Characterizing water-health pathways and perceptions among diverse system actors in a rural Western Highlands community of Guatemala

by

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Author's Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Statement of Contributions

I, Joshua Garcia-Barrios, authored Chapters 1, 2, and 4 of this thesis under the co-supervision of Dr. Warren Dodd and Dr. Brian Laird. These chapters were prepared for this thesis and not for publication. Chapter 3 was prepared as a manuscript with the intent of publication. Co-authors of the manuscript are indicated in Chapter 3 and their contributions to the work are described below.

Chapter 3

I, under the co-supervision of Dr. Dodd and Dr. Laird, have been the primary researcher and contributor to the preparation of the manuscript to date, including data collection, analysis, and write-up. Contributions from co-authors have been primarily to total research efforts as members of the research team.

Dr. Brian Laird is a co-supervisor of this thesis and research project. Dr. Laird has contributed to study design and reviewing and revising of the manuscript.

Emily Kocsis is a current doctoral candidate at the University of Waterloo and has been a close collaborator on the research project. She has contributed to study development and design, data collection, and overall data interpretation and analysis.

Sara Wyngaarden is a member of the research team and a collaborator on the study as the Monitoring and Evaluation Coordinator for Mennonite Central Committee's Guatemala-El Salvador Program. Sara has contributed through study coordination, design, and partnership development.

Magnolia Roblero is a member of the Red de Productores y Promotores Agroecologicos del Departamento de San Marcos and assisted with data collection and participant recruitment.

Rony Aguilar is a member of Pastoral de La Tierra San Marcos and was a key contributor to study design and coordination. Rony also assisted in developing data collection tools and providing key contacts in the study community.

Dr. Laura Jane Brubacher is a postdoctoral fellow at the University of Waterloo and a member of the research team, contributing through study design and analysis discussions.

Dr. Matthew Little is an Assistant Professor at the University of Victoria and has provided guidance on the overall research work as a thesis committee member.

Dr. Hannah Neufeld is an Associate Professor at the University of Waterloo and has provided guidance on the overall research work as a thesis committee member.

Dr. Warren Dodd is a co-supervisor of this thesis and research project. Dr. Dodd acquired funding to support the partnership that guided this research and has contributed to study design and reviewing and revising of the manuscript.

Abstract

Background: Rural livelihoods in Latin America are disproportionately vulnerable to poor health outcomes from water risks. In the Western Highlands of Guatemala, rural communities face compounding issues such as geography related challenges, population growth, and poverty that increase vulnerability to water-health risks. To inform water-health interventions, there is a need for research that considers and examines the proximal, intermediate, and distal water-health pathways influencing rural community health and wellbeing. This study aimed to characterize these pathways for a Westen Highland community of Guatemala and to examine how these pathways were perceived among local system actors.

Methods: Semi-structured qualitative interviews were conducted across two data collection phases during May-June 2023 and October-December 2023 in Tojchoc Grande, Guatemala. Interviews were conducted with local farming and non-farming community members, water managers, and health workers. Interviews were audio recorded, transcribed verbatim using Sonix transcription software, and thematically analyzed using an inductive approach. Following data analysis, an adapted three-level water-health framework was used to categorize major themes under proximal, intermediate, and distal pathways.

Results: Diverse and multi-scalar water-health pathways were characterized in the community, with similarities and differences in perceptions of these pathways across actor groups. Proximal water-health pathways included issues related to geographic proximity to water system infrastructure, climate and weather variability, and risky water use, sanitation, and hygiene issues. Intermediate water-health pathways related to population growth, water withdrawals for agriculture, and administration challenges decreasing community water levels. Distal water-health pathways related to broader socio-economic factors such as poverty and migration influencing healthcare and water access, as well as broader institutional factors like state-absence shaping challenges for local water administration and public health delivery.

Conclusion: This study highlighted the complexity of water-health pathways among diverse actors in a rural community in the Western Highlands of Guatemala. The results demonstrate the intricate interplay of proximal, intermediate, and distal pathways shaping health and wellbeing at local level. Crucially, it was observed that intermediate and distal pathways played a substantial role in shaping reported health outcomes, highlighting their importance alongside proximal factors. By highlighting the differential perceptions among local actors, this research emphasizes the need for context-specific interventions that address the multi-scalar and multi-faceted nature of water-health challenges facing rural communities. Understanding and addressing these pathways are crucial for designing effective water-health interventions that can mitigate risks and support rural public health and wellbeing.

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Dedication

To Osvaldo and Enjee.

And to the rural farmers of Guatemala and Tojchoc Grande.

Volcano Tajumulco, San Marcos Guatemala
November 2023

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List of Abbreviations

CEnR	Community-engaged Research
CSIS	Center for Strategic and International Studies
DPSEEA	Driving Force-Pressure-State-Exposures-Effect-Action Framework
E. coli	*Escherichia coli*
FAO	Food and Agricultural Organization of the United Nations
PTSM	Pastoral de La Tierra San Marcos
MCC	Mennonite Central Committee Guatemala-El Salvador Office
RED-PPAS	Red de Productores y Promotores Agroecologicos del Departamento de San Marcos
NGO	Non-governmental organization
UN	United Nations
WHO	World Health Organization
RWLI	Rural Water Livelihoods Index
SSHRC	Social Sciences and Humanities Research Council
IPCC	Intergovernmental Panel on Climate Change
WWDR4	World Water Development Report

Chapter 1: Introduction

1.1 Water, Health, and Rural Livelihoods

Water plays a vital role in the development, prosperity, and overall wellbeing of rural communities, serving as a critical resource for agricultural production, economic development, and public health (Gordon et al., 2023; International Labour Organization, 2019; K.B. Smith et al., 2008; Strasser, 2003). However, the relationship between water and rural health is complex and shaped by a variety of different pathways (Garrick & Hall, 2014; International Labour Organization, 2019; Sullivan et al., 2010). Whether through proximal pathways concerning biophysical characteristics, intermediate pathways encompassing ecological changes and disturbances, or tertiary pathways related to broader social, economic, and institutional factors, the nexus between water and health for rural communities is multi-faceted and multi-scalar (Butler, 2024; Butler & Harley, 2010; Grigg, 2018; Mabhaudhi et al., 2016; McMichael, 2013; Paudel et al., 2021; Walls & McGarvey, 2023). Importantly, perceptions of water-health pathways vary among community actors (Aracena et al., 2020; Haeffner et al., 2018; Jaakkola et al., 2018). Individual experiences, identities, and subjectivities can shape personal perceptions of water-related health issues and ultimately shape individual health outcomes (Anthonj et al., 2022; Leroy et al., 2022; Magalhães et al., 2022; Maurice et al., 2019; Morales et al., 2020; Sultana, 2020). Therefore, characterizing complex water-health pathways and perceptions of those pathways among local actors in rural communities is critical for informing resource management initiatives and public health delivery.

As global stressors, including population growth and climate change, continue to exacerbate water-health challenges, rural communities in the Global South face heightened vulnerability to water-health risks (Cissé, 2019; Clasen et al., 2014; Connor, 2015; Haines et al., 2006; Maurice et al., 2019; World Health Organization, 2023a). Nowhere is this more evident than in the Western Highlands of Guatemala, where residents face a myriad of challenges stemming from limited public health initiatives for sanitation and hygiene, low government

support for water monitoring and infrastructure development, and dependence on water intensive agriculture for subsistence and economic purposes (Braghetta, 2006; Cheatham et al., 2022; Copeland, 2023; Enge & Martinez-Enge, 2019; Kondash et al., 2021; Lopez-Ridaura et al., 2019; Luby et al., 2008; Poder & He, 2011; Prado Córdova et al., 2013; Ruano & Milan, 2014; Trudeau et al., 2018; Vásquez & Aksan, 2015). Consequently, communities in this region endure high levels of morbidity and mortality from water-related health issues (Besnier, 2021; Enge & Martinez-Enge, 2019; Gragnolati & Marini, 2003; Owen et al., 2010; Poder & He, 2011). Elevated rates of diarrhea, *E. coli* infections, dehydration, malnutrition, and deaths from waterborne illnesses account for the largest preventable disease burden in the region (Besnier, 2021; Enge & Martinez-Enge, 2019; Gragnolati & Marini, 2003; Luby et al., 2008; Oomman et al., 2003; Owen et al., 2010; Poder & He, 2011; Ruano & Milan, 2014). Given these pressing water-health issues, there is an urgent need to prioritize research in the Western Highlands of Guatemala to inform water-health interventions and policies to support public health in these communities (Cheatham et al., 2022; Copeland, 2023; Enge & Martinez-Enge, 2019; Oomman et al., 2003; Poder & He, 2011; Vásquez, 2013).

Understanding and delineating the complex water-health pathways influencing health and wellbeing in the Western Highlands is imperative for informing effective resource management and public health interventions (Baccarelli et al., 2023; Jalloh et al., 2018; World Health Organization, 2023b). To fully capture the complexities of these pathways, it is important to engage with the diverse perspectives and perceptions of local system actors, including local farmers relying on water for their crops, water managers overseeing distribution systems, and health workers witnessing the health impacts firsthand (Anthonj et al., 2022; Aracena et al., 2020; Cheatham et al., 2022; Goldman et al., 2001; Haeffner et al., 2018; Schuster-Wallace & Dickson, 2017). Indeed, the input from diverse local stakeholders provides invaluable insights into the intricate dynamics that shape their water-health perceptions and can serve as a foundation for informing policies and interventions (Bolaños-Valencia et al., 2019; Bourguignon et al., 2023; Jin et al., 2011; Leroy et al., 2022; Morales

et al., 2020; Nichter, 2008; Schuster-Wallace & Dickson, 2017; Spicer et al., 2020; Sultana, 2007, 2020).

This thesis seeks to characterize the proximal, intermediate, and distal water-health pathways influencing a rural community in the Western highlands of Guatemala. Additionally, this thesis seeks to examine how these pathways are perceived by various local water system actors including community members, water managers, and health workers. In this introductory chapter, I discuss the different levels of water-health pathways, explore the importance of examining local system actor perspectives for informing public health initiatives, and provide background information on water and health issues in Guatemala.

1.2 Water-health challenges for rural communities globally

According to the World Health Organization (WHO), ensuring access to safe drinking water and adequate sanitation is paramount for alleviating the global burden of water-borne disease (Gundry et al., 2004; Hulton & World Health Organization 2012; World Health Organization, 2023a). As of 2022, over 1.7 billion individuals relied on drinking water sources contaminated with fecal matter, with the majority of affected individuals residing in low-income countries (Gundry et al., 2004; Hulton & World Health Organization 2012; Wolf et al., 2023; World Health Organization, 2023a). Clean and sufficient water not only enables good hygiene practices, but also plays a pivotal role in curbing water-related illnesses such as cholera, dysentery, typhoid, and polio, which collectively contribute to approximately 505,000 diarrheal deaths annually (Gundry et al., 2004; Hulton & World Health Organization, 2012; Hutton, 2013; Wolf et al., 2023; World Health Organization, 2023a). The availability and integrity of water resources is not only critical for health but is also intricately linked with economic productivity and social development, as it is necessary for irrigation, household needs, ensuring food security, and sustaining livelihoods (Azupogo et al., 2023; Clasen et al., 2014; Connor, 2015; Hulton & World Health Organization, 2012; Hutton, 2013; International Labour Organization, 2019; Kondash et al., 2021; Su et al., 2011; Wolf et al., 2023).

Rural communities in the Global South are disproportionately vulnerable to risks from water-health pathways (Cissé, 2019; Connor, 2015; Hutton, 2013; Mabhaudhi et al., 2016; Wolf et al., 2023; World Health Organization, 2023a). Factors such as poor sanitation, inadequate hygiene, biophysical characteristics, population growth, and poverty can contribute to negative health outcomes like water-borne illness and malnutrition from reduced water quality, quantity, access, and availability (Cissé, 2019; Connor, 2015; Hutton, 2013; Mabhaudhi et al., 2016; Wolf et al., 2023; World Health Organization, 2023a). To illustrate, in East, West, and Southern Africa face elevated risks to water-borne illnesses due to a reliance on decentralized water sources such as springs that are prone to contamination from agricultural runoff and untreated sewage (Anthonj et al., 2018; Mabhaudhi et al., 2016; Ntouda et al., 2013; Osunla & Okoh, 2017; Pickering & Davis, 2012). Similarly, in Latin America, limited access to information about waterborne diseases and proper hygiene practices in rural communities contribute to widespread diarrheal diseases and malnutrition as demonstrated in studies in Peru and Bolivia (Akhmouch, 2012; Barlow & Clarke, 2004; Furgal, 2002; Lastrucci et al., 2020; Mekonnen et al., 2015; Patrick et al., 2021; Soares, et al., 2002). Addressing water-health challenges faced by rural areas requires contextually relevant research that considers the unique biophysical, ecological, and socio-economic factors that shape water-health pathways, and prioritizes understanding the multi-faceted and multi-scalar ways in which water impacts rural health (Aracena et al., 2020; Goldman et al., 2001; Grigg, 2018; McMichael, 2013).

Traditionally, water-health research in rural contexts has predominantly focused on studying the proximal pathways through which water impacts health such as those concerning waterborne illnesses due to water quality, sanitation, and hygiene issues (Brown et al., 2013; Fewtrell et al., 2005; Grigg, 2018; Morris et al., 2017; Patrick et al., 2021; Schuster-Wallace & Dickson, 2017). For instance, the widely utilized 'Five F's' model (representing fluids, fingers, food, fields, flies), developed by the WHO in the 1960s underscores various direct pathways through which microbial water contaminants can affect health, including the ingestion of contaminated water, transmission through contaminated food or surfaces, and

exposure to waterborne pathogens via environmental pathways (Brown et al., 2013; Kawata, 1978; Pickering et al., 2018; Walker et al., 2013; Wolf et al., 2023). While this model and other proximally focused models have provided valuable insights into direct impacts of water on health, they fail to account for broader systems-level pathways that can shape water-health outcomes (Cook & Bakker, 2012; Garrick & Hall, 2014; Grigg, 2018; Mabhaudhi et al., 2016; Paudel et al., 2021; Schuster-Wallace & Dickson, 2017). Pathways such as water competition reducing local water quantity and contributing to malnutrition (i.e., intermediate pathways) or the socio-economic conditions shaping hygiene education and subsequent risky water use (i.e., distal pathways) are neglected by many water-health frameworks (Al Wazni, et al., 2023; Gentry-Shields & Bartram, 2014; Morris et al., 2017).

There is a growing recognition of the need to understand and address intermediate and distal level pathways within water-health research (McMichael, 2013; Morris et al., 2017; Schuster-Wallace & Dickson, 2017). Studies increasingly demonstrate that intermediate and distal water-health pathways necessarily shape proximal water-health pathways, and that future water-health challenges around the world will primarily be driven by intermediate and distal health pathways, rather than proximal ones (Cheatham et al., 2022; International Labour Organization, 2019; Morris et al., 2017). For instance, Walls and McGarvey demonstrated that intermediate and distal factors are responsible for 66% of the variation in mortality from environmental health pathways in the United States (Walls & McGarvey, 2023). These studies highlight the importance of examining broader ecological, socio-economic, and institutional factors that influence water access and quality, as they are integral to understanding and addressing broader water-health pathways more comprehensively (Morris et al., 2017; Varis et al., 2017; Walls & McGarvey, 2023).

Other frameworks such as the Rural Water Livelihoods Index (RWLI) and the Driving Force-Pressure-State-Exposures-Effect-Action (DPSEEA) framework, have contributed to a more holistic understanding of intermediate and distal water-health pathways in rural communities (Calow et al., 2006; Furgal, 2002; Gentry-Shields & Bartram, 2014; Khan et al., 2007; Sullivan et al., 2003; Wwap, 2012). The RWLI, developed by the Food and

Agriculture Organization (FAO), serves as an index for assessing the water-related factors influencing rural livelihoods, with the aim of supporting poverty reduction efforts (International Labour Organization, 2019; Sullivan, 2002, 2003, 2010). This framework considers not only proximal determinants like biophysical water characteristics, but also intermediate and distal determinants such as corruption and economic conditions (Sullivan, 2002, 2003, 2010). Similarly, the DPSEEA framework, developed for the United Nations' 4th World Water Development Report (WWDR4), examines how intermediate and distal driving forces like population growth and socio-economics shape health outcomes through the water environment (Gentry-Shields & Bartram, 2014; Wwap, 2012). While both frameworks have had widespread uptake and have proven valuable in elucidating distal water-health pathways in rural communities, limitations and gaps exist (Gentry-Shields & Bartram, 2014; McMichael, 2013; Sullivan et al., 2010). Firstly, the RWLI lacks specificity in addressing public health issues, instead focusing on water and wellbeing issues as they relate to poverty, agriculture, and water management broadly (Sullivan, 2002, 2003). Likewise, the DPSEEA framework primarily focuses on intermediate and distal determinants in relation to water-related diarrheal diseases, overlooking other health outcomes (Al Wazni et al., 2023; Gentry-Shields & Bartram, 2014; Government of Scotland, 2008). Secondly, both frameworks are constrained by their scope, neglecting social, institutional and economic contexts that are critical for understanding local dynamics and developing context-informed interventions (Gentry-Shields & Bartram, 2014; Grigg, 2018; Morris et al., 2017). Indeed, as discussed by recent reviews, there remains a notable gap in water-health research that adequately considers intermediate and distal water-health pathways within local contexts (Cook & Bakker, 2012; Garrick & Hall, 2014; Paudel et al., 2021).

1.3 Overview of the three-level environment-health framework

To bridge this gap, a three-level environment-health framework that categorizes not only proximal but also intermediate, and distal pathways can be employed in a water-health context (Butler, 2024; Butler & Harley, 2010; Walls & McGarvey, 2023). This framework was initially developed by scholars including Haines and later elaborated on by Butler and

McMichael to categorize different pathways through which climate change was predicted to impact human health (Butler, 2024; Butler & Harley, 2010; Haines et al., 1993; McMichael, 2006, 2013). Since its inception, the framework has been applied in many contexts and scales (Brubacher et al., 2024; McMichael, 2013; Walls & McGarvey, 2023). Notably, the framework featured in the Sixth Intergovernmental Panel on Climate Change (IPCC) report to scope the climate change-health impacts for Indigenous communities worldwide (Cissé et al., 2022). Additionally, it has been applied at smaller scales to identify environment-health pathways, such as those at regional levels in Saami Indigenous populations in the European Union relating to climate change, or those studies at city scales like one in characterizing environment-health pathways in Graz, Austria (Butler, 2024; Butler & Harley, 2010; Jaakkola et al., 2018; Reischl, 2014). By encompassing proximal, intermediate, and distal pathways, researchers can capture a wide array of potential health determinants, including both direct and indirect influences (Brubacher et al., 2024; Morris et al., 2017; Walls & McGarvey, 2023). Additionally, the framework's suitability for incorporating a wide range of factors—from biophysical water characteristics and local water management practices to hygiene behaviors and socio-economic conditions—ensures a thorough exploration of the local health landscape (Butler, 2024; Morris et al., 2017). This is particularly important in less-studied settings, where traditional health frameworks might not capture the full scope of influencing factors (Cook & Bakker, 2012; Garrick & Hall, 2014; Paudel et al., 2021).

At its core, the framework categorizes environmental health pathways into three distinct levels: proximal, intermediate, and distal (Brubacher et al., 2024; Haines et al., 1993; McMichael, 2006, 2013; Morris et al., 2017). These levels provide a structured approach for understanding and categorizing water-health pathways that operate at different temporal and spatial scales (McMichael et al., 2006, 2013; Morris et al., 2017). In the context of this framework, pathways refer to the processes through which factors like weather and climate, population growth, and socio-economic conditions affect water resource characteristics. Alterations in water resource characteristics such as quality, quantity, accessibility, and availability, in turn contribute to health outcomes such as waterborne illnesses, malnutrition,

and negative social health. An example of a water-health pathway is depicted in Figure 1 below.

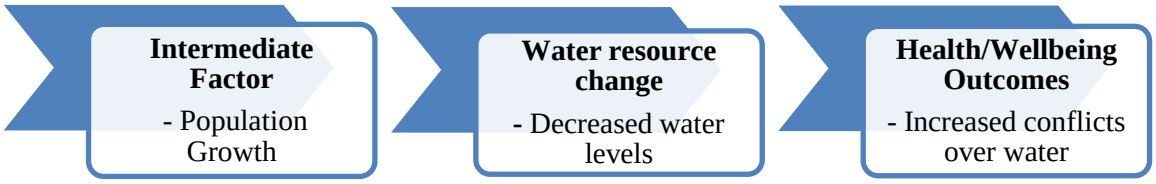

Figure 1. Schematic of an intermediate water-health pathway

Proximal pathways represent immediate or direct factors that can directly impact health such as biophysical factors, water infrastructure, hygiene and sanitation within a specific community or context (Brubacher et al., 2024; McMichael, 2006, 2013; Morris et al., 2017). These factors are often observable and measurable, such as rainfall variability or inadequate sanitation facilities (Butler & Harley, 2010; McMichael, 2013; Morris et al., 2017; Walls & McGarvey, 2023).

Moving to the intermediate level, the pathways become more complex, involving broader ecological and system factors that influence water-health outcomes (Butler & Harley, 2010; McMichael, 2013; Morris et al., 2017; Walls & McGarvey, 2023). This level encompasses phenomena such as water competition and land-use changes which may have indirect effects on water quantity, availability, and access (Butler & Harley, 2010; McMichael et al., 2006, 2013; Morris et al., 2017; Walls & McGarvey, 2023). Intermediate pathways operate over longer temporal and spatial scales compared to proximal pathways, reflecting the cumulative impacts of various environmental stressors and human activities (Butler & Harley, 2010; McMichael, 2006, 2013; Morris et al., 2017; Walls & McGarvey, 2023).

At the distal level, the water-health pathways extend further, encompassing systemic and structural factors that shape the broader social and economic context within which water-health interactions occur (Brubacher et al., 2024; Butler & Harley, 2010; Garrick & Hall, 2014; McMichael, 2013; Morris et al., 2017; Walls & McGarvey, 2023). These factors

include institutional constraints and socio-economic inequalities, which may influence water management policies, resource allocation, and access to hygiene education (Grigg, 2018; McMichael, 2013). Distal pathways operate at the macro-level, shaping both intermediate and proximal pathways (Grigg, 2018; McMichael, 2006, 2013; Morris et al., 2017; Mutiga et al., 2010; Walls & McGarvey, 2023).

Importantly, each progressive level of the framework influences and shapes pathways at lower levels as can be seen in Figure 1 below (Butler, 2024; Butler & Harley, 2010; McMichael, 2006, 2013; Morris et al., 2017; Walls & McGarvey, 2023). For example, while proximal pathways relate to issues like poor water quality from lack of sanitation in a community, proximal pathways are shaped by broader intermediate and distal factors such as water administration and poverty (Brubacher et al., 2024; Butler, 2024; Butler & Harley, 2010; McMichael, 2006, 2013; Morris et al., 2017; Walls & McGarvey, 2023).

Unlike more narrowly focused frameworks, the three-level framework allows for a more comprehensive exploration of potential water-health pathways in diverse contexts (Brubacher et al., 2024; Butler & Harley, 2010; Grigg, 2018; McMichael, 2006, 2013; Morris et al., 2017; Mutiga et al., 2010; Walls & McGarvey, 2023). By incorporating proximal, intermediate, and distal factors, the framework facilitates a holistic understanding of the complex interactions between biophysical, ecological, and institutional variables (Morris et al., 2017). This approach is particularly valuable in contexts where specific health issues may be unknown or under-researched, providing a foundation for identifying key determinants of water-related health outcomes and informing targeted public health interventions (Morris et al., 2017). The three-levels are explained in more detail in the following section.

1.3.1 Proximal water-health pathways: biophysical characteristics, geography and water infrastructure, and sanitation and hygiene

In the context of rural communities dependent on agriculture for food security and livelihoods, biophysical characteristics including weather, and climate play a crucial role in shaping water-health outcomes (Cissé, 2019; Kondash et al., 2021; Lopez-Ridaura et al.,

2019; Mabhaudhi et al., 2016; Pickering et al., 2018; Schuster-Wallace & Dickson, 2017; Varis et al., 2017). Weather patterns, including rainfall, temperature, and humidity, directly influence agricultural productivity, crop yields, and household food security for those engaged in subsistence agriculture (Fyles & Madramootoo, 2016; Kassaye et al., 2021; Lopez-Ridaura et al., 2019; Mabhaudhi et al., 2016; Varis et al., 2017). For example, in Ethiopia, fluctuating rainfall patterns have been shown to impact agricultural productivity, leading to food insecurity and malnutrition (Dimitrova, 2021; Randell et al., 2021). Recent studies in rural Ethiopia have revealed that prolonged dry seasons are resulting in crop failures, causing food shortages, inadequate diets, and chronic undernutrition in households (Kassaye et al., 2021; Mank et al., 2021). These studies elucidate the important role of weather and climate mediating health outcomes from water and agriculture.

Additionally, community geography and water infrastructure have an important role in shaping health outcomes within communities, as water systems connect households and communities to potable and irrigation water for maintaining personal hygiene, sanitation, and agriculture (Haeffner et al., 2018; Leroy et al., 2022; Poder & He, 2011; Sultana, 2020; Taylor et al., 2015). To illustrate the importance of geography and water infrastructure on health, a study conducted in rural communities in Nepal highlighted the health implications of proximity to local water irrigation and potable systems (He et al., 2018). This study found that households located closer to irrigation systems, such as canals or wells, had better access to water for agricultural purposes (He et al., 2018). As a result, these households were able to cultivate a wider variety of crops throughout the year, leading to improved nutrition and food security (He et al., 2018). In contrast, households located farther away from irrigation systems faced challenges in accessing water for agriculture, leading to lower crop yields and increased incidence of malnutrition (He et al., 2018). This research underscores emphasizes the importance of geography and water infrastructure in shaping health outcomes, particularly in rural agricultural communities (He et al., 2018; Islam et al., 2020).

Issues related to sanitation and hygiene are critical drivers of proximal water-health pathways, particularly in rural areas of Latin America where access to clean water and proper

sanitation facilities remains a challenge (Brown et al., 2013; Fewtrell et al., 2005; Gordon et al., 2023; Mara, 2003; Vásquez & Aksan, 2015). In this region, inadequate sanitation systems and poor waste management practices often contaminate drinking water sources with pathogens such as bacteria, viruses, and parasites, posing significant health risks (Brown et al., 2013; Fewtrell et al., 2005; Gordon et al., 2023; Mara, 2003; Vásquez & Aksan, 2015). Limited access to improved sanitation facilities and treated drinking water exacerbates the situation, leading to higher incidences of waterborne diseases (Brown et al., 2013; Fewtrell et al., 2005; Gordon et al., 2023; Mara, 2003; Vásquez & Aksan, 2015). Additionally, inadequate hygiene behaviors, such as insufficient handwashing facilities and poor sanitation practices, further contribute to disease transmission (Bosch et al., 2001; Brown et al., 2013; Clasen et al., 2014; Fewtrell et al., 2005; Vásquez & Aksan, 2015). Furthermore, individual-level risk perceptions associated with contaminated water or hygiene practices have an important role in shaping health behaviors and outcomes (Anthonj et al., 2022; Haeffner et al., 2018; Maurice et al., 2019; Nichter, 2008). If people perceive a high risk associated with unsanitary practices or contaminated water sources, they may be more likely to adopt preventive measures (Anthonj et al., 2022; Haeffner et al., 2018; Maurice et al., 2019; Nichter, 2008). In contrast, if individuals underestimate the risks, they may be less inclined to take necessary precautions, thereby increasing their vulnerability to water-related health issues (Anthonj et al., 2022; Haeffner et al., 2018; Maurice et al., 2019; Nichter, 2008). Notably, negative health outcomes such as diarrhea and dehydration resulting from poor hygiene practices, coupled with risk perceptions associated with waterborne illnesses, have been extensively documented in the Global South. (Adams et al., 2020; Fewtrell et al., 2005; Sharma Waddington et al., 2023). A recent systematic review and meta-analysis revealed that effective sanitation, hygiene practices, and global risk prevention measures were associated with a 17% decrease in all-cause mortality and a 45% decrease in mortality due to diarrhea (Sharma Waddington et al., 2023). These findings underscore the critical role of sanitation and hygiene practices in influencing water quality and health outcomes, highlighting the significance of individual risk perceptions in shaping health behaviors as key pathways to

improved health (C. Anthonj et al., 2022; Haeffner et al., 2018; Maurice et al., 2019; Nichter, 2008).

1.3.2 Intermediate water-health pathways: changes and disturbances to systems and processes

Intermediate water-health pathways encompass a continuum of factors mediated by changes and disturbances in biophysical, ecological, and governance systems and processes (Akhmouch, 2012; Burnley, 2011; Haeffner et al., 2018). Such changes include deforestation, agriculture and population related water withdrawals, and water system administration dynamics (Prado Córdova et al., 2013; Walls & McGarvey, 2023). Changes at this level can affect water available for human uses, alter water flows, and impact the quantity and quality of water delivered to water users, ultimately influencing a range of health outcomes (Akhmouch, 2012; Burnley, 2011; Gibson et al., 2002; Haeffner et al., 2018; Laino-Guanes et al., 2016; Mutiga et al., 2010).

Changes in biophysical and ecological systems and processes, such as deforestation and agricultural water withdrawals can shape water-health outcomes (Akhmouch, 2012; Burnley, 2011; Gibson et al., 2002; Haeffner et al., 2018; Laino-Guanes et al., 2016; Mutiga et al., 2010). Deforestation, for example, can decrease water evapotranspiration, decrease groundwater recharge rates, and alter river flows, resulting in altered water quantity and availability (Arima et al., 2014; Laino-Guanes et al., 2016; Levy, et al., 2018; Souza Jr et al., 2019). These changes can ultimately contribute to an increase in health risks resulting from a decrease in the amount of water available for consumption and other uses (Arima et al., 2014; Levy et al., 2018; Souza Jr et al., 2019). Indeed, these types of water-health pathways have been documented in the Amazon rainforest region of Brazil, where extensive deforestation has been linked to adverse health outcomes such as dehydration and malnutrition in local communities following prolonged dry periods and food shortages (Magalhães et al., 2022). Deforestation disrupts the hydrological cycle, decreased groundwater recharge, and altered river flow patterns (Arima et al., 2014; Laino-Guanes et al., 2016; Levy et al., 2018; Souza Jr et al., 2019). Additionally, another study conducted in

the Brazilian Amazon found a significant association between deforestation rates and the incidence of waterborne diseases such as malaria and diarrhea (Santos & Almeida, 2018). Communities located downstream of deforested areas experienced higher rates of these diseases, highlighting the indirect health consequences of deforestation on water systems and public health (Arima et al., 2014; Levy et al., 2018; Santos & Almeida, 2018; Souza Jr et al., 2019).

Additionally, ecological changes such as those related to agricultural practices and water withdrawals are important factors shaping intermediate water-health pathways (Fyles & Madramootoo, 2016; Garrick & Hall, 2014; Hays, 2023; Lebek et al., 2021; Messerli, Viviroli, & Weingartner, 2004). Water withdrawals for irrigation purposes can contribute to overuse and competition for limited water resources, exacerbating water scarcity and ecological degradation (Fyles & Madramootoo, 2016; Hays, 2023; Lebek et al., 2021; Messerli et al., 2004). More specifically, competition among rural farmers or stakeholders for water access can lead to conflicts and water scarcity issues (Gleick, 1998; Gleick & Heberger, 2014; Mutiga et al., 2010; Sultana, 2011). In the Murray-Darling Basin of Australia, competition for water resources between agriculture and environmental conservation has raised concerns about its impact on public health, particularly for downstream users (Connell, 2015; Docker & Robinson, 2014; Holland et al., 2015; Levy & Sidel, 2011). The basin supports a significant agricultural industry, heavily reliant on irrigation for crop production (Connell, 2007, 2015; Docker & Robinson, 2014; Holland et al., 2015). However, increased agricultural water withdrawals and upstream population growth have led to the depletion and degradation of downstream water quantity and quality (Connell, 2007, 2015; Docker & Robinson, 2014; Holland et al., 2015). These withdrawals diminish the amount of water available in downstream rivers, reducing water levels during dry periods, exacerbating drought conditions, and contributing to food insecurity (Connell, 2007, 2015; Docker & Robinson, 2014; Holland et al., 2015). Overall, water withdrawals are important determinants of water availability and quantity and related health outcomes for

downstream ecosystems, households, and communities (Gleick, 1998; Gleick & Heberger, 2014; Mutiga et al., 2010; Sultana, 2011).

Lastly, issues with water administration systems and processes can contribute to water-health risks, particularly in rural areas reliant on decentralized water systems lacking technical expertise, monitoring, and adequate funding (Gershberg et al., 2009; Grigg, 2018; Haeffner et al., 2018). Inadequately managed water sources may increase the risk of waterborne diseases and health risks due to exposure to contaminants and pathogens (Gershberg et al., 2009; Haeffner et al., 2018). Moreover, the governance and management of water resources influence the equitable distribution, allocation, and utilization of water resources (Gershberg et al., 2009; Haeffner et al., 2018). Effective water management and administration are essential for balancing competing demands for water, ensuring environmental sustainability, and safeguarding public health (Grigg, 2018). Water management practices encompass a range of activities, including water allocation, regulation, monitoring, and enforcement of water quality standards (Gershberg et al., 2009; Haeffner et al., 2018). In regions where water resources are scarce or prone to overuse, efficient water management strategies are crucial for optimizing water use efficiency, minimizing wastage, and mitigating the impacts of water scarcity on public health (Gershberg et al., 2009; Grigg, 2018; Haeffner et al., 2018). For example, in rural communities in the Mekong Delta region of Vietnam, challenges with water quantity management and equitable access have significant implications for public health (Biggs et al., 2012; Herbst et al., 2009; Phung et al., 2015; Sebesvari et al., 2012). Studies in the Mekong Delta have found that inadequate water quantity management has resulted in declining groundwater levels and reduced flow in rivers and canals, particularly during dry seasons (Biggs et al., 2012; Phung et al., 2015; Sebesvari et al., 2012). This inadequate management has led to water shortages for drinking, irrigation, and domestic use, affecting hygiene and sanitation standards across communities (Biggs et al., 2012; Phung et al., 2015; Sebesvari et al., 2012). Overall, these water administration dynamics play a crucial role in supporting agricultural productivity, enhancing crop yields, and food security.

1.3.3 Distal water-health pathways: Socio-economic and institutional related water-health risks

Distal water-health pathways encompass broader socio-economic and institutional factors that shape the complex interplay between water resources and human health (Garrick & Hall, 2014; Morris et al., 2017; Mutiga et al., 2010; Nagabhatla et al., 2021; Sullivan et al., 2010; Varis et al., 2017). These factors operate at macroscopic scales, influencing access to clean water, water governance funding, and public health provisions ultimately impacting health outcomes at the community and population levels (Garrick & Hall, 2014; Morris et al., 2017; Mutiga et al., 2010; Nagabhatla et al., 2021; Sullivan et al., 2010; Varis et al., 2017). Understanding these distal pathways is crucial for addressing downstream water-health challenges and achieving equitable health outcomes (Garrick & Hall, 2014; Morris et al., 2017; Mutiga et al., 2010; Nagabhatla et al., 2021; Sullivan et al., 2010; Varis et al., 2017).

Distal water-health pathways involve socio-economic challenges such as poverty and migration influencing various dimensions of water resources (Abayawardana & Hussain, 2003; Besnier, 2021; Bosch et al., 2001; Gragnolati & Marini, 2003; Sullivan, 2002). Rural communities often disproportionately experience challenges with poverty, facing limited economic opportunities, insufficient access to basic services, and political marginalization (Calow et al., 2006; International Labour Organization, 2019; Lebek et al., 2021; Molden et al., 2001; Strasser, 2003; Sullivan et al., 2010; Vásquez, 2013). Poverty may limit access to safe water, health services, and sanitation infrastructure, as well as hinder the adoption of hygienic practices (Abayawardana & Hussain, 2003; Adams et al., 2020; Bosch et al., 2001; Garriga & Foguet, 2013). As a result, rural populations experience increased incidence of water-borne illnesses due to inadequate investment in sanitation infrastructure, lack of clean drinking water, and limited healthcare resources (International Labour Organization, 2019; Islam et al., 2020; Mabhaudhi et al., 2016; Penn et al., 2017; Randell et al., 2021; K. B. Smith et al., 2008; Strasser, 2003). Additionally, migration in rural communities is a significant distal factor associated with water and health outcomes of migrant sending communities. To illustrate, the Centre for International and Strategic Studies (CSIS), the

World Bank, and Potsdam Institute for Climate Impact Research have all recently highlighted how low economic opportunities, coupled with environmental vulnerability and water insecurity have been significant disruptors of rural livelihoods in the Northern Triangle (i.e., Guatemala, Honduras, and El Salvador) and have been main contributors to migration from Latin America to the southern border of the United States (Dodd, Cerna, Orellana, Humphries, Kipp et al., 2020; Dodd, Cerna, Gomez, Orellana, Humphries, Sadoine et al., 2020; Reyer et al., 2017; Savoy & Mendez Leal, 2022; Wyngaarden et al., 2023). Importantly, remittances sent back home from migrant families can be pivotal in improving water sanitation infrastructure (Abdelali-Martini & Hamza, 2014; Adida & Girod, 2011; Ge et al., 2011). For example, a In the lower Todgha of Morocco, where surface irrigation water is limited, the inflow of international remittances has increased water access through water infrastructure projects like well construction and diesel pump acquisition (de Haas, 2006). Migrant households receiving remittances were found to be, on average, 25% more likely to invest in water pumps and sanitation infrastructure compared to non-migrating households (de Haas, 2006). Furthermore, remittances from migration can have positive impacts on water-related health outcomes by providing households with the financial means to invest in improved water and sanitation infrastructure as previously demonstrated in Mexico, China and Syria (Abdelali-Martini & Hamza, 2014; Adida & Girod, 2011; Ge et al., 2011). These case studies highlight the complex interplay between socio-economic factors and water-health pathways, emphasizing the importance of addressing broader determinants of health to achieve sustainable improvements in water-related health outcomes.

Institutional challenges such as lack of state support for local water administration and public health can reduce the ability for water administrators and public health officials to effectively manage local water-health needs (Garrick & Hall, 2014; Gleick & Heberger, 2014; Sultana, 2011; Vásquez, 2013). In regions affected by conflict, disruptions to infrastructure and governance systems can lead to the breakdown of water supply and sanitation services, increasing the risk of waterborne diseases and other health issues (Garrick & Hall, 2014; Garriga & Foguet, 2013). To illustrate, while the Democratic Republic of the Congo (DRC)

is Africa's most water-abundant country, widespread armed conflicts and political challenges have left millions without access to safe sources of drinking water and local water administrators unable to manage water needs of communities (Burnley, 2011; Burt & Keiru, 2014; Nagabhatla et al., 2021). As a result, many communities in the DRC have had to rely on foreign aid organizations for water infrastructure development (Burnley, 2011; Burt & Keiru, 2014; Nagabhatla et al., 2021). For instance, Oxfam initiated the longest piped water distribution system in the mountainous Mutamba region in 2019, benefiting over 80,000 residents (Oxfam, 2019). In relation to public health, regions affected by weak governance and lack of funding, such as in rural areas of Afghanistan, stakeholders face challenges in providing hygiene education to communities (Burt & Keiru, 2014). Research in rural Afghan villages have highlighted how the absence of a functioning state and limited resources have hindered efforts to implement hygiene education programs (Aluisio et al., 2015; Mubarak et al., 2016). These studies have found that without proper funding and institutional support, health officials struggled to reach communities with crucial information on handwashing, sanitation, and safe water practices (Aluisio et al., 2015; Mubarak et al., 2016). Consequently, inadequate hygiene education contributed to high rates of waterborne diseases and preventable illnesses among the population (Aluisio et al., 2015; Mubarak et al., 2016).

Overall, there are many ways in which water can impact rural health as evident by the discussion above. By characterizing the types of health impacts faced by communities through proximal, intermediate, and distal water-health pathways better public health and development interventions and policies can be created. However, critical to the success of such interventions is the inclusion of the perspectives and perceptions from diverse local system actors in order to understand community needs and concerns.

1.4 Actor perspectives in water research

Understanding water-health issues as perceived by local system actors is crucial for developing contextually and locally relevant public health policies and interventions to address the various water-health pathways (Baccarelli et al., 2023; Yamey, 2011). By engaging with diverse actors within a water system such as community members, water

system managers and health workers, researchers can gain a more nuanced understanding of the individual- and community-level factors shaping water-health pathways (Anthonj et al., 2022; Cheatham et al., 2022; Herbst et al., 2009; Leroy et al., 2022; Nichter, 2008; Spicer et al., 2020). Actor groups bring unique insights shaped by their identities, perceptions, and subjectivities within the community or water systems (Bourguignon et al., 2023; Herbst et al., 2009; Holmes et al., 2023; Jalloh et al., 2018; Morales et al., 2020; Nichter, 2008; Sultana, 2020). For example, community members may offer invaluable insights into local water use practices, cultural beliefs, and health outcomes experienced firsthand; water managers can provide expertise on infrastructure, water quality monitoring, and distribution systems; and health workers can contribute important information on the prevalence of waterborne diseases and the health impacts observed in the community (Anthonj et al., 2019; Burt & Keiru, 2014; Essendi et al., 2015; Goudet et al., 2011; Haeffner et al., 2018; Marcillo et al., 2020; Morales et al., 2020; Williams et al., 2015). Additionally, recognizing the subjectivities and identity work of individuals within water systems, further enriches our understanding of water-health pathways and informs the development of more inclusive and effective interventions (Balasubramanya et al., 2022; Lawless et al., 2015; Sultana, 2007, 2020).

Previous water and health research has emphasized the importance of actor perspectives and identities for informing policy decisions, supporting environmental programming, and reducing water-health risks (Brown et al., 2020; Cheatham et al., 2022; Dobbie & Brown, 2014; Haeffner et al., 2018; Harvey et al., 2018; Mumbi & Watanabe, 2020; Saborío-Rodríguez et al., 2021). By investigating actor perspectives, decision-makers can better understand the rationale behind user actions, behaviors, and adaptation practices, as well as learn about the most pressing water system needs (Brown et al., 2020; Cheatham et al., 2022; Haeffner et al., 2018; Harvey et al., 2018; Saborío-Rodríguez et al., 2021). Research has shown that water-related behaviors and actions are often determined by actors' perceptions and beliefs of available water resources (Garin et al., 2002; Haeffner et al., 2018; Hale et al., 2015; Rinaudo & Garin, 2005). To illustrate, a recent systematic review found evidence that

risk perceptions of water resources were significant determinants of water-related behaviors such as seeking and utilizing sanitation services (Anthonj et al., 2022).

Research across Latin America has examined the importance of examining how individual-level perceptions and experiences of water-health pathways impact wellbeing, decision-making, and engagement with water systems (Morales et al., 2020; Rowles et al., 2018; Sobczak et al., 2013). For example, a study in Oaxaca Mexico investigated perceived and actual water quality in rural communities (Rowles et al., 2018). Researchers found that perceptions of high water quality due to the purity of spring water among community members led to risky water usage (Rowles et al., 2018). Other research in rural communities in Latin America has emphasized the need for comprehensive assessment of multi-level water-health pathways to inform local governance and evaluate community health needs (Leroy et al., 2022; Marcillo et al., 2020; Maurice et al., 2019; Morales et al., 2020; Rowles et al., 2018; Sobczak et al., 2013). For example, in a study with rural communities Argentina, researchers used interviews, surveys, and participatory workshops with community members, to examine beliefs, customs, and concerns regarding water quality among the Mapuche people (Morales et al., 2020). The study identified a discrepancy between local perspectives and scientific assessments of water quality that highlighted the importance of incorporating local knowledge and values into water quality assessments and interventions (Morales et al., 2020). Overall, these studies demonstrate that actor engagement is essential for addressing water quality issues and promoting health in rural communities.

1.5 Water and health issues in Guatemala

Guatemala is characterized by an abundance of freshwater resources in the form of streams, lakes, rivers, and other sources (Cheatham et al., 2022; Gil-Rodas et al., 2021; US Army Corps of Engineers, 1990). These resources are influenced by a myriad of natural features specific to the region (Marini et al., 1998). The country's topography, characterized by mountains, volcanoes, and steep slopes, contributes to rapid runoff and erosion, affecting surface water quality and sedimentation rates within river basins (Somers & McKenzie, 2020; US Army Corps of Engineers, 1990; Wade et al., 2022). However, regional variations

in climate exist due to Guatemala's complex topography, with coastal lowlands experiencing different rainfall patterns than the highland regions (US Army Corps of Engineers, 1990). Also, geological factors such as volcanic activity and complex hydrogeological formations influence groundwater recharge rate, formation of springs and rivers, and concentration of naturally occurring environmental contaminants (Somers & McKenzie, 2020; US Army Corps of Engineers, 1990; Wade et al., 2022). Local and global climate factors, including seasonal variations in precipitation, temperature, and climate patterns such as El Niño also exert significant influence on water availability and variability throughout the country and influence agricultural productivity (Somers & McKenzie, 2020; US Army Corps of Engineers, 1990; Wade et al., 2022; Wyngaarden et al., 2023). The significance of farming in Guatemala and reliance on water resources cannot be overstated, as agriculture contributes significantly to the country's economy, food security, and rural livelihoods (Hoy & Belisle, 1984; Lopez-Ridaura et al., 2019). Small scale farmers, who comprise the majority of agricultural producers in Guatemala, rely heavily on access to water resources for their subsistence and income generation (Somers & McKenzie, 2020; US Army Corps of Engineers, 1990; Wade et al., 2022).

In the Western Highlands region of Guatemala, the varied geography presents contrasting agricultural landscapes shaped by differences in climate, topography, and farming practices (Hoy & Belisle, 1984; Immink & Alarcon, 1993; Lopez-Ridaura et al., 2019; Marini et al., 1998; Veblen, 1978). While lowland regions support large-scale commercial agriculture utilizing extensive irrigation systems, highland areas predominantly feature smallholder farming and subsistence agriculture, often relying on rainfed irrigation techniques (Hellin et al., 2017; Hoy & Belisle, 1984; Immink & Alarcon, 1993; Lopez-Ridaura et al., 2019). Highland farmers cultivate crops like maize, beans, and coffee using farming methods suited to the mountainous terrain and rainfed agriculture, often with limited access to surface water and relying more on groundwater and rainwater harvesting (Hellin et al., 2017; Hoy & Belisle, 1984; Immink & Alarcon, 1993; Lopez-Ridaura et al., 2019). Moreover, climate change poses significant challenges to water resources in Guatemala, with projections

indicating shifts in precipitation patterns, increased frequency of extreme weather events, and altered hydrological regimes especially in the Western Highlands (Hellin et al., 2017; Hoy & Belisle, 1984; Immink & Alarcon, 1993; Lopez-Ridaura et al., 2019). Changes in rainfall patterns could impact agricultural productivity, freshwater ecosystems, and overall water security, exacerbating existing health vulnerabilities in rural communities (Hellin et al., 2017; Hoy & Belisle, 1984; Immink & Alarcon, 1993; Lopez-Ridaura et al., 2019).

While Guatemala possesses an abundance of freshwater resources, political, social, and institutional challenges have resulted in only 60% of the country's water supply coming from safely managed sources (Cheatham et al., 2022; Trudeau et al., 2018; Vásquez, 2010, 2013; Vásquez & Aksan, 2015). Low-quality water services have been attributed to weak government institutions, widespread corruption, and industrial abuses leading to only 17% of Guatemala's rural population having access to treated municipal water systems (Vásquez, 2013; Vásquez & Aksan, 2015). Following the 30-year Guatemalan civil war, a series of natural resource decentralization policies were enacted which relegated water resource administration to local governing bodies and committees that lacked government oversight, training, or support (Cheatham et al., 2022; Copeland, 2023; Foster & Araujo, 2004; Holder, 2006; Ruano et al., 2011). As a result, the predominantly small-scale farming rural population is reliant on independently developed and locally led water systems and infrastructure, with over ten thousand rural communities maintaining their own water systems (accounting for 40% of rural population) (Cheatham et al., 2022; Foster & Araujo, 2004; Vásquez, 2010; Vásquez & Aksan, 2015). These community-based systems are often user-funded and lack technical, physical, and financial capacity, raising concerns for water availability, quality, and long-term sustainability (Cheatham et al., 2022; Foster & Araujo, 2004; Holder, 2006; Vásquez, 2010, 2013).

Challenges in water management have led to a high incidence of waterborne diseases in the Western Highlands, with diarrheal diseases alone contributing to over 20% of deaths among children under five years old (Braghetta, 2006; Trudeau et al., 2018; Vásquez, 2010). Moreover, parasitic infections such as giardiasis and cryptosporidiosis are prevalent,

affecting an estimated 20% of the Guatemalan Population (Braghetta, 2006). Open defecation remains common in many areas, with around 30% of rural households lacking access to improved sanitation facilities, further exacerbating water contamination (Braghetta, 2006; Trudeau et al., 2018; Vásquez, 2010).. The lack of access to adequate healthcare services in rural areas compounds these water-health challenges, with limited human resources and health infrastructure hindering efforts to address water-related health issues effectively (Cheatham et al., 2022; Foster & Araujo, 2004; Holder, 2006; Vásquez, 2010, 2013).

1.6 Study research objectives and context

While attention in the literature has been given to characterize climactic vulnerabilities and health issues with respect to agriculture in the Western Highlands of Guatemala, few studies have given attention specifically to proximal, intermediate, and distal water-health pathways impacting Western Highlands communities. Furthermore, those studies that have included water and health issues in this region have generally lacked in-depth consideration to how perspectives and perceptions vary among system actors. As such, there is a need for research that can inform evidence-based interventions that are tailored to community contexts. This thesis seeks to address this research gap through the following objectives.

1. Characterize the proximal, intermediate, and distal water-health pathways impacting a rural Highland community Guatemala
2. Examine how perceptions of these pathways differ among diverse system actors

1.7 Study Location and Research Partnership

As part of an ongoing collaborative research project with local community partners (see section 2.1 for more details), a qualitative research project was conducted in the community of Tojchoc Grande, San Marcos. The community is located in the municipality of Tacaná, that consists of mostly rural, hillside communities across mountainous terrain and some smaller urban centers. Tojchoc Grande itself is a small rural hillside community of approximately 1,500 people. Small-scale agriculture consisting of *milpa*, a crop growing

system where corn, beans and squash are grown simultaneously, is the main subsistence and economic output. Traditional gender roles are rigid in the community with agricultural labor typically conducted by men and household work and caregiving responsibilities are typically conducted by women. Out-migration creates an important economic and socio-cultural dynamic in the community, as many community members have migrated or have family members who have migrated to the United States or Canada for employment opportunities. Poverty and food insecurity are also prevalent due to a lack of economic opportunities in the community and region, together constituting a primary driver of migration out of the community.

1.8 Summary of Manuscript and contributions

The research described in this thesis is presented as a co-authored manuscript (see Statement of Contributions for further information on co-authorship). In Chapter 3, I present a manuscript describing findings from a qualitative case study on the water and health pathways as experienced by actors in the community of Tojchoc Grande. This chapter discusses the complexity of water and health pathways in the community and how different actors highlight different experiences and perceptions of these pathways, with implications for local and regional intervention strategies. The results are discussed in context of water-health research, and other development research across Latin America and the Global South.

The remainder of the thesis proceeds as follows: in Chapter 2, I detail the overall methodology and methods employed in this work; Chapters 3 presents the manuscript described above; in Chapter 4, I provide a conclusion to the thesis, followed by references and appendices relevant to the entire document. Overall, the thesis makes an important contribution toward characterizing complex water-health pathways in one context and highlights the significance of examining broad actor experiences within this context. The information presented herein can be used by non-governmental organizations and researchers to shape water-health interventions in rural communities and provides an example of applying a three-level framework for water and health issues at a local level.

1.9 Positionality Statement

My personal experiences, subjectivities, and identity have shaped my involvement and engagement with the research topic and process. As such, this section elaborates on my positionality with regards to the content of this thesis and the research project it contains.

During my undergraduate degree at the University of Waterloo I worked as a research assistant with Dr. Brian Laird studying environmental contaminants in northern Indigenous communities. This work was formative in developing my research interests relating to environmental health with rural and Indigenous communities and has been important for developing my understanding of how rural and remote communities are disproportionately at risk to environmental health issues.

Furthermore, my own ethnic and racial experience being a Guatemalan-Canadian has had significant bearing on the way I have conducted this research and how I have straddled insiderness, outsiderness, and inbetweenness throughout the research process (Breen, 2007; Dwyer & Buckle, 2009; Kerstetter, 2012). Coming from a family of mandarin orange farmers, my families' teachings and our farming background in Guatemala has been a primary motivator for my own engagement in this work. These teachings have informed my own understandings of the challenges faced by rural farmers in Guatemala and contribute to the axiological underpinnings of this research (Brown & Duenas, 2020; Patterson & Williams, 1998). However, having myself grown up in Canada for most of my life, my experiences with rural farming having been distinct from those of my own family and farmers across Guatemala, especially in comparison to those in Tojchoc Grande, where I had no previous experience prior to beginning the research study. While I have some insider knowledge and understanding through my Guatemalan heritage, my Canadian upbringing and lack of direct connection to the specific study location also positions me as an outsider in certain respects (Breen, 2007; Dwyer & Buckle, 2009; Kerstetter, 2012). Indeed, the consequences of holding experiences of both an insider and outsider manifested in various ways throughout the research (Breen, 2007; Dwyer & Buckle, 2009; Kerstetter, 2012). For example, during my time in Tojchoc Grande, my own Canadian identity was of particular

interest to some research participants wanting to learn more about Canada and the foreign agricultural worker programs (a topic I did not know much about when first starting this research project) and how I, as a Guatemalan, ended up in Canada. In some ways, being both a Guatemalan and a Canadian legitimized the work I did for some participants, increased suspicion for others, or significantly sidetracked interviews. Navigating the interplay of my own Canadian and Guatemalan identities was challenging. Efforts were taken to uphold research ethics by ensuring that ethics documents and key background information was always shared with participants, and I made an effort to be as transparent as possible with participants of my own background when appropriate. Here I benefited from the efforts of the research team including E. Kocsis (doctoral candidate and collaborator) and M. Roblero (local Guatemalan research assistant), as they facilitated interviews and conversations with research participants and community members.

Lastly, my own experience with what would appear to have been an acute gastrointestinal illness during my fieldwork serves as an important point of reflection for how I engaged with the data during analysis. “Have any of you gotten sick from the water yet”, a participant asked, chuckling as they handed our team cups filled with water. Ironically, this interaction occurred during the last week of my data collection and a couple of days before I fell severely ill from what was deemed to be a parasitic infection from contaminated food or water. In Chapter 3 of this thesis, I discuss how there is a continuum of perceptions on water contamination and illness throughout the community. My own experience with sickness during data collection might be an important point of reflection and reflexivity through which results and data have been presented and analyzed.

Chapter 2: Research Methods

2.1 Research Approach, Partnerships, Methodology, and Study Design

This research study employed a Community-Engaged Research (CEnR) approach emphasizing collaboration and partnership with community stakeholders throughout the research process (Anderson & Cidro, 2019; Dodd et al., 2023; McMaughan et al., 2021; Strand et al., 2003). As such, a variety of community stakeholders were involved, including:

- Community members from Tojchoc Grande: local residents who actively participated in the research process, providing valuable insights, perspectives, and lived experiences related to the research topic.
- Members of a local agroecological network in Tojchoc Grande known in Spanish as Red de Productores y Promotores Agroecologicos del Departamento de San Marcos (RED-PPAS): this network comprises individuals and groups dedicated to promoting agroecological practices and sustainable agriculture in the department of San Marcos. Their expertise and knowledge were instrumental in shaping the research agenda and informing data collection and analysis.
- A non-governmental organization (NGO) partner, Pastoral de La Tierra San Marcos (PTSM): PTSM is a community-based organization that works in San Marcos, Guatemala, supporting the uptake of agroecological practices and facilitating social organizing activities. As a local partner, PTSM provided logistical support, facilitated community engagement, and helped ensure the research aligns with local priorities and needs.
- Mennonite Central Committee's Guatemala-El Salvador Office (MCC): MCC is a multinational NGO that provides accompaniment, financial support, development assistance, and peacebuilding initiatives to local organizations worldwide, including PTSM. As a funding and capacity-building partner, MCC played a crucial role in supporting the research project, enabling the implementation of activities and fostering collaboration among stakeholders.

In adhering to CEnR principles, partners have played integral roles in shaping the research endeavor and processes(McMaughan et al., 2021; Strand et al., 2003). Their input spanned various aspects of the research, including the overall methodology, research objectives, and data collection tools (McMaughan et al., 2021; Strand et al., 2003).

The research partnership began in 2021 when members of PTSM approached MCC with an interest of implementing a research project to better understanding themes of food, water, migration, and health experienced by their partner communities in San Marcos. Previous collaboration between MCC and Dr. Dodd led to connections between PTSM and our research team at the University of Waterloo (inclusive of Dr. Dodd, Dr. Laird, Dr. Brubacher, E. Kocsis, and myself).

I have been a key collaborator within this research team along with a PhD candidate (E. Kocsis) and MCC's evaluation and monitoring coordinator (S. Wyngaarden) since the beginning of 2022 in establishing the research partnership by participating in planning meetings, corresponding with PTSM staff, and participating in community meetings. During July 2022, myself, E. Kocsis, S. Wyngaarden, travelled to San Marcos to meet with PTSM staff. Here members of PTSM expressed interest in conducting environmental monitoring work related to contamination in the community of La Blanca, San Marcos, where the presence of agribusiness and monocrop plantations has led to community concerns of contamination of water sources (Hellin et al., 2017; Lopez-Ridaura et al., 2019). However, due to a variety of logistical and time constraints, this project was postponed, as it was determined to not be feasible for the scope of my master's thesis research. Additional community engagement meetings were conducted by E. Kocsis and S. Wyngaarden in November 2022 in Tojchoc Grande. During these meetings the RED-PPAS network and PTSM staff identified Tojchoc Grande as a potential study location due to the abundance of water, presence of agroecological practices, and because the community had high levels of out-migration which shaped rural livelihoods and dynamics (Hellin et al., 2017; Lopez-Ridaura et al., 2019). Further discussions and meetings took place and all partners agreed on the suitability of initiating a water, food, and health project through my master's thesis work

and the doctoral work of E. Kocsis in Tojchoc Grande. My research and this thesis focuses on the water components of this community-engaged collaborative research project.

By actively engaging with these partners, I sought to co-create knowledge that was relevant and meaningful to the communities and partners involved (Anderson & Cidro, 2019; McMaughan et al., 2021; Mikesell et al., 2013; Strand et al., 2003). Through ongoing dialogue and collaboration, the CEnR approach facilitated the integration of diverse perspectives, ensuring that the research design and methodology resonated with the needs, interests, and priorities of community partners (Anderson & Cidro, 2019; McMaughan et al., 2021; Mikesell et al., 2013). It should be noted that a CEnR was chosen in part given PTSM's hope of having a researcher driven project. Notably, Guatemalan organizations, including NGOs like PTSM are often overburdened and face challenges in engaging with Guatemalan academic institutions due to limited funding and inadequate state support for research initiatives (Anderson & Cidro, 2019; Gershberg et al., 2009; Israel et al., 1998; McMaughan et al., 2021; Mikesell et al., 2013; Strand et al., 2003). Consequently, my collaboration and engagement with PTSM leveraged my research experiences and abilities, as well as the University of Waterloo research team's resources to design and implement the research study. Practically, this meant that data collection tools were developed, and funding was secured by the University of Waterloo research team. Through this researcher-driven approach, I aimed to bridge the gap between academic research and community research priorities, fostering meaningful collaboration and knowledge exchange to address pressing water and health issues in Tojchoc Grande.

Based on consultations and discussions with community members, a qualitative intrinsic case study methodology was chosen to explore water and health issues in Tojchoc Grande (Bowleg, 2017; Brown & Duenas, 2020; Patterson & Williams, 1998). Recognizing the significance of these issues to the community, the intrinsic case study approach was deemed appropriate for its ability to provide in-depth insights and understanding of the context-specific factors influencing water and health dynamics in the community (Baxter & Jack, 2008; Crowe et al., 2011). Intrinsic case study methodology focuses on a single case for its

own sake and uniqueness, allowing for a deep exploration of the complexities and nuances of the phenomenon under study (Baxter & Jack, 2008; Crowe et al., 2011). Unlike instrumental or collective case studies, which aim for cases that are "typical" of other cases or comparison across cases, an intrinsic case study can provide a rich, detailed description of a particular phenomenon in a unique context (Baxter & Jack, 2008; Crowe et al., 2011). This methodology was ideal to meet the study objectives for a number of reasons. First, case study methodology is well suited for the descriptive nature of this research (Baxter & Jack, 2008; Crowe et al., 2011). As one of the main study objectives was to characterize water and health issues, case study methodology was deemed appropriate (Baxter & Jack, 2008; Brown & Duenas, 2020; Crowe et al., 2011). Secondly, a case study approach can facilitate an understanding of different perceptions of meanings, contexts, and processes of actors within community settings, aligning with the other main objective of understanding how experiences of water and health are differentially experienced among diverse local system actors (Baxter & Jack, 2008; Crowe et al., 2011). Lastly, the case study methodology aligns closely with the interests and priorities of our community partners, who have expressed a keen interest in studying a specific phenomenon (i.e., water and health) in one specific community for its uniqueness (i.e., relatively high levels of access to water resources and highly developed agroecological network) in contrast to other communities in the region.

2.2 Data collection, procedures, and sources

Data collection involved observations, field notes, photos, and semi-structured interviews conducted across two phases in Tojchoc Grande (Crowe et al., 2011; Phillippi & Lauderdale, 2018; Ponelis, 2015; Watts, 2011; Youngs & Piggot-Irvine, 2012). The first phase of data collection was exploratory in nature as I had limited knowledge of the water and health issues in the community (Crowe et al., 2011). Additionally, this phase aimed to gain a comprehensive understanding of the community dynamics and the local water system. Building upon the insights I gained from the first phase, the second phase of data collection was more intentional, focusing on addressing the second research objective with respect to understanding different actor perspectives in the community (Crowe et al., 2011; Phillippi &

Lauderdale, 2018; Ponelis, 2015; Watts, 2011; Youngs & Piggot-Irvine, 2012). Consequently, I used purposive sampling to conduct interviews with specific actor groups during the second phase (Cohen et al., 2007; Rai & Thapa, 2015; Tongco, 2007). I also aimed to triangulate and further elaborate on the findings from the first phase, providing a more comprehensive understanding of how water and health issues are perceived by different actors in the community (Warren & Karner, 2010; Youngs & Piggot-Irvine, 2012).

Data collection was primarily conducted in the community of Tojchoc Grande. Data collection procedures for this study involved the development of two qualitative interview guides tailored for each objective (Turner, 2010; Warren & Karner, 2010). The interview guides aimed to facilitate open and in-depth discussions while allowing flexibility for participants to share their perspectives and experiences (Turner, 2010; Warren & Karner, 2010). The first interview guide consisted of questions relating to participant background information and open-ended questions on various dimensions of water and health (Turner, 2010; Warren & Karner, 2010). Interview guide questions were separated by domains (Penn et al., 2017). These domains included questions relating to water and health issues with respect to environmental, sanitation and hygiene, infrastructure, and socio-economic factors initially informed by water-health, socio-hydrological, and water security research (Haeffner et al., 2018; Hale et al., 2015; Penn et al., 2017) (Appendix 1). Following preliminary analysis, which involved listening to interview recordings, transcript processing (i.e., formatting and reading of transcripts along with analytic memos), as well as discussions surrounding impressions, codes, and patterns with team members, an updated interview guide was created for the second phase of data collection (Saldaña, 2021). The second interview guide focused on adding questions to understand water-health dynamics among different actor groups (Appendix 2). Questions from the first interview guide were retained in the second phase of data collection to triangulate and elaborate on data between phases (Turner, 2010; Warren & Karner, 2010).

The interview guide was developed collaboratively with input from community partners, including Tojchoc Grande community members, RED-PPAS, and PTSM (Strand et al.,

2003). This collaborative approach ensured that the interview questions were culturally sensitive, contextually relevant, and aligned with the research interests and needs of community partners (Strand et al., 2003). Feedback was also provided from research team members including Dr. Dodd, Dr. Laird, Dr. Brubacher, and E. Kocsis. The research team engaged in an iterative process, reflecting on new insights gained during data collection and modifying the interview guide accordingly. This iterative approach ensured that the interview guide remained responsive to the community context and ensured that the questions would be relevant for addressing the study's research objectives.

Semi-structured interviews served as the primary method for data collection (Turner, 2010; Warren & Karner, 2010). This approach allowed for the exploration predefined topics while also enabling participants to express their thoughts and experiences freely (Clarke, 2006; Cohen et al., 2007; Turner, 2010). Techniques such as active listening, probing, and clarification were employed during interviews to ensure a rich and comprehensive understanding of participants' viewpoints (Jepson et al., 2015; Lehoux et al., 2006). The semi-structured nature of the interviews allowed for the generation of unexpected themes and insights, contributing to the depth of the data collected (Jepson et al., 2015; Lehoux et al., 2006). The semi-structured questions provided a framework for data collection across interviews, but also permitted the flexibility to probe emerging topics and ask follow-up questions of participants (Cohen et al., 2007; Jepson et al., 2015; Lehoux et al., 2006; Turner, 2010), and enabled participants to share their experiences through narratives, descriptions, and explanations (Turner, 2010).

Sampling procedures were designed to ensure representation of diverse perspectives and experiences (Hennink et al., 2017; Warren & Karner, 2010). More specifically, I used a purposive sampling approach to select participants who could provide valuable insights into the water and health issues in Tojchoc Grande (Rai & Thapa, 2015; Tongco, 2007). During the first phase of data collection, participants were purposively sampled from a list of community members who were members of the RED-PPAS agricultural network and who had access to water resources for domestic and agricultural use. During the second phase of

data collection, participants were purposively sampled according to their role as water managers and health workers. I also made an effort to include individuals from different demographic groups, geographic locations, occupations, and actor groups that were not interviewed during the first phase of data collection to capture diverse viewpoints within Tojchoc Grande. Additionally, snowball sampling was used to identify potential participants through referrals from initial interviewees, further enriching the diversity of the sample (Naderifar et al., 2017; Parker et al., 2019). Data saturation was sought based on interviewing specific people that could speak on topics from a specific viewpoint (Braun & Clarke, 2019b; Hennink et al., 2017; Naderifar et al., 2017; Nelson, 2016; Sebele-Mpofu & Serpa, 2020). For example, since Tojchoc Grande is divided into 10 different sectors, saturation was deemed to be achieved when at least one community member and one water manager from each sector was interviewed. Similarly, as there were only four health workers in the community, saturation was achieved from this sub-group because all health workers were interviewed at least once.

Obtaining informed consent was an essential aspect of the data collection process (Brounéus, 2011; Cohen et al., 2007; Tong et al., 2007). Prior to conducting interviews, I provided participants with detailed information about the study objectives, procedures, and their rights as participants (Arifin, 2018; Brounéus, 2011). All participants were assured of the confidentiality of their responses and were given the opportunity to ask questions or seek clarification and to opt out at any point of the study (Arifin, 2018; Brounéus, 2011; Tong et al., 2007). Written consent was obtained from all participants, and verbal consent was reaffirmed at the beginning of each interview session (Arifin, 2018; Brounéus, 2011; Tong et al., 2007). For participants who may have had limited literacy, verbal explanations of the consent form were provided and verbal consent was accepted to indicate consent (Arifin, 2018; Brounéus, 2011).

2.2.1 Data Collection Phase 1 (May 2023 – June 2023)

During Phase 1 of data collection, the primary objective was to conduct exploratory data collection to gain insights into water systems and resources and the relevant water-health

issues for community members. This phase began with E. Kocsis and I travelling to San Marcos, where meetings were held with PTSM staff to discuss and refine the interview guides. The time in San Marcos also included training sessions with a local research assistant (M. Roblero) from Tojchoc Grande. These training sessions focused on interview techniques and the testing and refinement of the interview guide (Jepson et al., 2015; Lehoux et al., 2006). These training sessions were also intended to familiarize M. Roblero with the research objectives, interview protocols, and ethical considerations of the study. Additionally, these training sessions allowed for M. Roblero to provide input and local perspectives on the data collection tools (Strand et al., 2003). This process provided valuable insights into how the questions might be perceived and their relevance to the community, enhancing the overall quality of the data collection process.

Following the preparation and meetings in San Marcos, myself, E. Kocsis, and M. Roblero traveled to the community of Tojchoc Grande and spent approximately one month there for data collection. During this phase of data collection M. Roblero, who also served as a community guide, played a pivotal role in participant recruitment, leveraging her networks within the community to identify and engage potential participants. Participants were initially recruited purposively, leveraging contacts from Magnolia's network and individuals associated with the RED-PPAS network.

The interview process, from recruitment to conducting interviews, was attuned to the context of the community. In consultation with the M. Roblero, Dr. Dodd and E. Kocsis, we collectively decided that it would be best to conduct interviews collaboratively (with E. Kocsis, M. Roblero, and myself) to increase our familiarity with the community, to facilitate peer debriefing following interviews, and to coordinate logistics (e.g., transportation to the homes of participants living in remote areas). E. Kocsis and M. Roblero conducted the first half of interviews related to questions focused on E. Kocsis’s doctoral thesis research interview guide relating to agroecology, migration, and food/agriculture. After these questions were completed, I conducted the second half of interviews which contained my questions relating to water and health.

Interviews were conducted in various locations, including fields, participants' homes, and at the local school, based on convenience and availability of participants (Strand et al., 2003). The length of interviews lasted between 15 minutes to one hour and 30 minutes. Audio recordings of interviews were recorded on mobile devices (i.e., cellphones and audio recorders) unless participants did not consent to being recorded (Warren & Karner, 2010) . Group interviews were also conducted at times since many family members would drop-in during interviews and express interest in the research topics (Warren & Karner, 2010). For family members that would drop-in, they were given the option to join-in the interview or to be interviewed separately, based on the preference of the person who was initially interviewed and in an attempt to be inclusive of interested community members (Warren & Karner, 2010).

A total of 25 interviews were conducted during Phase 1, predominantly with small-scale farmers and a roughly equal number of men and women were interviewed. Approximately half of interviewees were members of the RED-PPAS network with access to water resources through potable or irrigation systems. Other participants included community residents involved as teachers, homemakers, and laborers. Toward the end of Phase 1, as the community water administration structures were clarified, I had the opportunity to interview two water managers of some of the local water committees. These interviews generated important data on concerns related to waterborne illnesses not previously expressed, which informed, in part, the data collection tools (i.e., Phase 2 semi-structured interview guide) and objective for Phase 2.

2.2.2 Data Collection Phase 2 (October 2023 – December 2023)

Following preliminary data analysis, discussion with team members (including E. Kocsis and Dr. Dodd), and thesis committee members, the aims of the second phase of data collection were developed (Braun & Clarke, 2012; Saldaña, 2021). The second phase aimed to delve deeper into water-health issues and how they were experienced and perceived among different actor groups. As such, the interview guide was updated to include questions relating to community roles within water systems (Appendix 2) (Warren & Karner, 2010). As with

Phase 1, the interview guide underwent iterative refinement based on feedback from the University of Waterloo research team and community members.

During Phase 2, I spent approximately six weeks in Tojchoc Grande. A similar process was followed as in Phase 1, with some time spent in San Marcos for discussion and meetings with PTSM staff. Importantly, two interviews were conducted with two members of PTSM staff who had worked closely in developing the local agroecological programs and networks in Tojchoc. These interviews were important for context building and provided insight into the history of agricultural programs and water systems in the community.

Phase 2 prioritized interviewing water managers from different water committees throughout the community, local health workers, and community members lacking potable or irrigation water access. 24 interviews were conducted, lasting between 30 minutes to one hour and 30 minutes. Approximately two thirds of interviews were conducted with men and one third of interviews conducted with women. During Phase 2, thematic divergence between my work and E. Kocsis's work became pronounced. Having developed deeper relationships and trust within the community, it was decided that the majority of interviews during this phase would be conducted independently. However, due to time constraints, scheduling conflicts, or for pragmatic reasons, joint interviews were occasionally necessary between myself, E. Kocsis, and M. Roblero similar to those conducted during Phase 1.

2.3 Data Analysis

The data analysis in this study was conducted in two phases to align with the multi-phase data collection approach. Initially, I undertook a preliminary review and coding of data gathered during the first phase of data collection, concurrently maintaining analytic memos as I reviewed the transcripts. Subsequently, I collaborated with E. Kocsis to review the codes and memos, identifying patterns and topics that warranted further exploration. Summaries from this review, along with identified data gaps, were then discussed upon with Dr. Dodd, Dr. Laird, and members of the thesis committee, including Dr. Little and Dr. Neufeld during my thesis proposal defense. Their input and the review with E. Kocsis shaped the design and

focus of the second phase of data collection and guided the final analysis (Saldaña, 2021; Turner, 2010). Following the second phase of data collection, all data, including transcripts and notes from both phases, were collated for analysis.

As the overall research methodology and research objectives were primarily exploratory and descriptive in nature, thematic analysis was deemed an appropriate analytic method since it allowed for understanding of themes and topics that were previously unknown to me (Braun & Clarke, 2006, 2012, 2014, 2019a; Brown & Duenas, 2020; Byrne, 2022; Saldaña, 2021). An inductive thematic analysis approach was employed using the steps described below, focusing on identifying recurring patterns and developing themes across interview transcripts (Braun & Clarke, 2012, 2014; Saldaña, 2021). The thematic analysis process outlined below was informed by work conducted by Braune and Clarke and other scholars (Braun & Clarke, 2014, 2019a; Byrne, 2022; Saldaña, 2021). Importantly, I recognize that my own experiences and subjectivities necessarily affect the way I analyze data, code, and generate themes, and ultimately decide what data is of interest and should be elaborated on (Braun & Clarke, 2019a; Coulter et al., 2020). In recognition of my potential biases, I took a reflexive approach during analysis by keeping analytic memos as to why decisions were made and to document my thinking process as well as discussing codes and themes with team members (i.e., Dr. Dodd, E. Kocsis, Dr. Brubacher) to review my interpretation of data (Braun & Clarke, 2019a).

2.3.1 Step 1: Familiarization with data and initial analysis

The data analysis began with a process of familiarizing and immersing myself with the data that had been collected. Verbatim transcripts from audio recordings were generated using Sonix transcription software. The process of manually editing and formatting transcripts (i.e., clarifying speakers, correcting errors) into word documents allowed for an initial familiarization of the data. Once all transcripts were edited, I began a process of reading and re-reading the interview transcripts and listening to recordings of the interviews to gain a deep familiarity of the content and context for each interview, referring to field notes and photographs collected when needed (Braun & Clarke, 2012; Saldaña, 2021; Warren &

Karner, 2010). Through this process, I familiarized myself with the nuances of participants' responses, and began identifying key topics and patterns (Braun & Clarke, 2012; Saldaña, 2021; Warren & Karner, 2010). Additionally, memo notes were created on transcript margins containing my own thinking process, ideas, and impressions of the transcript texts (Braun & Clarke, 2012; Saldaña, 2021; Warren & Karner, 2010). All transcripts were read at least once before beginning formal coding to generate ideas and patterns from the data (Braun & Clarke, 2012; Saldaña, 2021; Warren & Karner, 2010).

2.3.2 Step 2: Generating initial codes

Following the familiarization process I proceeded to generate initial codes through an open coding process. The coding process involved going through the transcripts line by line and organizing and labelling segments that could be assessed in a meaningful way (Braun & Clarke, 2012; Saldaña, 2021; Warren & Karner, 2010). For example, when participants were talking about water issues with respect to contamination, a code like “water quality” was applied to the relevant text segment. Coding was primarily data-driven and the entire data set was coded. As suggested by Braun and Clarke, as many codes for patterns were generated as possible and codes were created manually by highlighting the segment and labelling the code (Braun & Clarke, 2012; Saldaña, 2021; Warren & Karner, 2010). After the open coding process, an organization process was conducted. This process involved putting all codes (and their segments) into a word document in order to clarify redundancies and merge codes where appropriate.

2.3.3 Step 3: Generating themes

Once all data had been initially coded and collated, this process resulted in a long list of different codes identified across the dataset. Then, I shifted my focus of analysis to broader themes rather than individual codes, which involved sorting the codes into potential themes and compiling all relevant coded data extracts within these identified themes (Braun & Clarke, 2006; Saldaña, 2021; Warren & Karner, 2010). I began to analyze the codes and consider how they might combine under a broader theme. During this phase, I started to

contemplate the relationships between codes, themes, and different levels of themes, such as main overarching themes and sub-themes within them, making note of these relationships in analytic memos. Some initial codes evolved into main themes, while others formed sub-themes, and some were discarded altogether.

2.3.4 Step 4: Reviewing themes

To refine a set of candidate themes, I discerned that some candidate themes may not truly represent themes due to insufficient supporting data or excessive diversity within the data (Braun & Clarke, 2006; Saldaña, 2021; Warren & Karner, 2010). Additionally, I found that seemingly distinct themes could merge into one, or vice versa, and used criteria of internal homogeneity and external heterogeneity (Braun & Clarke, 2006; Patton, 1990). This entailed ensuring that themes exhibited meaningful coherence within the data while also maintaining clear distinctions between them. Internal homogeneity ensured that each theme represented a cohesive and focused aspect of the data, while external heterogeneity guaranteed that themes remained distinct from one another, capturing unique patterns or dimensions within the dataset. This phase comprised two levels of reviewing and refining themes. At the first level, I reviewed all collated extracts for each theme to assess whether they formed a coherent pattern. If candidate themes demonstrated coherence, I proceeded to the next level. Otherwise, I re-evaluated the problematic theme or considered relocating data extracts to existing themes or discarding them from the analysis. Once I was satisfied with the candidate themes' representation of the coded data, I evaluated the validity of individual themes relative to the entire dataset as a whole. Next, I re-read the entire dataset to ensure themes aligned with the data and identified any missed data for coding within themes (Braun & Clarke, 2006; Saldaña, 2021; Warren & Karner, 2010). Recoding from the dataset was common as coding was an ongoing process. If the theme list aligned well with the dataset, I proceeded to the next phase. However, if discrepancies arose, I returned to further review and refine coding until a satisfactory list of themes was achieved. I was cautious not to engage in endless recoding and stopped refining when adjustments no longer added substantial insights.

By the end of this phase, I had a clear understanding of my themes, their interrelationships, and the overarching narrative they conveyed about the data.

2.3.5 Step 5: Defining and naming themes

Once I had a satisfactory theme list of my data, I proceeded to define and further refine the themes that I would present as results for the (Braun & Clarke, 2006; Saldaña, 2021; Warren & Karner, 2010)**.** Here, I ensured to avoid overcomplicating themes with too much content or make them overly diverse and complex. I revisited collated data extracts for each theme and organized these extracts into a coherent and internally consistent account. As part of the refinement process, I identified whether a theme contained any sub-themes. Sub-themes acted as themes-within-a-theme, providing structure to overarching themes and demonstrating the hierarchy of meaning within the data.

For example, in the analysis, one overarching theme related to the continuum of perspectives of proximal water-health pathways. This overarching theme contained several sub themes relating to “location and access” of water sources, in addition to “sanitation and hygiene”. However, these final themes and sub-themes resulted from a process of refinement of initial ones. By the end of this phase, I could clearly define what each theme encompassed. I used analytic memos to maintain an audit trail to document the coding process and the rationale behind theme development. In addition, regular discussions within the University of Waterloo research team helped to mitigate bias and enhance the validity of interpretations (Braun & Clarke, 2006; Warren & Karner, 2010).

2.3.6 Step 6: Theme categorization and manuscript preparation

After developing and reviewing the major themes, a challenge I faced related to managing the complexity and seemingly diffuse nature of some of the participant responses and themes. For example, while many participants highlighted the connections between migration or poverty and water, the impact of these issues seemed more indirectly related to health outcomes in contrast to other themes such as those related to water contamination or water administration. This complexity created a challenge in adequately framing the relative

importance of different themes in terms of water-health challenges. I brought this challenge up with team members including Dr. Dodd who directed me to a three-level environmental-health framework which could help me manage and organize this complexity. Following a literature review of three-level framework and other commonly used water-health frameworks, I decided that the three-level framework was most appropriate because it addressed not only proximal water-health pathways, but also intermediate and distal water-health pathways relevant to the study results. In addition, the three-level framework was chosen for its flexibility to incorporate diverse water-health pathways compared to other frameworks with more strictly defined pathways (see section 1.2).

Once I had a set of fully worked-out themes, I worked toward writing up the analysis. The write-up of the analysis, including data extracts, provided an account of the story conveyed by the data within and across themes in a manuscript to be submitted to a scientific journal. The overall narrative presented moved beyond a description of the data and made arguments in relation to the research objectives. Special attention was given to discerning divergence and congruence in themes across transcripts from the two phases of data collection and exploring variations among participants and groups based on factors such as occupation, geographic location, and actor group. This approach allowed for a nuanced understanding of the water-health pathways experienced by different community actors.

2.3.7 Results categorization

Following the thematic analysis, an adapted three-level framework was used to categorize and organize themes to facilitate comparison among actor groups and to highlight key differences in the levels and scales of major themes and sub-themes. Originally developed to elucidate different health risk pathways associated with climate change, the three levels of the framework provided a foundation for categorizing water-health risk pathways. In the framework's initial use, proximal pathways included direct biological and physical consequences of climate change and health, like injuries from extreme weather events; intermediate level changes involved changes to systems and processes like infectious diseases (e.g., dengue, Zika virus) spreading geographically as tropical climates expand to

temperate latitudes; and distal level pathways related to indirect impacts like increasing mental health issues in farming communities from climate anxiety (Butler & Harley, 2010; McMichael, 2013). The framework's primary goal was to illustrate how some health outcomes stemming from environmental or climatic pathways are often shaped by increasingly broad, indirect, and complex factors (Butler & Harley, 2010; McMichael, 2013). To date, there is limited research that adapts this three-level framework to specifically categorize water-health pathways. Thus, a challenge I experienced in adapting this framework was maintaining congruence with previous applications of the framework, while also expanding the levels and categorizes so that the themes identified through my analysis could be categorized at different levels of the framework.

To adapt the three-level framework to conceptualize the water-health pathways identified through this study, the original definition of the various levels of the framework were maintained. More specifically, proximal pathways included direct biological consequences of water (i.e., dehydration), intermediate pathways included risks mediated by changes in biophysical and ecology-based systems and processes (i.e., water flows), and distal pathways included broader structural and societal dynamics such as poverty and migration. With these foundational definitions, I reviewed different applications of the three-level framework as well as the broader water-health literature to examine how other studies have defined or categorized water-health pathways. For example, while the original three-level framework did not include sanitation or hygiene at any level of the framework, many water-health studies have focused on the proximal role of sanitation and hygiene in shaping water-health outcomes. Thus, sanitation and hygiene were included as proximal water-health pathways shaping health outcomes within the adapted framework I included in this study.

2.3.8 Framework adaptation

Following the thematic analysis, an adapted three-level framework was used to categorize and organize themes to facilitate comparison among actor groups and to highlight key differences in the levels and scales of major themes and sub-themes. In the framework's initial inception proximal pathways included direct biological and physical consequences of

climate change and health, like injuries from extreme weather events; intermediate level changes involved changes to systems and processes like infectious diseases (e.g., dengue and Zika virus) spreading geographically as tropical climates expand to temperate latitudes; distal level pathways related to indirect impacts like increasing mental health issues in farming communities from climate anxiety (Butler & Harley, 2010; McMichael, 2013). The framework's primary goal was illustrating how not all health impacts from environmental or climatic pathways are easily identifiable and are often shaped by increasingly broad, indirect, and complex factors, with each level of the framework containing increasing the complexity of the health pathway. However, since its inception the framework has proliferated and been used to conceptualize different levels and types of environment-health pathways, not just those related to climate change.

To date, there has not been a study adapting this framework to specifically categorize water-health pathways. Instead, all other applications of this framework have categorized either climate- or other environmental-health pathways. And so a challenge in adapting framework was maintaining agreement with previous applications while also expanding the levels and categorizes so that the themes generated could be categorized at different levels of the pathway

The process for adapting this framework was as follows. Firstly, the original definitions from McMichael's and Butler's formulation were kept. Such that proximal pathways included direct biological consequences of water (i.e., dehydration), intermediate pathways included risks mediated by changes in biophysically and ecology-based systems and processes (i.e., water flows), distal pathways included broad consequences related to things like socioeconomics. Secondly, a review of different applications of this framework and water health literature was conducted to see how other studies have defined or categorized water-health pathways. For example, while McMichael and Butler did not include sanitation or hygiene under any of the pathways, many other studies have defined these as proximally located in relation to health and wellbeing outcomes and so were included under proximal pathways (Butler & Harley, 2010; Grigg, 2018; McMichael, 2013) .

2.4 Research ethics and funding

Ethics approvals were obtained from the Research Ethics Boards of the University of Waterloo (REB #45058) and from the research office of Mennonite Central Committee. Funding across the research phases were provided by the Social Sciences and Humanities Research Council (SSHRC) through a Joseph-Armand Bombardier Canadian Graduate Scholarship (SSHRC-CGS), and a Michael Smith Foreign Study Supplement, and from the University of Waterloo through an International Experience Award and a Global Health Policy and Innovation Research Centre Graduate Research Award.

2.5 Language considerations

All data gathered for this study were obtained in Spanish, while the research findings are presented in English. Decisions regarding the translation of data were guided by existing literature on inter-lingual research (Jentsch, 1998; Kosny et al., 2014; H.J. Smith et al., 2008; van Nes et al., 2010). Following recommendations from these scholars, the original language of the data was retained throughout the analysis process to ensure the accuracy and validity of interpretation (van Nes et al., 2010). Interview recordings were transcribed using software equipped with Spanish capabilities (e.g., Sonix). The codebook was primarily developed in English; however, if the translation of a key word or phrase in a data-driven code obscured its distinct meaning, the Spanish wording was preserved (H. J. Smith et al., 2008). The coding process was conducted using the Spanish transcripts, and thematic analyses were carried out with continuous reference to the original Spanish quotations. Key quotations were translated into English for inclusion in the manuscripts. Given the thematic approach to analysis, conceptually-equivalent translation strategies were deemed appropriate rather than literal translations (H. J. Smith et al., 2008).

Chapter 3 - Characterizing water-health pathways and perceptions among diverse system actors in a rural Western Highlands community of Guatemala

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3.1 Introduction

Rural populations in Latin America and the Caribbean are disproportionately vulnerable to water-related health risks due to their dependence on water for livelihoods and food security (Brown et al., 2013; Calow et al., 2006; Gordon et al., 2023; International Labour Organization, 2019; Mabhaudhi et al., 2016; Mekonnen et al., 2015; Reyer et al., 2017; Sullivan et al., 2010). These risks arise from a combination of factors, including difficulty delivering water across mountainous terrains, low institutional support for water systems, and socio-economic challenges like poverty that shape the quality, quantity, accessibility, and availability of water resources (Akhmouch, 2012; Furgal, 2002; Mekonnen et al., 2015). Consequently, negative health outcomes such as water-borne illnesses, dehydration, malnutrition, and poor social wellbeing are prevalent in rural areas (Calow et al., 2006; International Labour Organization, 2019; Sullivan et al., 2010). For instance, in Latin America and the Caribbean, over 12% of the rural population lacks basic drinking-water services, while more than 30% lack access to water sanitation or hygiene services (Fewtrell et al., 2005; Reyer et al., 2017). The health impacts of these water-health challenges are particularly prominent among children under five years of age, who experience a disproportionate burden of waterborne diseases, malnutrition, and death from diarrheal diseases (Gordon et al., 2023; Morris et al., 2017; Trudeau et al., 2018; Vásquez & Aksan, 2015; Walls & McGarvey, 2023).

Importantly, the health outcomes experienced by rural communities in Latin America resulting from inadequate water quality, quantity, and availability are influenced by proximal, intermediate, and distal pathways (Akhmouch, 2012; Calow et al., 2006; Cheatham et al., 2022; International Labour Organization, 2019; Luby et al., 2008; Mekonnen et al., 2015; Trudeau et al., 2018; Vásquez, 2013). Proximal pathways include direct water-health outcomes such as water-borne illnesses, undernutrition, food insecurity from challenges related to biophysical characteristics (e.g., geography, weather, climate), and sanitation and hygiene (Bopp et al., 2024; Grigg, 2018; Paudel et al., 2021; Schuster-Wallace & Dickson, 2017). In contrast, intermediate and distal pathways are more complex, and encompass health outcomes such as food insecurity and poor social wellbeing (e.g., conflict) from disturbances or changes in ecological processes or systems (Cook & Bakker, 2012; Grigg, 2018; McMichael, 2013; Paudel et al., 2021). Population growth, for instance, represents a change in ecological systems that can increase local water demands, and contribute to higher water withdrawals, subsequently increasing risks to food security (Falkenmark, 1990; Gentry-Shields & Bartram, 2014; Mahlknecht et al., 2020). Distal pathways refer to the negative health outcomes that arise from broader socio-economic and institutional conditions (Cook & Bakker, 2012; Garrick & Hall, 2014; Paudel et al., 2021). While proximal water-health pathways such as hydrological characteristics or sanitation and hygiene challenges have been well documented in Latin America, less attention has been given to examining intermediate and distal pathways influencing water-health outcomes such as ecological disturbances or institutional conditions (Akhmouch, 2012; Brown et al., 2013; Cheatham et al., 2022; Gentry-Shields & Bartram, 2014; Gordon et al., 2023; Grigg, 2018; Mahlknecht et al., 2020; Mekonnen et al., 2015; Paudel et al., 2021). Moreover, the studies that have investigated more distal water-health pathways often prioritized studying distal pathways at regional rather than local levels, contributing to a gap in understanding how water-health pathways are experienced and perceived by local community actors (Butler, 2024; Butler & Harley, 2010; Gentry-Shields & Bartram, 2014; Morris et al., 2017; Varis et al., 2017; Walls & McGarvey, 2023). Addressing these gaps requires the use of comprehensive frameworks that can capture the multi-faceted and multi-scalar nature of water-health pathways (Butler, 2024;

Morris et al., 2017; Walls & McGarvey, 2023). A promising approach to addressing this literature gap is the implementation of a three-level environment-health framework in a water-health context (Butler & Harley, 2010; McMichael, 2013; Walls & McGarvey, 2023). This framework delineates proximal, intermediate, and distal dimensions of water-related health impacts, providing a holistic understanding of the broad water pathways shaping health and wellbeing (McMichael, 2013; Morris et al., 2017; Walls & McGarvey, 2023). Additionally, this framework is well-suited to less-studied contexts due to its broad and flexible nature, allowing for the inclusion of diverse and context-specific factors and pathways (McMichael, 2013; Morris et al., 2017; Walls & McGarvey, 2023). By adopting such an approach, there is an opportunity to more deeply examine the ways in which water shapes health outcomes among diverse local system actors (Brown et al., 2013; Gentry-Shields & Bartram, 2014; Gordon et al., 2023; Grigg, 2018; Mara, 2003).

This study presents findings from a community-engaged study that aimed to characterize the proximal, intermediate, and distal water-health pathways impacting local actors in a Western Highlands community of Guatemala. This region, marked by mountainous terrain, grapples with significant water-related health challenges, exacerbated by historical and environmental factors (Hellin et al., 2017; Hoy & Belisle, 1984; Immink & Alarcon, 1993; Lopez-Ridaura et al., 2019). Following the Guatemalan civil war, decentralized natural resource management laws left rural communities dependent on locally led and managed water systems (Cheatham et al., 2022; Goldman et al., 2001; Luby et al., 2008; Trudeau et al., 2018; Vásquez, 2010; Vásquez & Aksan, 2015). These systems often struggle due to limited resources and infrastructure, leading to inadequate access to clean water and proper sanitation facilities (Falkenmark, 1990; Marcillo et al., 2020; Trudeau et al., 2018; Vásquez, 2010, 2013). Consequently, rural communities face heightened risks of waterborne illnesses and hygiene-related health issues (Trudeau et al., 2018; William F. Vásquez, 2010, 2013). Additionally, the Western Highlands are highly vulnerable to climate change impacts, including erratic rainfall patterns and prolonged droughts, further exacerbating water scarcity and health risks (Harvey et al., 2018; Ruano & Milan, 2014; Wade et al., 2022). In this context,

understanding the different water-health pathways experienced by local system actors is critical for informing effective interventions and policies to foster community wellbeing in this region (Garin et al., 2002; Lawless et al., 2015; Mardero et al., 2023; Morales et al., 2020; Schuster-Wallace & Dickson, 2017; Sobczak et al., 2013). Thus, the objectives of this study were 1) to characterize the proximal, intermediate, and distal water-health pathways; and 2) to examine how these health pathways are differentially perceived by diverse local system actors in the rural Western Highland community of Tojchoc Grande, Guatemala.

3.1.1 Study context

The community of Tojchoc Grande is located in the mountainous regions of San Marcos, Guatemala and primarily relies on groundwater springs situated within three micro-watersheds (Marini et al., 1998; Somers & McKenzie, 2020). These groundwater springs serve as the main water source for gravity-based distribution systems that supply water to households spread across ten sectors within the community. The accessibility and quantity of water provided to each household is dependent on its physical proximity to the water sources and distribution systems. Notably, most households across community sectors have access to potable water systems, but only some sectors have sufficient water quantity to support irrigation systems.

The community's water infrastructure is comprised of tubed water systems that deliver water directly to households and sprinkler systems from strategically positioned gravity-based distribution tanks. Two distribution systems transport potable and irrigation water separately to households. Tubed water infrastructure delivers potable water to system tanks designated for domestic purposes, such as drinking water and cleaning. For irrigation purposes, sprinklers connected by tubes to the water systems support agricultural activities. Additionally, some households, particularly those equipped with rainwater catchment systems, utilize alternative water sources during periods of scarcity or as supplementary resources for non-potable uses. Throughout the community, *pilas* or sink basins are ubiquitous and serve as crucial water storage units, with most households using them for everyday chores such as washing clothes. Moreover, the recent installation of a solar

powered water pump in the town center acts as the primary water source for households in the center sector.

Water administration in the community is overseen by community-based water committees for each water sector, comprising three to four members in the role of "water manager" (WM). Community members are elected to represent their respective sectors and serve as liaisons between community members and the broader water administration structures. The community's water management system operates on a decentralized model, with each sector having its own water committee responsible for overseeing water distribution and management. Water managers are responsible for the management, development, and maintenance of distribution systems within each water sector. Their duties include ensuring the upkeep of physical infrastructure, collecting payments, and facilitating the implementation of new infrastructure projects. Other participant roles important to the community and grouped in this study include farming and non-farming community members, and health workers. Farming community members (FCM) are those participants primarily involved in small-scale agriculture (predominantly of *milpa*, a crop system where corn, beans, and squash are farmed together); non-farming community members (NFCM) are those whose primary occupations include laborers, teachers, and homemakers; and health workers (HW) include nurses and those in local public health roles.

3.2 Methods

3.2.1 Research design

As part of an ongoing collaborative research project, the research design was guided by community-engaged research (CEnR) principles, emphasizing collaboration and partnership with community stakeholders throughout the research process. Community partners included the community members of Tojchoc Grande and local non-governmental organizations (NGOs) including Pastoral de la Tierra San Marcos (PTSM), Red de Productores y Promotores Agroecologicos del Departamento de San Marcos (RED-PPAS), and Mennonite

Central Committee's Guatemala-El Salvador Program (MCC). These partners provided input on study objectives, design, and data collection tools.

3.2.2 Data collection

Data were collected across two separate phases. During the first phase (May-June 2023), exploratory qualitative inquiry methods were employed to examine community dynamics and broad issues related to water and health. The second phase (October-December 2023) sought to better understand water-health pathways from the perspective of different water system actors. The data collection tools used for both phases included semi-structured interviews, observations, photos, and field notes. The interview guides for the interviews were developed iteratively in consultation with community partners.

During the first phase of data collection, participants were recruited purposively, leveraging the networks and contacts of the research team and community partners. The initial recruitment process primarily recruited individuals associated with the RED-PPAS network and consisted of community members engaged in small-scale agriculture. During the second phase of data collection, community members were recruited purposively based on their role in the community and a deliberate effort was made to recruit participants from actor groups not interviewed during the first phase. More specifically, non-farming community members, water managers from each community sector, and health workers were deliberately recruited during the second phase of data collection. Across both phases of data collection, 49 participants were interviewed for this study (see Figure 2 for breakdown of study participants across actor groups).

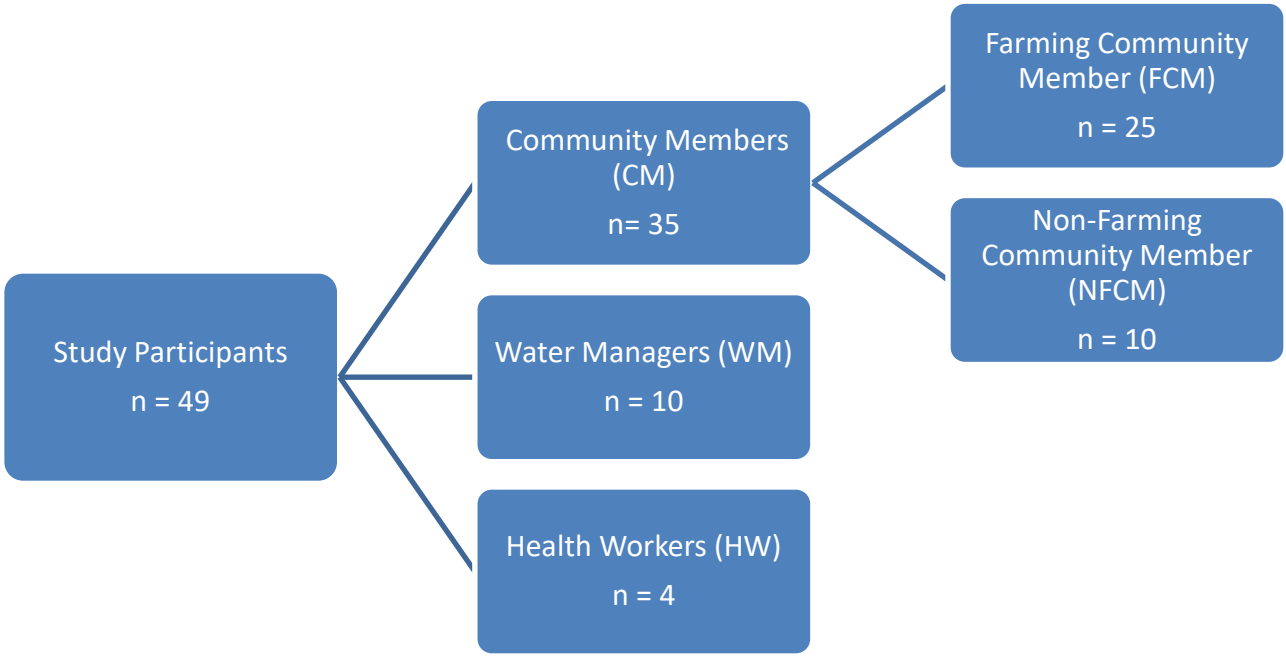

Figure 2. Breakdown of actor groups interviewed about water-health pathways in Tojchoc Grande, Guatemala (n=49)

3.2.3 Data analysis

Audio recordings from both phases of data collection were transcribed verbatim using Sonix transcription software. An inductive thematic analysis was conducted to analyze transcripts using similar steps previously outlined by Braun and Clarke (Braun & Clarke, 2014, 2019a, 2019b; Saldaña, 2021). This process involved familiarization with transcripts by reading and re-reading the entire transcript set and keeping analytic memos, line by line open coding of transcripts of significant patterns, generation of themes from codes, reviewing themes, and defining themes. Codes and themes were reviewed among team members to enhance rigor and validity of the coding process. Photos, field notes, and observations were referenced during analysis to fill information gaps and to provide context to the interview transcripts.

To further facilitate the analysis of the developed themes, an adapted three-level water-health framework, inclusive of proximal, intermediate, and distal water-health pathways, was used to categorize major themes as depicted in Figure 3 below. Proximal water-health pathways encompass the most direct consequences for health and wellbeing from water issues including those related to biophysical factors, weather patterns, climate, water infrastructure. Intermediate water-health pathways include those risks mediated by changes in ecological, and system-based processes such as population growth. Distal pathways include broader health and wellbeing outcomes related to socio-economic (e.g., poverty) and institutional factors (e.g., state-absence).

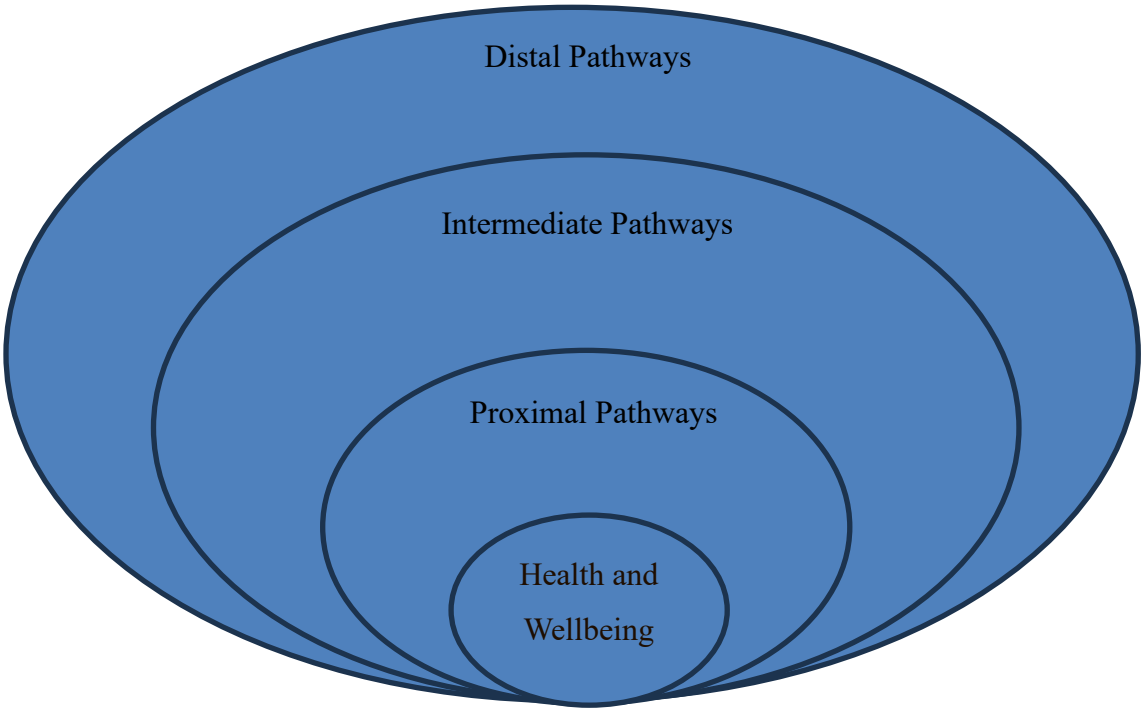

Figure 3. Three-level water-health framework overview

3.2.4 Ethical considerations

Ethics approvals were obtained from the relevant research ethics boards including the University of Waterloo's Human Research Ethics Board (REB #45058) and MCC's Research Ethics Board prior to commencing data collection activities. Informed consent was obtained

from all participants prior to data collection, and measures were taken to maintain participant confidentiality.

3.3 Results

3.3.1 Proximal water-health pathways

3.3.1.1 Biophysical factors as determinants of water-health pathways

All actor groups identified biophysical factors such as geographic location relative to water infrastructure, weather patterns, and climatic variability as primary determinants of health with respect to water quantity and availability. Importantly, these issues were discussed most frequently by community members. The types of concerns over water quantity and availability expressed by community members depended on their proximity and degree of connectedness to the community water systems and their engagement with agriculture.

Community members who had access to at least one of the potable or irrigation water systems generally viewed community water resources as abundant for personal uses (i.e., cooking, cleaning, bathing) and for sustaining agriculture, noting how water resources were readily available for homes located downstream of the distribution tanks. Indeed, as indicated by one farming community member:

> We usually never run out of potable water and can use water to irrigate our crops, which is not the same in other communities. It's more of an issue for those in the center or those above the [water] tanks where the tubes don't reach them (FCM1).

As alluded to by the participant above, community members who lacked access to either system noted that the amount of water available to households depended on their proximity to these systems. For individuals with limited access, strategies for obtaining water included purchasing bottled water, borrowing from neighbors, or relying on rainwater stored in *pilas* (water basins) or other rainwater collection systems. As one non-farming community member mentioned:

> Here in the center the water doesn't reach us. It's the same for everyone around the center. Everyone below has water. We mostly just buy the water and use whatever we have stored in the *pilas*. Yes, we wish that we could be connected but it just doesn't reach (NFCM1).

Participants both with and without access to the water systems noted the significance of household location relative to water sources for household water access.

Relatedly, extended dry periods and the climactic dry season were of concern for all community members with respect to decreased potable and irrigation water. For farming community members in particular, water scarcity issues were most noticeable during dry periods or droughts:

> The water here is abundant. But sometimes it goes down. You see right now, the sprinklers are going we've got water, but it will go down during the summer [dry season] (FCM2).

Respondents like this farming community member tended to discuss periods of scarcity and rainfall variability as impacting health through reduced food security or negative impacts on economic wellbeing. As elaborated on by another farming community member expressing concerns about reduced food production:

> One worries about putting food on the table sometimes… the rainy season is coming later and there's less rain when it does fall. It's not the same as it used to be. Before the rain would come down consistently and the water levels were high. But now it's gone down and sometimes it's not enough for the crops. We'll end up not having enough for the next harvest and lose money (FCM3).

The concerns shared by this farming community member highlighted broader concerns throughout the community about how rainfall variability and changing water patterns negatively impacted food security and economic wellbeing. Participants expressed worry about the delayed arrival of the rainy season and reduced rainfall when it did fall. This variability resulted in insufficient water for crops, posing a threat to future harvests and financial stability. When probed about why these changes might be occurring, one farming community member said "They say the climate is changing but it's hard to say. Maybe it's that or maybe because we keep cutting trees (FCM3)". This sentiment was shared by other

farmers, who expressed uncertainty about why rain patterns were changing over time but attributed these changes to either climate change or local ecological changes like deforestation.

While water managers and health workers spoke about access and quantity issues with less frequency, they also identified biophysical characteristics including geographic location in relation to water infrastructure as impacting the wellbeing of other community members. As one water manager mentioned "It depends on which sector. Some do, some don't [have water] depending on where they are (WM1)." This sentiment was reiterated by a health worker when talking about water access, "It's harder here in the center, here not everyone has water and they have to buy it (HW1)." Overall, actors within these groups often emphasized water access and quantity issues at sector or community level rather than at an individual level.

3.3.1.2 Continuum of perspectives and perceptions of water quality, sanitation, hygiene, and risky water use among actor groups

There was variation among actor groups regarding perceptions of water quality, sanitation, hygiene, and risky water use throughout the community. Community members generally reported high satisfaction with available water quality and rarely reported health issues related to water contamination. For example, one farming community member shared, "No I've never been sick. It comes directly from the spring. It's not contaminated. We don't worry about contamination. It's of high quality (FCM4)." Similar to this participant, many community members explained that because water systems were sourced directly from natural mountain springs, they posed little risk of contamination.

In addition, community members explained that both the potable and irrigation systems were connected to the same source, leading some to believe it was safe to consume water from the irrigation systems. Some participants exclusively utilized the irrigation systems for both farming and consumption such as one farming participant who explained their use of only one system: "It's the same water in both systems. We only use the one system (irrigation

system) because they're both from the spring. It's the same so we can drink from it (FCM4)." Similarly, a farming community member who was a member of the RED-PPAS explained their households ability to switch systems during periods of low water levels.

> If the potable system water levels go down, we can just switch to irrigation system. It has more water [the irrigation system], so during dry periods if our neighbors need water we share with them from the irrigation system (FCM5).

The quotations above illustrate the reliance and trust in the irrigation system not only as a backup water source, particularly during dry periods when water levels in the potable system may decrease, but also as a source of drinking water. Community members viewed the irrigation system as having a more abundant water supply, making it a viable alternative during times of scarcity for themselves and neighbors. Importantly, despite the perception that the water springs were of high quality, all participants mentioned the need to boil water prior to consumption. Additionally, when probed further about previous experiences with symptoms like vomiting or diarrhea, some participants would make connections between these health outcomes and water quality.

While certain water managers shared the perspectives endorsed by community members, with a few even acknowledging their utilization of irrigation systems for household consumption, this sentiment was not universal among all managers. Several water managers voiced concerns regarding community-wide water contamination arising from agricultural runoff and animal waste, making connections between this contamination and observations of water-related illnesses. One water manager stated, "Some people are getting sick. The waterways aren't totally protected, and people downstream of waste or pollution might be getting exposed to fertilizer or other waste (WM2)."

The degree of concern among managers regarding water-related health issues and the safeguarding of water systems from contaminants appeared to vary depending on factors such as the specific sector, length of tenure on water committees, and role within the community. For instance, a lead water manager in one sector expressed heightened concerns about water-health issues, advising against drinking water from the irrigation systems for all community members. However, another manager in a similar position but working in a

different sector held different views, stating that consuming water from the irrigation systems was safe as long as it was boiled. Additionally, there was uncertainty among water managers regarding the extent of monitoring and treatment conducted on the water systems, with conflicting accounts provided regarding chlorination in the distribution tanks.

Health workers highlighted concerns about water contamination and waterborne illnesses related to risky water use, unsanitary conditions, and poor personal hygiene. As one health worker explained:

> People get sick all the time from the water. We see it most in the children. They come in with vomiting or diarrhea and end up getting dehydrated, and sometimes having to travel to the hospital. …The homes aren't always clean and there's animal waste around. …They'll touch something dirty and not wash their hands, or eat something that wasn't washed properly. It's not just the children who lack fully developed hygiene habits of hand washing or eating something dirty, but sometimes the parents too…proper hygiene education isn't available in the community and people don't always know. With respect to the contamination, a lot of the water is contaminated. And people drink the water on occasions without boiling it. Sometimes they'll forget to boil water and make some juice. Or drink from the taps when they're out in field. People get amoebas or parasites or who knows (HW2).

Health workers highlighted the incidence of illnesses such as vomiting, diarrhea, and dehydration in the community, occasionally necessitating hospital visits, especially among children. Health workers also noted limited access to hygiene education in the community, contributing to residents consuming untreated water and improperly washed food, potentially exposing themselves to pathogens.

3.3.2 Intermediate Pathways

3.3.2.1 Environmental change, administrative challenges, and water withdrawals

Notable intermediate water-health pathways related to environmental change, human and agricultural activities, and water-administration challenges impacting water quantity and availability were discussed across participants. These issues were especially highlighted by community members involved in small-scale agriculture as well as water managers.

Through interviews with farming community members, a frequently identified issue related to the impacts of deforestation on water quantity. Farming community members expressed concerns about how local deforestation for firewood and commercial purposes had consequences for the ability of forests to regulate local water flows and hydrological patterns. As pointed out by one participant:

> People keep cutting down the trees for firewood or to sell it. The water levels are going down because of it. The trees, the forest, holds water. It's happening everywhere in the community. The water used to be much higher, but now there's not as much. And we all have to be conscious of this, we have to be careful or else we won't have as much water in the future. We do our part… we make sure that we're only cutting from the trees allocated to us. If we do cut, we have to plant more trees. For every tree we cut we'd need to be planting ten more trees, to protect the forest for our children. (FCM6).

These concerns were shared by many other farming community members, who elaborated on the potential future impacts of deforestation on young family members and the need for concerted tree planting efforts. When probed about challenges with conservation, many community members discussed how a lack of awareness and education contributed to deforestation:

> It's that not everyone things about the other impacts [on water]. They'll [other community members] take the firewood they need and leave it at that. We need to educate others but it's hard. Not everyone knows about why its important, but we all need to be more conscious about it, but it's hard to do for the community (FCM7).

In addition to the education and awareness issues for forest conservation discussed by the participant above, they also alluded to broader community-wide challenges for managing natural resources. Farming community members suggested a collective need for increased understanding and education of the impacts of deforestation, particularly on water resources. However, many acknowledged the difficulty of implementing such initiatives within the community.

While the role of deforestation and education challenges were also noted by water managers, many managers instead attributed water level concerns to agricultural water withdrawals and overuse. Water managers highlighted the intensive use of water for irrigation purposes,

particularly during the dry season, on depleting water resources and diminished downstream flow rates. This concern was highlighted by one water manager, who compared deforestation and water use for agriculture:

> Yes, the deforestation is one of the factors. But there are other reasons. People will keep their sprinklers going all the time, year-round, even if they shouldn't be and they don't think about how that affects other people below them. They don't see it, we do. …We all have to do our part to conserve the water but its hard to get people to listen (WM3).

The issue of overuse from irrigation, as highlighted above, was discussed by nearly all managers. Water managers, in particular, expressed concerns about upstream water withdrawals and overuse affecting the amount of water available to downstream users and households. As further explained by the manager quoted above, "someone above will have their sprinkler running all day, and they won't see how the person below them [their water] get's a lot lower (WM3),". The concerns of this water manager illustrate the broader concerns on how more intensive water uses by farmers higher up on the mountainsides could sometimes lead to shortages for users downstream. In addition to the issue of overuse from irrigation, most managers also discussed the challenges with administering and managing water throughout the community. As put by one sector's lead water committee member:

> We'll try to get people to use less water and ask them to think about the other people around them. If they use too much they don't see how for families below them are affected, they'll have almost no water to use for the day. But it's hard, because there's so much water around here compared to other places people think that it's completely abundant, but it's not. The water is going down over time. We have noted it. Yes there's enough now, but it won't always be that way if things stay the same. …People will have leaky faucets or need tubes that need changing and we'll [the committee] offer to fix it but people say no, because they don't want to let us and they don't want to pay. They say, 'well I paid for the project already, why should I pay more?' and we don't have any way to manage these issues (WM4).

The above quotation illustrates the types of administrative challenges faced by water managers across the community. Water managers emphasized the necessity of community members using water responsibly; however, they highlighted the difficulties they faced in persuading people to conserve water, especially when there was a perception of abundance.

Water managers expressed their frustration over their limited capacity to regulate water usage and enforce water conservation measures due to a lack of cooperation among community members. For example, a few managers expressed a desire to meter water usage but cited community distrust and conflicts as barriers to implementing these conservation measures.

3.3.2.2 Population dynamics and migration

Population dynamics and growth were highlighted by all community members and water managers as contributing to water resource strain. When asked about how water levels have changed over time, a community member not engaged in agriculture and living in the center of the community noted fluctuations from population growth.

> People are having a lot of children. And those children when they grow up they get their own land and their own water projects for their crops and families, which is bringing the level down for everyone. And so people are using more everyday (NFCM2).

Both farming community members and water managers attributed changes to water levels across the community to local population growth, an increasing number of households, and expanding water projects. Additionally, a few participants pointed to community migration dynamics as having an important role in mediating population impacts on water withdrawals.

> Some people are even moving into the community from around [the nearby community of] Tacaná. They see the water and think there's more opportunity to cultivate. So they move here and start taking water. (FCM8).

> All the time the population is growing. The families are getting bigger or sometimes there are people who move into the community from outside. What happens is that if there's a new home then they need to get connected to the water projects so it just draws more water out (WM5).

A few farming community members and water managers, like the participant above, noted how in-migration to the community was driven by access to water and land resources compared to surrounding areas, with the influx of newcomers placing additional demands on the water systems. Similarly, some water managers spoke about how increasing family sizes and in-migration were contributing to water system expansion and increasing withdrawals from the water systems.

Of note is that intermediate water health issues were not discussed at length by health workers. While some health workers provided cursory remarks related to concerns about the potential connection between family sizes and lack of access to adequate sanitation infrastructure, intermediate water-health pathways were not a focus of responses provided by health workers.

3.3.3 Distal water-health pathways

3.3.3.1 Poverty, healthcare utilization, and remittances

Community members in the study highlighted how poverty significantly impacted their ability to address health issues, particularly those related to waterborne illnesses. One non-farming community member expressed the challenges they face, stating that even if their child fell ill due to waterborne diseases, they lacked the financial means to seek appropriate medical treatment.

> When we get sick there's not much we can do. If one of the children has vomiting or diarrhea from water, the medicine isn't available or we don't have money to pay for the medicine to go to the doctor anyway, we just use the plant medicine (NFCM3).

Community members stressed their reliance on herbal remedies due to either the lack of available medication or financial constraints that hindered their access to healthcare services during times of illness. Additionally, poverty played a significant role in influencing migration decisions among participants, with remittances often serving as crucial funding sources for improving water access within the community. For instance, one non-farming community member highlighted how remittances were being utilized to finance water infrastructure projects aimed at addressing water-related challenges in the community.

> There are no jobs here, everyone migrates. A lot of the new projects you see around are from the remittances, water projects are being funded with remittances. Everything you see around, the roads the new water pump, it's all from remittances. Before, the school [in the center] didn't have any water. But now because of the remittances there's more projects (NFCM4).

This quote highlighted the pervasive impact of migration and remittances on community development, as described by many community members. They elaborated on how the scarcity of employment opportunities had led to a significant portion of the community migrating to the United States or Canada in search of better job prospects. However, they emphasized that the funds sent back home to the community in the form of remittances played a crucial role in financing various community projects. Community members collectively highlighted the instrumental role of remittances in funding water projects, including the installation of a new water pump and underscored how visible improvements in the community, such as new roads and infrastructure, were largely attributable to these remittance-funded projects. Additionally, community members provided poignant examples of how remittances directly benefited essential facilities and community wellbeing, such as the local school, which previously lacked access to water but now enjoyed improved facilities and infrastructure due to remittance-funded initiatives. Overall, the quote underscored the significant contributions of migration and remittances to community development and highlighted the transformative impact of external financial support on water infrastructure.

3.3.4 **Institutional challenges: state-absence negatively influencing local water governance and public health delivery**

Extensive discussions among water managers and health workers revealed that institutional challenges within the Guatemalan government constituted the distal water issues in the community.

Water managers underscored how the lack of government provision or support for local water systems hindered their ability to maintain system integrity effectively. They cited issues such as a lack of technical expertise, inadequate training, role confusion, and underfunding, impeding their capacity to maintain, monitor, and test water supplies.

> The government doesn't help us. We don't receive any training; we just have to figure it out. There's no support for monitoring or testing, and we lack the expertise for this. We don't know how to manage it all but the government

> doesn't help. It's all corrupt, any of the money that should be helping us stays in the government (WM5).

As mentioned by the participant above, water managers expressed frustration with the lack of government support and resources provided to address water management issues. Additionally, many managers perceived government corruption as a significant factor contributing to problems within the water systems. Furthermore, some water managers stressed the necessity of relying on local efforts and external assistance due to the absence of state support. One manager explained:

> We have to manage all of this. It's all developed and funded by the community, the remittances help… well, there was one NGO thirty years ago that came and helped start the systems. Without them we'd still be carrying water to our homes. (WM6).

This statement highlights the community's self-reliance in managing their water systems. The infrastructure and funding for these systems have been largely driven by local initiatives, with remittances providing additional support. The reference to an NGO's assistance underscores the long-term impact of external aid in laying the foundation for the community's water infrastructure and how without this initial support, the residents would still be facing the challenges of manually transporting water to their homes.

Similarly, health workers expressed a desire to educate community members on sanitation and hygiene practices but face constraints due to underfunding and limited capacity to deliver public health services. As put by one health worker when asked about the challenges with public health education in the community,

> We wish we could [teach hygiene], but look, right now, we're in one of the biggest municipalities [Tacaná] in the department [San Marcos]. And there's just not enough health personnel to teach. We're the ones who have to end up educating people [on hygiene] but there's not enough personnel. We don't get the support to do that kind of thing (HW3).

This quote illustrates the significant challenges faced by health workers in delivering essential public health education to communities, particularly regarding sanitation and hygiene practices. Health workers spoke on the mismatch between the considerable population size of the municipality and the limited number of healthcare professionals

available to provide education and support. The burden falls on the existing health workers, who find themselves stretched thin trying to fulfill multiple roles, including educating communities on hygiene practices. The lack of support and resources further exacerbates the challenge, leaving health workers feeling ill-equipped to address these critical public health needs effectively.

The major themes discussed by different actor groups for each pathway level are summarized in Table 1 and depicted in Figure 4 below.

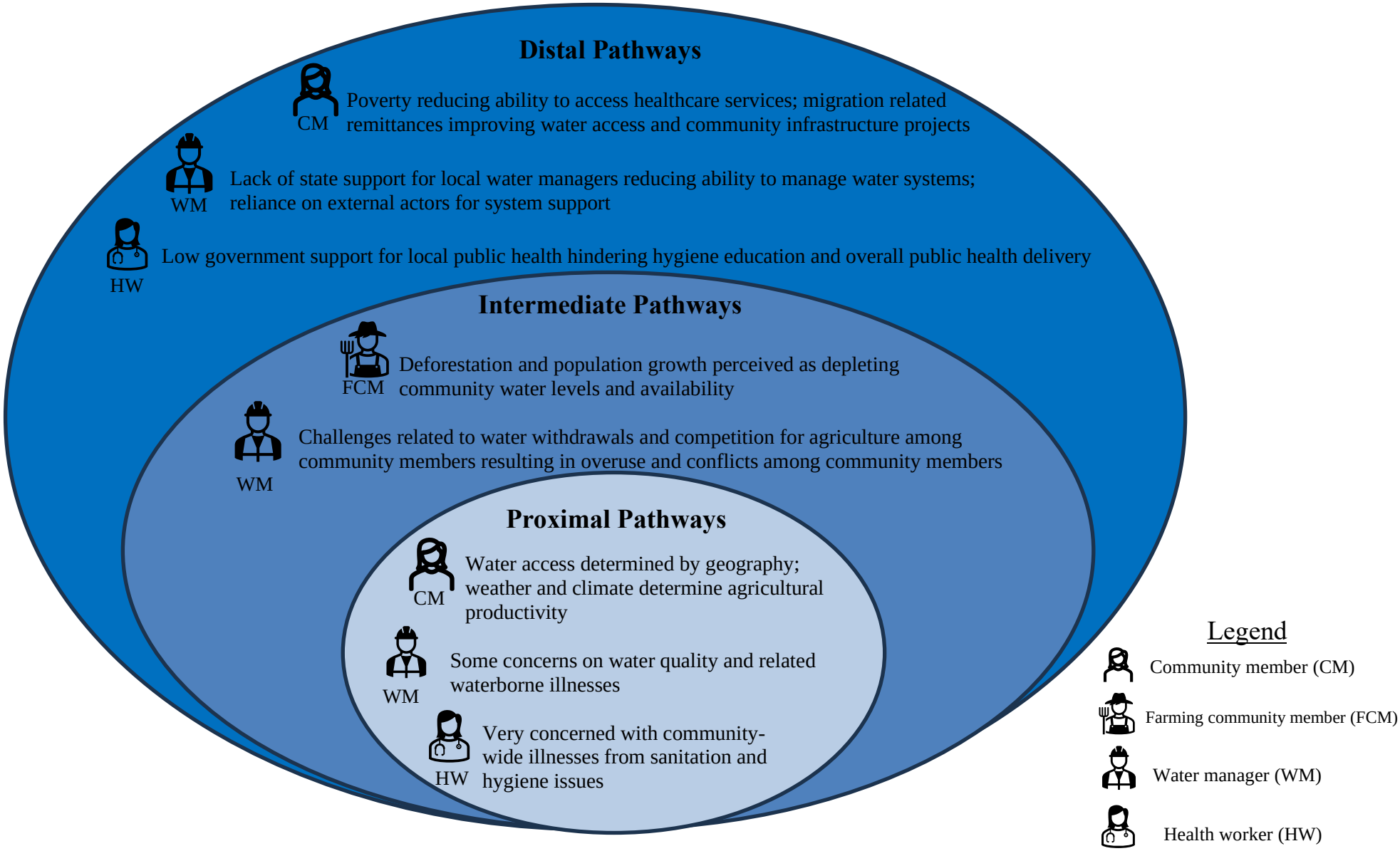

Figure 4. Perceptions of water-health pathways among actors in Tojchoc Grande, Guatemala

Table 1. Summary of major themes discussed by diverse actor groups for different water-health pathways in Tojchoc Grande, Guatemala.

		Water-health Pathway Level		
		Proximal	Intermediate	Distal
Actor Group	Community Members	Geographic location determining access to potable and irrigation water systems Climate and weather variability determine crop yields Low concerns of water contamination from perceptions of spring water quality	Farmers concerned with local deforestation and reduced water levels Population growth contributing to water project expansions and increase water withdrawals	Poverty reducing ability to obtain health services and medical care when experiencing illness Remittances supporting local public projects and increased access to water resources
	Water Managers	Concerns of water-borne illness and contamination throughout the community depending on sector and role on water committee	Concerns about overuse among farmers resulting in depleting water levels and impacts for downstream users Administration and governance challenges limiting ability to regulate water usage	Government absence resulting in low support for water managers External support from NGOs helped establish water systems, remittances important for maintain and funding systems
	Health Workers	Very concerned with community-wide water-borne illness and dehydration especially among children due to poor sanitation, hygiene, water contamination	Minor concerns on family size growth and risks from hygiene	Lack of municipal and state support for public health activities Difficulty teaching health behaviors due to low capacity and insufficient personnel for public health education

3.4 Discussion

This study characterized the proximal, intermediate, and distal water-health pathways influencing a rural community in the Western Highlands of Guatemala and examined how those pathways were differentially perceived among local system actors. In doing so, we have highlighted the multi-level and diverse nature of water-health pathways for a rural community and improved understanding of how these pathways are experienced by local system actors. Main contributions from this work include elucidating specific water-health pathways that are currently impacting a community in the Western Highlands, demonstrating how intermediate and distal water-health pathways are critical determinants of health and wellbeing in a rural setting, and capturing diverse actor perceptions of these pathways, highlighting the imperative to include a variety of actor groups to best inform water-health research and interventions. These contributions are discussed in more detail below.

3.4.1 Rural health is influenced by diverse and complex interplay of proximal, intermediate, and distal water-health pathways

Many of the specific water-health pathways characterized in this study have been corroborated by previous research across Latin America (Akhmouch, 2012; de Esparza, 2009; Furgal, 2002; Gil-Rodas et al., 2021; Läderach et al., 2021; Mekonnen et al., 2015; Reyer et al., 2017; Rowles et al., 2018). Similar to our work, biophysical characteristics, water management issues, and broad socio-economic and institutional challenges have been well established as important determinants of water-health outcomes across Latin America (Akhmouch, 2012; de Esparza, 2009; Furgal, 2002; Gil-Rodas et al., 2021; Läderach et al., 2021; Mekonnen et al., 2015; Reyer et al., 2017; Rowles et al., 2018). However, certain pathways described in our study stand out as particularly noteworthy.

In relation to sanitation and hygiene issues, community members in our study generally expressed low concerns about water quality issues, and believed that the water resources sourced from natural springs were of high quality, in contrast to the views of water managers and health workers. Relatedly, recent research across Latin America has underscored the significance of water risk perceptions as major determinants for risky water use (Harvey et

al., 2018; Marcillo et al., 2020; Maurice et al., 2019; Rangecroft et al., 2023; Rowles et al., 2018). Studies conducted in Mexico, Peru, Argentina, and other Latin American communities consistently point to beliefs in spring water purity as a significant factors influencing risky water usage behaviors (Harvey et al., 2018; Marcillo et al., 2020; Maurice et al., 2019; Rangecroft et al., 2023; Rowles et al., 2018). This finding may suggest that certain perceptions about water quality from subterranean water sources may contribute to risky water behaviors, such as consuming untreated water (Harvey et al., 2018; Marcillo et al., 2020; Maurice et al., 2019; Rangecroft et al., 2023; Rowles et al., 2018). The widespread documentation of local perceptions and risky water use across Latin America may reflect broader regional challenges in public health education and the governance of water resources (Akhmouch, 2012; Barlow & Clarke, 2004; Mekonnen et al., 2015; Soares et al., 2002). Limited access to accurate and timely information about water quality and sanitation practices, coupled with the decentralization of water management and state-absence in rural areas, may create conditions conducive to misconceptions and risky behaviors (Akhmouch, 2012; Barlow & Clarke, 2004; Mekonnen et al., 2015; Soares et al., 2002). Therefore, addressing these challenges may necessitate region-wide public health education efforts. (Kondash et al., 2021; Mardero et al., 2023; Pham, et al., 2019; Shaffril, et al., 2018).

Many of the community's challenges in this study revolved around issues of quantity and availability of water resources for both agriculture and domestic use. The intricate interplay among various pathways—such as climate and rainfall variability, deforestation, water withdrawals, and population growth—simultaneously shaping water levels and availability in the community underscores the complexity and multi-faceted nature of the water-health pathways influencing and shaping rural livelihoods (Laino-Guanes et al., 2016; Santos & Almeida, 2018; Souza Jr et al., 2019). Extensive evidence from the Western Highlands and across Latin America also demonstrates that challenges related to water quantity and availability are influenced by a variety of factors, including water competition, climatic conditions, and population growth (Ataroff & Rada, 2000; Laino-Guanes et al., 2016; Lopez-Ridaura et al., 2019; Luby et al., 2008; Mapulanga & Naito, 2019; Ruano & Milan, 2014;

Zhang & Wei, 2021). These studies have suggested that addressing the multi-faceted and complex nature of these issues in communities like Tojchoc Grande may require interventions at multiple levels to alleviate strains and pressures on water systems (Cheatham et al., 2022; Hellin et al., 2018; Lopez-Ridaura et al., 2019; Milan & Ruano, 2014; Prado Córdova et al., 2013; Vásquez, 2013).

The relationship between migration dynamics and water in our study further illustrates the complex pathways linking water and health. Many participants in our study highlighted the profound impact of economic constraints on their community, with some recounting personal experiences of livelihood instability leading to migration. As such, factors such as deforestation, rainfall variability, and population growth, identified in our research, are perceived to exacerbate these economic challenges and may contribute to the decision to migrate. While no single factor exclusively triggers migration, the cumulative influence of these interconnected issues may contribute to migration choices (Kondash et al., 2021; Mardero et al., 2023; Pham et al., 2019; Shaffril et al., 2018). Indeed, emerging research in the Western the Western Highlands and across Latin America provide compelling evidence of how these multifaceted water pressures intersect with economic constraints to influence migration decisions (Aracena et al., 2020; Cissé, 2019; Harvey et al., 2018; Luby et al., 2008; Milan & Ruano, 2014; Reyer et al., 2017; Ruano & Milan, 2014; Shaffril et al., 2018). For instance, a study by the United Nations University has found that increased rainfall variability and decreased crop outputs are contributing to decisions to migrate out of Guatemala's Western Highlands (Milan & Ruano, 2014; Ruano & Milan, 2014). It is imperative to recognize the profound effects of these multiple pathways on migration and to explore strategies aimed at strengthening water resources to mitigate migration pressures (Milan & Ruano, 2014; Ruano & Milan, 2014). Furthermore, the intersection between migration, remittances, and water access deserves particular attention from public health and development authorities. Our findings regarding the impact of remittances on water access are relatively unexplored in current rural health research (Acosta et al., 2008; Salazar, 2008; Vasco, 2011). Within the realm of water and health, promoting remittance investments in

water infrastructure could provide a pathway to improving water security and access for recipient communities (Shafiq & Gillani, 2018; Terrelonge, 2014). Public health organizations and development stakeholders should view this as a potentially promising avenue for supporting community investment in infrastructure projects and improving public health (Shafiq & Gillani, 2018; Terrelonge, 2014).

These collective insights from both our research and existing literature underscore the multifaceted nature of water-health pathways and emphasize the need for comprehensive strategies to address water-health issues.

3.4.2 Intermediate and distal factors drivers of water-health pathways

This research demonstrates the complexity of water-health pathways, with intermediate and distal factors such as governance and broad socio-economic factors having a crucial role in shaping water and health pathways in a local context. It is notable that most of the water-health issues discussed by participants in this study were intermediate or distal in nature rather than proximal. These results emphasize the importance of understanding and intervening at intermediate and distal levels relating to factors like local governance or broad institutions, in addition to proximal level interventions, as these intermediate and distal pathways shape other proximal pathways and ultimately shape local community water-health experiences. For instance, while proximal pathways may directly link issues like water contamination to health outcomes, intermediate and distal factors such as governance structures, socio-economic conditions, and historical legacies mediate and amplify these pathways. By examining the broader intermediate and distal pathways in which water systems operate, we gain insights into the root causes of water-related health disparities and vulnerabilities.

Traditionally, research in the field of water and health has predominantly focused on proximal pathways, emphasizing determinants such as water quality, sanitation, and hygiene practices (Brown et al., 2013; Kawata, 1978; Pickering et al., 2018; Walker et al., 2013; Wolf et al., 2023). While these proximal factors undoubtedly play a crucial role in shaping health

outcomes, emerging evidence suggests that intermediate and distal pathways exert significant influence on current and future health risks (Morris et al., 2017; Varis et al., 2017; Walls & McGarvey, 2023). Existing studies and frameworks, such as the Water Poverty Index and the DPSEEA (Driving Force-Pressure-State-Exposures-Effect-Action) framework, have attempted to incorporate more distal dimensions and factors into the analysis of water and health (Gentry-Shields & Bartram, 2014; Sullivan, 2002, 2003). However, there remains a notable gap in understanding how these distal factors manifest at the local level and contribute to health outcomes in specific communities (Gentry-Shields & Bartram, 2014; Sullivan, 2002, 2003).

Existing literature increasingly calls for further investigation into comprehending intermediate and distal factors shaping water and health (Cook & Bakker, 2012; Garrick & Hall, 2014; Paudel et al., 2021). For instance, studies examining dimensions of water security have emphasized the role of governance structures in shaping water access and distribution, and health outcomes like dehydration and diarrhea (Madon et al., 2018; Nelson-Nuñez et al., 2019). Similarly, investigations into the factors influencing water resource sustainability in rural areas have highlighted historical factors like colonial legacies and land tenure systems, which shape contemporary water governance and resource management practices (Akhmouch, 2012; Bopp et al., 2024; Gibson et al., 2002; Madon et al., 2018; Meeks, 2018). Recent reviews have emphasized the necessity of integrated approaches that consider both proximal and distal factors to address water-related health challenges effectively (Cook & Bakker, 2012; Garrick & Hall, 2014; Paudel et al., 2021). These studies advocate for a holistic understanding of intermediate and proximal determinants of health, recognizing the interconnectedness of governance, institutional, and ecological factors in shaping water-health outcomes (Cook & Bakker, 2012; Garrick & Hall, 2014; Paudel et al., 2021). The findings of this study contribute to bridging this gap by demonstrating the significant impact of intermediate and distal pathways on local health issues in rural communities. By highlighting the role of factors such as ecological perturbations, governance structures, and socio-economic disparities, this research underscores the urgency and need for upstream

interventions and further investigation into the complex interplay between these distal determinants and health outcomes.

3.4.3 Actor identities, roles, and subjectivities important for water-health pathways

The success of public health interventions is contingent upon their contextualization to specific systems and the needs of system actors (Baccarelli et al., 2023; Goudet et al., 2011; Nichter, 2008). Tailoring interventions to the types of perceptions discussed above can increase intervention effectiveness (Baccarelli et al., 2023; Cheatham et al., 2022; Nelson, et al., 2021). For example, sanitation infrastructure projects may be beneficial in improving overall hygiene, but without considering the specific hygiene education needs or governance issues within a community, its impact may be limited (Garrick & Hall, 2014; Nelson et al., 2021; Poder & He, 2011; Rowles et al., 2018). Previous research has highlighted the critical role of individual perceptions, identities, and subjectivities in determining individual and group health behavior and health intervention success (C. Anthonj et al., 2022; Maurice et al., 2019; Mumbi & Watanabe, 2020; Nichter, 2008; Rowles et al., 2018). Therefore, by understanding actors' perceptions, policymakers and community organizations can tailor health interventions to the realities and needs of communities (Baccarelli et al., 2023). The findings from our study underscore the significance of capturing multiple actor perceptions and experiences to comprehend local contexts comprehensively. Factors such as identities, social position, and subjectivities influence actors' priorities and needs, emphasizing the critical importance of incorporating diverse perspectives into future interventions (Anthonj et al., 2022; Maurice et al., 2019; Mumbi & Watanabe, 2020; Nichter, 2008; Rowles et al., 2018). By including individuals with varied backgrounds, policymakers and practitioners can gain insights to inform policies and interventions effectively (C. Anthonj et al., 2022; Maurice et al., 2019; Mumbi & Watanabe, 2020; Nichter, 2008; Rowles et al., 2018).

Existing literature provides further insights into the importance of understanding actor perceptions for informing policy decisions, supporting environmental programming, and reducing water-health risks (Brown et al., 2020; Cheatham et al., 2022; Dobbie & Brown, 2014; Haeffner et al., 2018; Harvey et al., 2018; Morales et al., 2020; Mumbi & Watanabe,

2020; Saborío-Rodríguez et al., 2021). By investigating actor perspectives, decision-makers can better understand the rationale behind user actions, risk behaviors, as well as learn about the most pressing water system needs to tailor interventions (Brown et al., 2020; Cheatham et al., 2022; Haeffner et al., 2018; Harvey et al., 2018; Saborío-Rodríguez et al., 2021). Studies have shown the importance of including multiple actor perspectives for intervention planning and tailoring interventions to specific water and health needs (Anthonj et al., 2022; Dobbie & Brown, 2014; Madon et al., 2018; Maurice et al., 2019; Morales et al., 2020; Nelson et al., 2021; Nichter, 2008; Saborío-Rodríguez et al., 2021; Ssozi-Mugarura, et al., 2015). To illustrate, previous research including intervention studies in Tanzania and Uganada have found improved water and health outcomes such as decreased diarrheal disease incidence in communities where interventions were implemented based on the specific community dynamics and needs (Madon et al., 2018; Ssozi-Mugarura et al., 2015). Furthermore, work done on local knowledge and subjectivities have underscored individual perceptions and identities as critical in shaping water-related health outcomes (Sobczak et al., 2013; Sultana, 2011, 2020).

By integrating the perceptions from local community members, water managers, and community health workers, we elucidate how personal identities, perceptions, and subjectivities to shape water-related challenges and health outcomes. By considering the differentiated impacts across proximal, intermediate, and distal levels, interventions can be more targeted, contextually relevant, and effective in mitigating water-related health hazards.

3.4.4 Strengths and Limitations

The water-health pathways discussed above can be used to enrich understanding of the types of water and health challenges being faced by rural communities in Guatemala. While many studies in the Guatemalan context have worked to understand water-health issues with respect climate and agriculture, this study explicitly centers health issues with respect to water resources (Ruano & Milan, 2014; Saborío-Rodríguez et al., 2021; Wade et al., 2022). By focusing on water and health issues, this work brings focus to the complexity of water-health pathways in rural communities.

Despite its utility in categorizing water-health pathways, the three-level framework presents certain limitations. Trade-offs and difficulties arise in delineating distinct pathways, as they often overlap and interact in complex ways (Grigg, 2018; Morris et al., 2017; Walls & McGarvey, 2023). For example, climate affects water resources at proximal, intermediate, and distal levels (Cissé, 2019; Morris et al., 2017; Phung et al., 2015; Ruano & Milan, 2014). As such, future studies that wish to apply a similar framework for analysis should ensure clarity in the demarcations of water/environmental-health pathways. Another consideration is the reliance on individual experiences which may be subject to social desirability effects. Participants may have underreported water-related health issues due to concerns about privacy or social stigma. However, this study and the implementation of the three-level framework provides a valuable template for future research. Importantly, future studies can utilize the implementation of this framework to assess water-health needs in other contexts and with other system actors.

3.5 Conclusions

This study provided valuable insights into the complexity among water-health pathways in rural communities. While proximal concerns like access to water for agriculture are critical factors shaping household- and community-level health and well-being, these concerns are often intertwined with intermediate factors such as local governance and administration, as well as distal factors like socioeconomic conditions. Overlooking these intermediate and distal water-health pathways can hamper the effectiveness and sustainability of water-health interventions. Moreover, local community perspectives on these pathways may differ based on individual identities, subjectivities, and experiences. Thus, water-health interventions must be informed by actor dependent determinants to optimally address community water-health needs.

Chapter 4: Conclusion

This thesis research explored the water and health issues influencing the rural Western Highland community of Tojchoc Grande, Guatemala. In taking a community-engaged research approach, my research was conducted in partnership with local community stakeholders including the local community members from Tojchoc Grande, a local community agroecological network (RED-PPAS), a local non-governmental organization Pastoral de La Tierra San Marcos (PTSM), and a regional non-governmental organization (Mennonite Central Committee Guatemala-El Salvador) who informed study objectives, design, and data collection tools. A qualitative case study methodology was employed in order to meet the study objectives, aiming to understand water and health issues in this specific community based off of the interests of community partners. Through observations, field notes, and semi-structured interviews with local farming and non-farming community members, water managers, and health workers data on water and health dynamics in the community were collected. Results were categorized into different levels of water-health pathways, including proximal, intermediate, and distal. The results of this study were presented as manuscript (Chapter 3) which documented diverse water-health pathways (and perceptions of these pathways) among local system actors (Chapter 3). In this final chapter, I provide concluding thoughts on the study: first, I summarize key findings from the research; second, I consider strengths and limitations of the study; third, I reflect on the contributions to water-health literature; fourth, I reflect on the relevance of these results for community partners; finally, I consider future research and provide final comments on the thesis.

4.1 Summary of findings

The findings from this study were presented as a single co-authored manuscript (see Statement of Contributions for co-authorship information). The manuscript, presented in Chapter 3, describes proximal, intermediate, and distal water-health pathways influencing a rural community in Guatemala's Western Highlands. I drew on field notes, observations, and semi-structured interview methods with 35 community members, 10 water managers, and 4

health workers across two data collection phases to characterize these pathways and examine how perceptions of them varied among the diverse system actors.

Interviews with participants from this study revealed that a diversity of water-health pathways were influencing community health at all levels. Importantly, the perceptions of some of these pathways varied among participating actor groups.

Proximal water-health pathways (e.g., related to biophysical, water infrastructure, and sanitation and hygiene issues) were discussed by participants throughout the community. While there was some alignment on perceptions of proximal pathways among actor groups, other perceptions differed among the groups. For community members, biophysical factors like weather patterns, climate variability, and geographic location relative to local water infrastructure were of significant concern. Similarly, the importance of geographic location for water access was also discussed by other actor groups; however, water managers and especially health workers were more concerned with issues related to water quality, risky water use, and sanitation and hygiene issues in the community.

The intermediate level water-health pathways highlighted by participants related to changes in ecological systems and processes. Of note, is how perceptions of some intermediate pathways were both similar and varied among actor groups. For example, farming community members as well as water managers highlighted issues like deforestation on water levels. However, water managers also emphasized the impacts of overuse as well as administration challenges as being more significant drivers of water levels in the community. Further, both community members and water managers agreed on the role of population growth in reducing water quantity and availability. In contrast, such intermediate water-health pathways were not discussed at length by either health workers or non-farming community members.

Distal water-health pathways related to broader socio-economic and institutional challenges. Importantly, perceptions of these pathways varied among actor groups. Community members emphasized how poverty shaped their ability to access healthcare in times of sickness. Additionally, some community members discussed how migration related remittances were

critical in improving access to water resources throughout the community. Water managers noted how issues like state absence and a lack of funding and support impacted their ability to regulate and monitor water resources throughout the community. Similarly, health workers pointed to lack of government support in negatively affecting ability to educate community members about sanitation and hygiene.

The contextual insights from this study illustrate the complexity of the relationship between water and health in a rural setting. These results demonstrating the importance of not just proximal pathways for influencing health through things like sanitation and hygiene but also the importance of intermediate and distal pathways influencing community health through things like governance and institutional challenges. Additionally, the variations of perceptions among actors in this study highlight the importance of considering factors like identity, experiences, and subjectivities in understanding the nuanced dynamics of water and health. By understanding these diverse viewpoints, we can gain a more comprehensive understanding of complex water-health issues and better inform interventions based on the needs and priorities of different groups.

4.2 Strengths and limitations

Several strengths and weaknesses are evident in the present study. Firstly, strengths of this research pertain to its study design components and methodological decisions. A significant strength lies in its community engagement and close collaboration with local stakeholders. Partnering with RED-PPAS, PTSM, and MCC had a profound impact on the development and execution of the research. The centrality of these partnerships ensured that the study was firmly rooted in the contexts and interests relevant to the research partners. This was achieved by actively involving members from all participating organizations throughout the research process, soliciting their input on study design, objectives, and data collection tools. Consequently, the study's findings have the potential to directly inform and benefit the work of these organizations, aligning with their specific interests in the investigated topics.

In addition, there were both strengths and limitations regarding the breadth and depth of the case study methodology. On one hand, concentrating on a single case facilitated a thorough understanding of water and health dynamics within a specific community, which closely aligned with the research objectives and the interests of community partners (Crowe et al., 2011). This focused approach enabled an extensive exploration of the interrelated issues within that particular context. However, a limitation of this method is its potential lack of generalizability and applicability to other communities. The highly contextualized nature of the findings may restrict their relevance beyond the studied community. Nonetheless, focusing on a single community that held significance to community partners provided a unique opportunity to delve deeply into issues within Tojchoc Grande, Guatemala. Moreover, efforts were made to strike a balance between depth and breadth by recruiting individuals with diverse demographic and geographic characteristics within the community.

A methodological strength was the collection of data across two distinct phases. Collecting data over multiple time points allowed for the consideration of temporal developments or fluctuations in the phenomenon under investigation when comparing data across the two phases. By retaining questions from the interview guide used in the first phase of data collection for the subsequent phase, this sequential approach facilitated corroboration and cross-validation of results across different time periods, thereby enhancing the validity of the study's findings and conclusions. Additionally, spacing out data collection phases enabled reflection and reflexivity in the research process. During periods away from the community, I could identify topic areas needing additional data collection or adjustments based on preliminary analysis and discussions with team members.

The sensitive nature of the topic, particularly regarding water-related illnesses, may have introduced social desirability biases. Since some of the questions asked related to personal topics of experiences of health and illnesses, community members may not have been totally comfortable in discussing these issues especially with researchers from outside the community and from a different country (Sanzone et al., 2013). Community members in particular in contrast to water managers or health workers may have underreported instances

of illness due to a desire to present themselves and their community in a favorable light, less formal education, or due to discomfort (Sanzone et al., 2013). Some strategies I used to try and mitigate this bias, was building rapport with participants before the interview and reassuring them of the confidentiality of their responses. Additionally, I would be sure to reword questions and use broader terms of health or wellbeing if participants seemed uncomfortable with the line of questioning, and ultimately, allowing participants to decline answering if they felt uncomfortable in order to uphold ethical conduct.

The independent nature of my analysis, translation, and interpretation of transcripts without the assistance of other translators brought to light both strengths and weaknesses in the research process. Working independently had advantages tied to my deep familiarity with the data and its context. Being the sole translator enabled me to reflect on this knowledge, reducing the risk of misinterpretation or misrepresentation and ensuring accuracy and fidelity to the original meaning of the data (Sanzone et al., 2013). However, there were also limitations to this approach. One significant limitation was the potential for unfamiliarity with certain words or phrases, particularly in the rural context of San Marcos, where the vernacular is more similar to Mexican Spanish than Guatemalan Spanish (which I have more familiarity) (Sanzone et al., 2013). Furthermore, time constraints posed another limitation, as there was only one translator available for the task. Ideally, having a team of translators would allow for a more comprehensive and nuanced translation process (Sanzone et al., 2013). However, due to time limitations, this was not feasible. To mitigate these limitations, I consulted with other native Spanish speakers when encountering challenging words or phrases when unsure about specific connotations of sentences or phrasing. This collaborative approach helped to enhance the accuracy and reliability of the translations, despite the constraints of having only one translator.

4.3 Contributions to academic literature

This thesis research provides a number of contributions to the water and health academic literature. Firstly, this thesis contributes to the academic literature by providing insights to water-health pathways and the perceptions of these pathways currently influencing a rural

Western Highlands community of Guatemala. The various proximal, intermediate, and distal water-health pathways characterized in this work can provide guidance for informing future research questions or objectives in the region. For example, since our study highlighted factors like geographic location and deforestation as significant determinants of water availability studies may want to further investigate deforestation issues. Furthermore, the variations of perceptions found among different actor groups in this study lends to the growing body of evidence in Latin America demonstrating the significance of individual perceptions and identities for mediating health and wellbeing (Harvey et al., 2018; Marcillo et al., 2020; Maurice et al., 2019; Rangecroft et al., 2023; Rowles et al., 2018). In comparison to other work in Guatemala related to actor perceptions which have mostly studied farmer perceptions of agriculture or climate change, our study uniquely focuses on water issues among farmers, non-farmers, water managers, and health workers (Cheatham et al., 2022; Hellin et al., 2017; Hellin et al., 2018; Holder, 2006; Immink & Alarcon, 1993; Lopez-Ridaura et al., 2019; Ruano & Milan, 2014; Veblen, 1978). To expand on this growing body of evidence relating to perceptions among local actors, future water-health research should seek to incorporate actors not yet included in studies like ours. For example, understanding perceptions from energy providers or government officials can further characterize water-health dynamics in rural Guatemala (Cheatham et al., 2022; Kondash et al., 2021; Vásquez, 2013). Although climate change was not the focal point of this study, given Tojchoc Grande's location in a region highly susceptible to future climate shifts, these findings could offer valuable insights for future academic research (Hellin et al., 2017; Milan & Ruano, 2014; Ruano & Milan, 2014; Saborío-Rodríguez et al., 2021; Wade et al., 2022). Specifically, they could serve as baseline data for studying water-health dynamics over time in the community or the broader region.

Other contributions of this work relate to the adaptation and utilization of the three-level water-health framework. As discussed in Chapter 1 gaps exists in the ways that water and health issues have been traditionally investigated in rural contexts and the global south, as most research has focused on water-health issues as they relate to proximal pathways such as

from issues with sanitation and hygiene (Fewtrell et al., 2005; Schuster-Wallace & Dickson, 2017; Vásquez & Aksan, 2015). Furthermore, for those studies and frameworks that study intermediate or distal pathways they have not been applied or considered how those water-health issues are perceived at a local level (Gentry-Shields & Bartram, 2014). The work presented in Chapter 3 is dedicated to bridging this gap by employing a framework that accounts for multiple levels of pathways at the local community scale. Through the application of this framework, we conducted a systematic categorization of water-health pathways based on their proximal, intermediate, and distal nature. This analytic approach facilitated a comprehensive understanding of the myriad of water factors influencing health and wellbeing outcomes within the community. Although the findings of this study are inherently contextualized to the specific characteristics of the community under investigation, the utilization of this framework offers broader implications for researchers working in the fields of health, water, or development.

For future researchers seeking to utilize this adapted framework or to adapt the original version of the framework, particular consideration should be given to how different factors and health outcomes are categorized under each level and pathway of the framework. The process I followed (as outlined in section 2.3.8) primarily involved reviewing previous uses of the three-level framework and other literature discussing various scales of water-health pathways. One important consideration for adapting this framework is delineating different factors and health outcomes that may overlap at different levels. For example, in this work I categorized poverty and socio-economic conditions under distal pathways because of the indirect role these factors had for determining health outcomes related to water and healthcare access as discussed by participants. However, poverty and socio-economic conditions have a complex relationship with water and health and very well act through more proximal pathways. Future research that employs such a framework may need to include certain factors within multiple levels depending on the nature of factors and outcomes studied.

Additionally, in light of the findings from this study, it is recommended that future research delves deeper into the bidirectional relationships and feedback loops within the examined framework. While the current study highlighted the complex interplay among geography, poverty, and migration, future researchers should thoroughly analyze the directionality and feedback mechanisms between these and other factors. For instance, in the present study, geographical and poverty-related challenges adversely impacted health outcomes related to food security. However, migration emerged as a mitigating factor, where remittances helped participants overcome geographical challenges by enhancing access to water. This suggests that feedback from migration related remittances may alter the pathways influenced by geography and poverty. Future research should aim to elaborate on these dynamics, providing a more comprehensive understanding of how different pathways interact and influence one another over time. By doing so, researchers can contribute to the development of more effective interventions and policies that address the root causes and interconnected nature of health and water-related issues in vulnerable communities.

Relevance to partner organizations

This research was fundamentally grounded in a commitment to collaboration with local community partners in Guatemala. The results of this study hold profound significance for both the community partners and the individuals who actively participated in the research process. For our partner organizations, such as MCC and similar NGOs operating in San Marcos or Tojchoc, the findings of this research transcend academic interest, offering practical insights that can inform and shape future interventions and initiatives. Specifically, the implications of this study provide valuable guidance for understanding the complex dynamics of water-health pathways within the communities they serve. For MCC and other organizations operating in similar contexts, including PTSM or community organizations like RED-PPAS, the research findings offer actionable insights into the specific challenges and opportunities related to water and health in these communities.

By delving into the nuanced perceptions of community members in Tojchoc Grande, this work has provided a deeper understanding of the underlying issues and needs in the

community, which can be used by organizations working in Tojchoc for informing interventions and programming. In particular, for community partners like PTSM and MCC, the results of this work hold practical applications for their programming efforts. Firstly, the findings can serve as a roadmap for intervention planning, enabling organizations to prioritize and tailor interventions based on the identified water-health issues and the community's capacities for implementation. For example, while interventions such as water system expansions or chlorination may be necessary, organizations like MCC or PTSM, leveraging their expertise in governance and community engagement may be better equipped to address intermediate-level challenges related to governance or administration challenges.

Furthermore, the results of this study, coupled with the implementation of the water-health framework, provide PTSM, MCC, and RED-PPAS with blueprints on how to conduct research on similar topics in other communities. As discussed in Chapter 2, at the outset of this project, PTSM had initially envisioned my thesis project to be based in the community of La Blanca, driven by concerns of water contamination impacting local residents. However, due to time and logistical constraints, conducting the study in La Blanca was not feasible. Nevertheless, by redirecting the focus of the thesis work to Tojchoc, the outcomes of this study serve as a template for how water and health issues can be studied in other contexts. Importantly, the findings of this study offer a foundation for organizations like PTSM and MCC to conduct similar research in communities such as La Blanca. Leveraging their understanding of community characteristics, MCC, PTSM, and other organizations can utilize this framework as a template to investigate proximal, intermediate, and distal level pathways. By contextualizing and localizing water-health (or other environmental-health) pathways, PTSM and MCC can gain a deeper understanding of the underlying determinants influencing health outcomes and tailor interventions accordingly. Ultimately, our study and the application of the framework serve as a guide for future studies aimed at understanding water-related health challenges in local communities. By elucidating the complex interplay between water systems and health outcomes, our research offers insights into the scales of water-health issues that could be influencing a local context. Specifically, the results from

Tojchoc can serve as a reference point for designing and implementing studies aimed at understanding water-health or other environmental health issues other communities.

4.4 Future research and concluding remarks

Future research within Tojchoc Grande should aim to build upon the foundation of information established in this study. This might include replicating the methodology used here to gather more comprehensive data and insights into water-health pathways specific to the community, conducting follow-up studies, or integrate quantitative data from water monitoring to inform evidence-based public health initiatives and better understand the health risks experienced by communities.

In conclusion, this thesis research has contributed to our understanding of the complex interplay between water and health within the community of Tojchoc Grande. Through the adaptation and utilization of the three-level environment-health framework, I examined the multi-scalar pathways linking water, health, and wellbeing as perceived by local community actors. The findings of this study not only provide practical insights for local stakeholders and partner organizations, such as MCC and other NGOs operating in similar contexts, but also offer contributions to the broader field of environmental health research. Overall, by contextualizing and localizing water-health pathways, this study underscores the importance of considering actor perspectives and multiples scales of water-health pathways to understand water-health issues for a local community.

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Appendices

Appendix A

Phase 1 - Interview Guide (English) for semi-structured interviews with research participants

SECTION 3: WATER AND YOUR FARM – WATER SECURITY CONSIDERATIONS

Background/General Information

Question	Prompt
Can you tell me about the importance of water in your life?	
Walk me through your process of gathering water for your household	*Where do you usually go? How far away is it? How do you get there? What do you use to carry the water? How often/what time of day do you go? Is this a similar process for other members of your community?*
How is water managed in your community?	
What do you think about the water resources available to you?	*Is there usually enough water for your home? For your farming practices? For other uses? Is this similar around your community?*
How would you describe the quality of your water and the water in your community?	*Do you need to boil your water to drink it? Do you use water filters?*
Has anyone in your household experienced health challenges connected to your water supply?	*Have there been any health issues due to poor quality or not enough quantity?*
Has anyone in your community experienced health challenges due to water issues?	
Do you have easy access to water and sanitation services?	*Are there sanitation or wastewater treatment facilities in your community?*
Do people in your community have access to sanitation services?	

Gender

Question	Prompt
What is your role in managing water for your family?	*Who usually gets water for your family? Is this similar around the community?*
How much time do you spend getting water each day?	*Each week? Is this similar to other households in your community?*
Does this impact other household work or activities? If so, how?	

Environmental/Structural

Question	Prompt
What strategies has your family used to manage water resources?	*Does your family have any water infrastructure such as rain harvesting systems or irrigation systems? Do you know of any water infrastructure projects in your community?*
What strategies have other farmers in your community used to manage water resources?	
How has climate change impacted the water in your community?	*Has the amount of water available changed recently? Challenges with drought? Challenges with heavy rain and or/flooding?*
From your experience what role does the government play in managing water locally?	
Are there any businesses nearby that have been impacting water in your household or community?	

Cultural/Religious

Question	Prompt
Does water have any important cultural or spiritual significance for you? Does water have any important cultural significance in your community? Are religious groups in your community involved with managing water resources?	

Conclusion

- Is there anything else you would like to share about water management in your family?
- What do you see as the most pressing challenges related to water resources for your household? What about in your community?
- How can local organizations better support the management of water resources in your community? What do you see as the role of government officials in supporting the management of water resources in your community?

Phase 2 - Interview Guide (English) for semi-structured interviews with research participants

Water and health nexus among water users and managers

Name:

Age:

Occupation:

Number of family members:

Main sources of income:

General Water and Sanitation Questions

Question	Prompt
Can you describe the water resources available to you?	*Do you use both irrigation and drinking and irrigation projects?*
What are the different ways you use water?	*Do you use water for cooking? Cleaning? Laundry? Bathing? For other uses?*
Do you usually have enough water for the different uses?	*Does this change over time? When does the amount change?*
Has the amount of water changed over the years?	*Are the water levels different from a year ago, 5 years? 10 years?*
Why do you think the water levels are changing?	
How would you describe the quality of the water available for your family? How about for the rest of the community? If applicable, why do you think the quality is so high?	
Is your drinking water treated in anyway?	Chlorine? Do you boil your water?
Have you ever worried that your water might be contaminated?	
Have you or anyone in your family ever gotten sick from drinking water? If so, can you tell me about that experience?	Have you ever experienced symptoms like vomiting or diarrhea?
Have your children ever been sick from drinking contaminated water? How did you manage that situation?	

Have you ever had to purchase water or obtain it from a different source than you usually do? If so, why?	
What kind of bathroom/washroom do you use in your household?	How were these developed
How is toilet waste managed in your household? Is this the same throughout the community?	How often is your toilet, latrine, septic tank emptied and where? Who is responsible for that?
How is garbage waste managed in your household? How is it managed in your community?	Are there any services that manage garbage available to you? Do you burn your garbage?

Water, Health, Community Wellbeing, and the Environment

Question	Prompt
Do you have any health concerns for yourself or your family members?	
How do you manage health concerns for yourself and for your family?	Do you use local traditional medicines or pharmaceuticals?
Can you walk me through how you access medical or health services? Is this similar for other communities? Is there anything you wish you could do to improve you or your family's health?	Are there any medical or health clinics in the community? Where do you go when you need medicine?
How is the health of your animals?	Have you ever had to access veterinary services?
Has too little water ever had an impact on your life? Can you tell me about how you managed that experience? Has this ever resulted in not having enough food to eat?	
Has extreme weather ever had an impact on your life or on	For example, heavy rain fall (aguacenos), or frost? Droughts? Hurricanes?

Do you have any concerns about pollution or the levels of garbage in your community?	
How has population growth in the community impacted your water resources?	
Has any health professional or water directive/committee member ever given you guidance on health practice related to water?	
Has the ministry of health or any government official provided any advice?	

Social, political, and economic factors impacting water

Question	Prompt
Have there ever been any issues or conflicts or disputes for water resources in your community?	
How has migration or remittances impacted water resources for you or your community?	
Have people migrated because they didn't have enough water?	
Have people migrated because they didn't have enough water?	
Has migration/remittances helped people access water resources?	
Do you have any hope that the new government may improve water resources in the community?	

Water-users and manager relationship

Questions for Users	Prompt

Questions for Users	Prompt
Can you tell me about your relationship with the water committee and water committee members? How do the water committees shape your water use?	
Have water managers ever given you any advice or instructions on water use?	
Is there anything you would change about the water committees?	What are some ways the water committees can be improved?
What should be the governments involvement in managing water resource?	

Questions for Managers	Prompt
Can you tell me about your role and experience as a water committee member?	*How long have you been a member? What are your responsibilities?*
Can you describe the water committee and their function?	*How many members are in the committee? How many people does your committee serve?*
What motivated you to join the water committee?	
What are some of the challenges you face as a water committee member?	
What kind of infrastructure is used to distribute water to households? How is this maintained? How often is the water quality measured?	

Who in the is responsible for public health in the community? Do the water committees have a health role?	
Some people in the community have mentioned they drink water from the irrigation project, is this safe to drink?	
Is there anything you wished that users/farmers would do differently with their water resources?	
What are some ways the water committees can improve?	
What kind of support if any does the committee receive from the government?	
Would you prefer water resources were managed by the municipal government?	

Conclusion

- Is there anything else you would like to share about water and health in your family?
- What do you see as the most pressing challenges related to water resources for your household? What about in your community?
- How can local organizations better support the management of water resources in your community? What do you see as the role of government officials in supporting the management of water resources in your community?

Questions for Pastoral staff and other key informants

Water resources and systems	
From your perspective, what are the strengths and weaknesses of the water systems and resources in the community?	
How can the water systems be improved? What are the barriers to this improvement?	
Water, health, and environment	

What are the main health concerns in tojchoc grande?	And similar communities?
What are the health concerns with respect to water?	
How is climate change impacting water and food resources in places like tojchoc grande? How about similar communities?	
How is pesticide use impacting peoples health and their water resources in the community?	
How is contamination impacting peoples health and their water resources in the community?	
Social, political, economic factors impacting water resources	
Where do people get the money to support the water systems?	Are remittances impacting peoples access to water resources?
How are water disputes or conflicts impacting the community?	
What roles should the government have in managing water locally?	
Do you have hope that things might change given the current political situation?	

Appendix B

Research ethics approvals for qualitative data collection (#41222) University of Waterloo

UNIVERSITY OF WATERLOO

Notification of Ethics Clearance to Conduct Research with Human Participants

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Principal Investigator: Warren Dodd (School of Public Health Sciences)

Co-Investigator: Laura Brubacher

Co-Investigator: Brian Laird (School of Public Health Sciences)

Student investigator: Joshua Garcia-Barrios (School of Public Health Sciences)

Student investigator: Emily Kocsis

Co-Investigator: Sara Wyngaarden (Mennonite Central Committee)

File #: 45058

Title: Examining the nexus between rural livelihoods and social wellbeing among small-scale farming households living in complex socio-ecological systems in San Marcos, Guatemala

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The Human Research Ethics Board is pleased to inform you this study has been reviewed and given ethics clearance.

Initial Approval Date: 04/10/23 (m/d/y)

University of Waterloo Research Ethics Boards are composed in accordance with, and carry out their functions and operate in a manner consistent with, the institution's guidelines for research with human participants, the Tri-Council Policy Statement for the Ethical Conduct for Research Involving Humans (TCPS, 2nd edition), International Conference on Harmonization: Good Clinical Practice (ICH-GCP), the Ontario Personal Health Information Protection Act (PHIPA), the applicable laws and regulations of the province of Ontario. Both Boards are registered with the U.S. Department of Health and Human Services under the Federal Wide Assurance, FWA00021410, and IRB registration number IRB00002419 (HREB) and IRB00007409 (CREB).

This study is to be conducted in accordance with the submitted application and the most recently approved versions of all supporting materials.

Expiry Date: 04/11/24 (m/d/y)

Multi-year research must be renewed at least once every 12 months unless a more frequent review has otherwise been specified. Studies will only be renewed if the renewal report is received and approved before the expiry date. Failure to submit renewal reports will result in the investigators being notified ethics clearance has been suspended and Research Finance being notified the ethics clearance is no longer valid.

Level of review: Delegated Review

Signed on behalf of the Human Research Ethics Board

Karen Pieters

Karen Pieters, Manager, Research Ethics, karen.pieters@uwaterloo.ca, 519-888-4567, ext. 41495

This above named study is to be conducted in accordance with the submitted application and the most recently approved versions of all supporting materials.

Documents reviewed and received ethics clearance for use in the study and/or received for information:

file: Confidentiality Agreement_v.1_20230201.pdf

file: RecruitmentScript_Phone_Interviews_20230320_v.2.pdf

file: RecruitmentScript_Phone_FGDs_v.4_20230410.pdf

file: InterviewGuide_SSIs and FGDs_v.3_20230407.pdf

file: OralConsentLog_v.2_20230320.pdf

file: Consent Form_Interviews_v.3_20230407.pdf

file: Consent Form_FGDs_v.3_20230407.pdf

file: Information Letter_Interviews_v.4_20230410.pdf

file: Information Letter_FGDs_v.3_20230407.pdf

file: Verbal Consent Script_Int and FGDs_v.2_20230407 .pdf

file: AppreciationLetter_v.1_20230201.pdf

Approved Protocol Version 4 in Research Ethics System

This is an official document. Retain for your files.

You are responsible for obtaining any additional institutional approvals that might be required to complete this study.