experienced are echoed by many Indigenous communities; Indigenous water challenges are improving in some regions, but the process has been very slow. From November 2015 to March 2022, 132 advisories have been lifted from Indigenous communities, with 34 long-term drinking water advisories in 29 communities still in effect (GOC, 2022A). The cases of Walkerton and Shoal Lake are examples of the difference in response to lifting water advisories and installing water treatment infrastructure that meets quality standards.

APPENDIX-B

Indigenous Water Governance and Management Documents (SWOT Analysis) – Jaclyn Porter					
Label	Canadian Policy	Authority	Strengths	Weaknesses	Citation
A	Constitution Act (Section 35)	Federal Government	• recognizes and reaffirms the existing Aboriginal Treaty Rights of the Aboriginal peoples of Canada • Federal government is obligated to ensure safe drinking water to Indigenous communities	• limitations to Indigenous participation in policy decision-making • political fragmentation between Federal and Provincial responsibilities • neither confirms nor creates absolute Aboriginal rights	Lebel & Reed, 2010; House of Commons of Canada, 2016
B	The Water Regulations (2002)	Saskatchewan Provincial Government, and an appointed Minister from the Executive Council	• Guide and regulations for permit use, infrastructure maintenance, facility operation, and water quality and monitoring standards	• No mention of Indigenous communities or their drinking water quality regulations • Does not have Indigenous involvement in the management of water	Edwards, 2002
C	The Saskatchewan Water Corporation Act (2002)	Saskatchewan Provincial Government, Saskatchewan Water Corporation, & SaskWater	• An act meant to continue the work of the Saskatchewan Water Corporation • The continued provision of water and sewage services in the province • Provides details on roles and the responsibilities of each within the water corporation • Guidelines on financing, construction, and provision of infrastructure for drinking water and sewage	• No mention of Indigenous communities or their drinking water quality regulations • Does not have Indigenous involvement in the management of water	Statutes of Saskatchewan, 2002

D	First Nations Water Management Strategy (FNWMS) (2003-2008)	Indian and Northern Affairs Canada, & Health Canada	• 7-point plan for both reserve water and wastewater • A guide to implementing maintenance plans for treatment facilities to meet standards • Expansion of training and certification of operators • Federal Government provides for 80% of the total cost • $1.6 B provided by Federal Government for next 5 years	• small communities lack economies-of-scale to cover the remaining 20% • prior assessment estimates that $470M/year for the next decade to bring systems up to national standards • there is still an issue with lack of certified operators • continuing infrastructural deficiencies • lack of an expert panel for consultation	Hanrahan, 2017; Smith et al., 2006; Walder et al., 2017; Lebel & Reed, 2010; Galway, 2016; Morrison et al., 2015
E	The Water Security Agency Act (2005)	Saskatchewan Water Corporation & the Saskatchewan Watershed Authority	• guide for the protection of water resources for various purposes (domestic or agricultural use, recreation, and ecosystem function) • guidelines on financing, crown ownership, water management and rights, and legal enforcement	• No mention of Indigenous communities or their drinking water quality regulations • Does not have Indigenous involvement in the management of water • There is a section on water rights but no mention of Indigenous rights to water resources • Fed. Gov't has control of water resources on crown land; does not specify if this includes Indigenous reserves • Prov. Gov't has power over land outside of crown land (this could impact water entering Indigenous reserve lands)	Statutes of Saskatchewan, 2005
F	Water Protection Act (2006)	Non-government entities (i.e., watershed agencies)	• Commits to the protection of freshwater ecosystems	• Exclusion of Indigenous communities (under Federal jurisdiction) • risk of contaminants from external sources	Cuvelier & Greenfield, 2016

G	INAC Plan of Action for Drinking Water (PoAFNDW) (2006-2008)	Indian and Northern Affairs of Canada, Health Canada, Indigenous Chiefs & Councils	• introduced to further the aims of the FNWMS • $600 M provided by the Federal Government over 5 years • 5 major planned actions • enable Federal Government to work with FNCs on reserves to develop enforceable federal regulations to ensure safe, clean, and reliable DW on reserves • development of the Expert Panel on Safe DW for FNs (2006) • standards for design, construction, operation, and maintenance of water treatment systems, training and certification of operators, remote water monitoring and remedial plans • regular reporting and engagement with experts	• barriers to funding and capacity building, consultative practices • obstacles to expanding water provision to include small and private systems • barriers to operator training and monitoring programs • still a need for procedures to address and prevent waterborne illnesses and contaminants	Morrison et al., 2015

H	First Nations Water and Wastewater Action Plan (2006-2012)	Indian and Northern Affairs Canada, & Health Canada	• main objective to support FNCs on reserves to improve DW and WW standards • total of $3.98 B invested • representation of all involved • integrated and coordinated leadership • $330 M investment based on success of the PoAFNDW • Federal Government committed another $330 M to build and renovate reserve infrastructure and support long-term water quality strategy	• standards raised only to level that is experienced by Canadians living in similar population size and location	Morrison et al., 2015
I	The Environmental Management and Protection Act (2010)	Minister of Environment & Environment Canada	• statement that this act should not inhibit the rights of Aboriginal peoples • guidelines to environmental reporting and assessments, and implementation on protection plans, permits and notices • regulations on the management of water, wastes, and air pollutants to adhere to quality standards • Corrective action plans • Guide for enforcement on violations to the act	• Other than the one short statement, there is no other mention on environmental protection on Indigenous lands • No discussion on knowledge sharing or respect to cultural differences toward the environment • Fails to mention Indigenous rights to be first consulted on activities that can impact their land, water, and way of life	Statutes of Saskatchewan, 2010

J	Bill S-11: Safe Drinking Water Act (2010– died out before reaching debate on the order table)	Federal Government (bill was referred to the Standing Senate Committee on Aboriginal Peoples for examination)	• Meets one of seven goals set up in the First Nations Water Management Strategy	• Widespread opposition and First Nations concerns prevented bill from proceeding and resulted in it dying out • Would have met 1 goal of FNWMS by creating new regulations for FNC DW (but this was one goal out of seven) • not enough consultation with FNs • little clarity on who had legislative, administrative, and judicial control • parts conflicted with FN treaty right • regulations vary among provinces creating confusion and possible jurisdictional conflict • FNCs are being set up for failure (no support with the transfer of control)	Morrison et al., 2015; Bowen, 2011; Canadian Environmental Law Association, 2012; Alteo, 2011
K	Bill S-8: Safe Drinking Water for First Nations Act (2013)	Aboriginal Affairs & Northern Development Canada, Health Canada, Environment Canada, Governor in Council	• legal enforcement of water quality regulations and standards in FNCs • may incorporate provincial regulations into federal regulations to improve plans and strategies	• Takes away Indigenous authority on water management • puts majority of the power into the hands of non-Indigenous, Federal gov't • violates and does not protect Treaty Rights • violates 9 articles in UNDRIP • does not recognize Indigenous authority • does not ensure additional resources will be provided to meet regulations • places liabilities on FN leaders and water operators, leading them to risks of financial and criminal penalties	Morrison et al., 2015; COO, 2013; Assembly of First Nations, 2013; Canadian Environmental Law Association, 2012

L	Bill C-15: An Act Respecting the UNDRIP (2021)	A Federal Minister designated by the Governor in Council (to enforce & ensure the act's purpose and provisions are met) initiated by the Government of British Columbia	• clearly states purpose, objectives, goals, and reasonable outline for action • summary of UNDRIP and the rights and freedoms it includes • set timeline for consistent reporting (every 2 years) to ensure continued efforts are being made and less issues occur • details on what each clause means, its purpose, and actions to implement it	• suggests implementation of UNDRIP should be done by federal, provincial, territorial, and municipal governments • issue of inter-jurisdictional barriers	Fryer & Leblanc-Laurendeau, 2021; House of Commons of Canada (Minister of Justice), 2020: Fontaine, 2020

Appendix B-Table 1: SWOT Analysis of Canadian Watershed Policies.
Watershed management policies implemented in Canada with their strengths and weaknesses in relation to Indigenous watershed management and provision on reservation lands (A-L).

Indigenous Water Governance and Management Documents (Indigenous Interpretations and Legal findings) – Kelechi Nwanekezie				
Label	Policy	Authority	Themes	Citation
M	Treaty 4 (1874)	Signatories plus Canada (federal) plus Her Majesty the Queen	Water was never specifically discussed in Treaties except to delineate Treaty boundaries Sacred lands which were promised protection included "hunting territories, fishing territories, and gathering territories" all of which have been impacted in Treaty 4, 5, 6	Treaty 4 (15 September 1874). Qu'Appelle Treaty (Fort Qu'Appelle). Signed by 13 Cree, Saulteaux, Assiniboia.
N	Treaty 5 (1875)	Signatories plus Canada (federal) plus Her Majesty the Queen	Water was never specifically discussed in Treaties except to delineate Treaty boundaries Sacred lands which were promised protection included "hunting territories, fishing territories, and gathering territories" all of which have been impacted in Treaty 4, 5, 6	Treaty 5 (1875). Winnipeg Treaty (Berens River and Norway House). Signed by Cumberland, Shoal Lake, Red Earth, Her Majesty the Queen. Treaty 5 Adhesions (1876).

O	Treaty 6 (1876-1877)	Signatories plus Canada (federal) plus Her Majesty the Queen		Water was never specifically discussed in Treaties except to delineate Treaty boundaries Sacred lands which were promised protection included "hunting territories, fishing territories, and gathering territories" all of which have been impacted in Treaty 4, 5, 6	Treaty 6 (23 August 1876). Signed at Fort Carlton, Saskatchewan, and on 9 September 1876 at Fort Pitt, Saskatchewan with 17+ nations of Plains Cree (Nehiyawak), Denesuliné, Nakoda Sioux, Assiniboia,
P	Treaty Elders of Saskatchewan (2000; Harold Cardinal and Walter Hildebrandt)			Elder Waskahat: "The Commission said… All the creatures under the water, that too, I didn't come to ask you for them. That will continue to be yours." The principle of kanâtisiwin - cleanliness is not being met The Creator's gifts Iyiniw miyikowisowina included clean water	Cardinal, H., & Hildebrand, W. (2000). *Treaty elders of Saskatchewan: Our dream is that our peoples will one day be clearly recognized as nations*. University of Calgary Press.
Q	Aboriginal and Treaty Rights in Canada: Essays on Law, Equity, and Respect for Difference (1997; Asch)			*Sui generis* "of its own kind" no legal precedents – water not negotiated as a part of the Treaties. In addition, land was only shared to the depth of a plow (a few feet at the time). Thus, issues of groundwater, mining, canals and irrigation not negotiated.	Asch, M. (Ed.). (1997). *Aboriginal and treaty rights in Canada: Essays on law, equity, and respect for difference*. UBC Press.
R	UNDRIP (2007)	United Nations + signatories (Canada, provinces)		Free, prior, and informed consent (FPIC) is needed for all negotiations Ensures meaningful and effective participation in decision-making Governments (federal and provincial) constitutional duty to consult Indigenous peoples when it considers measures that might adversely impact their potential or established treaty rights Indigenous peoples as full partners in the natural resource and net-zero carbon economy and ensuring that Indigenous peoples have a seat at the table for decisions that may affect their communities	UN General Assembly, United Nations Declaration on the Rights of Indigenous Peoples : resolution / adopted by the General Assembly, 2 October 2007, A/RES/61/295, available at: https://www.refworld.org/docid/471355a82.html [accessed 28 October 2022]

S	Kawacatoose et al versus Her Majesty the Queen in Right of Canada (2019)	Individual Nations + Canada + Her Majesty the Queen	Specific reserves were created to protect fishing rights, and thereby claims to clean, fresh water. Specific bands were assigned claim on the reserve lands.	Kawacatoose First Nation et. al. and Star Blanket First Nation and Little Black Bear First Nation and Standing Buffalo Dakota First Nation and Peepeekisis First Nation v. Her Majesty the Queen in Right of Canadav. Her Majesty the Queen in Right of Canada v. Her Majesty the Queen in Right of Canada, 2019 SCTC 3 (CanLII), <https://canlii.ca/t/j1qbb>, retrieved on 2022-10-28
T	Osoyoos Indian Band versus Town Of Oliver, BC (2001)	Individual Nations + Canada + Her Majesty the Queen	Three implications follow from the *sui generis* nature of the aboriginal interest in reserve lands. First, it is clear that traditional principles of the common law relating to property may not be helpful in the context of aboriginal interests in land. Second, reserve land does not fit neatly within the traditional rationale that underlies the process of compulsory takings in exchange for compensation in the amount of the market value of the land plus expenses. Third, the aboriginal interest in land will generally have an important cultural component that reflects the relationship between an aboriginal community and the land and the inherent and unique value in the land itself which is enjoyed by the community. Because of these implications and the fact that the Crown owes a fiduciary duty to the band, it follows that a clear and plain intention must be present in order to conclude that land has been removed from a reserve.	Osoyoos Indian Band v. Oliver (Town), 2001 SCC 85 (CanLII), [2001] 3 SCR 746, <https://canlii.ca/t/51xr>, retrieved on 2022-10-28

Appendix B-Table 2: Indigenous Interpretations and Legal Findings of Canadian Watershed Policies.

Indigenous interpretation and legal findings were provided upon review of seven additional government documents that impacts Indigenous water rights, watershed management, and reserve community sovereignty of water resources (M-T)