IMPACT OF HURRICANES ON WATER SYSTEMS: POST-DISASTER RECOVERY EFFORTS IN SOUTHEAST TEXAS

A Thesis

by

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ABSTRACT

This research seeks to understand the vulnerabilities of water systems to disaster events by examining the impact of Hurricane Harvey on water security in the Golden Triangle, located in southeast Texas. The project utilized both primary and secondary data to create a narrative of the events in the Golden Triangle both during and post-Harvey, as well as how the water systems failed, recovered, and rebuilt. Secondary data was collected through the analysis of newspaper of the events surrounding Hurricane Harvey. Primary data was collected through semi-structured interviews with both community organizations and water operators of public water systems, to gain perspective of how water was affected from both an operational and community perspective. After analyzing the data, it displayed further evidence showcasing the importance of accessibility to aid, such as funding, had on the recovery of water systems following a disaster. The research also showed preliminary evidence of the importance of whether the water operators were public servants or private contractors in their accessibility to resources. This inequality in funding suggests a possible need to adapt to the municipalization of water systems. Overall, the project demonstrated how water systems are impacted following a disaster, and how Hurricane Harvey continues to affect the region, four years post-Harvey.

DEDICATION

This thesis is dedicated to Judy Vanderheiden. Thank you for always making me feel welcomed and at home, when I was so far away from my own home. Until we can meet again.

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NOMENCLATURE

EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
PWS	Public Water System
SDWS	Small Drinking Water System
SDWIS	Small Drinking Water Information System
TCEQ	Texas Commission on Environmental Quality
TDEM	Texas Division of Emergency Management
TML	Texas Municipal League
TWDB	Texas Water Development Board

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1. INTRODUCTION

Water insecurity is a broad theme that encompasses many fields of research. Definitions of water insecurity vary depending on the context of study, It is prevalent in research ranging from public health, food insecurity, water systems, and disasters (Chakraborty et al., 2019; Pierce et al., 2019; Wutich & Brewis, 2014), and scale. Water insecurity is prevalent in both the Global South and North across the different scales, such as within households, communities, and countries (Ranganthan, 2014). Cook and Bakker (2012) have identified four domains that water security research often falls into: human development, ecological sustainability, geopolitics and international relations, and vulnerability and risk. Due to the complexity behind its meaning, the definition behind water insecurity behind this thesis will rely on Meehan et al.'s (2020) definition as "…a lack of safe, reliable, sufficient, and affordable water for a thriving life (p. 2)." Through the combination of Meehan et al.'s (2020) definition and Cook and Bakker's (2012) interpretation of the four domains of water security, this project focus on the fourth domain – vulnerability and risk. Cook and Bakker (2012) define the intersection between vulnerability and water security as "… ''protection of vulnerable water systems, protection against water related hazards such as floods and droughts, sustainable development of water resources and safeguarding access to water functions and service (p 97). As mentioned previously, the definition of water security can hold various forms of interpretation, so it is important to understand how it is being utilized in this project.

An unexplored topic regarding water insecurity is the way natural disasters alter water systems and how the recovery process these systems must overcome. Natural disasters can be catastrophic, and recovery efforts can vary depending on the level of intensity and responses offered by government actors. However, not all communities receive equal levels of aid in the recovery process (Chakraborty et al., 2019; Derickson, 2014; Sovacool et al., 2018). Communities can face vulnerability due to social characteristics and traits create a pre-determined disadvantage for when a disaster does make landfall (Cutter et al., 2008; Faas, 2016).

Similar to water insecurity, there are many variations over the definition of 'vulnerability.' Lei's (2014) defines vulnerability as the "…degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes (p. 611)." The 'susceptible system' can vary from individual households to communities and this definition acts as the foundation for this project due to its broad generalization. For the scope of this project, the 'system' that is vulnerable are the water systems that are impacted by hurricanes. The project will be looking closely at both the system vulnerabilities, such as the extent of damage and flooding that Hurricane Harvey brought to water systems that led to their failures, as well as the social factors that contributed to the system vulnerabilities, such as lack of funding and governance.

This knowledge can determine which communities are the most vulnerable to recovery efforts and implementation of preventative measures and mitigation efforts. There is an abundant amount of research on the separate topics of which communities are most vulnerable due to disasters and which communities are most vulnerable due to water

systems, but there is a lack of literature on how the two can combine and affect one another (Collins, 2008; McFarlane & Harris, 2018). Specifically, while there is extensive research on the effects of natural disasters on communities, there is little research on how they influence water systems through social factors. An increase in this research can be used to encourage and promote support and funding for the municipal governments to implement said preventative measures, benefitting households in vulnerable communities. In particular, with drinking water, it can help understand how water systems are vulnerable and potentially damaged by disasters and the factors that prevent their recovery.

The thesis is organized as follows. Chapter 2 is a literature of three major subsections- vulnerability to disasters, social dimensions of water infrastructure, and high-income economies and water security. Chapter 3 describes the location of study, outlines the research design of this project, as well as goes into detail over the limitations and challenges of the project. Chapter 4 is where I outline the narrative of what happened to southeast Texas during Hurricane Harvey through my newspaper analysis, while Chapter 5 I detail the results from my semi-structured interviews with both water operators and community organizations. Chapter 6 is discussion of what my findings were, and chapter 7 offers a conclusion and some limitations of my research and future research considerations.

2. LITERATURE REVIEW

The current literature in academia lacks an intersection between disasters and water. As climatic disasters, such as hurricanes, continue to affect society, there is an increased need to better understand how resources are negatively affected. In the case of water security and hurricanes, there is a gap in the literature on the social dimensions of water infrastructure and how hurricanes and water security are related. This research project is attempting to bridge the gap in literature involving the effects that hurricanes have on water systems, and how they can potentially act as catalysts in the demise of water systems. However, prior to conducting research and establishing objectives, it is crucial to understand the current literature and identify research gaps. This chapter will have three sections - vulnerability to disasters, social dimensions of water infrastructure, and high-income economies and water insecurity - that each provide a short literature review on the current research within each topic. Following these three sections will then include a short conclusion that summarizes the intersection of all three topics and the present gaps that will guide the research project.

2.1. Vulnerability to Disasters

There is widespread research involving the various vulnerabilities communities can face following a disaster. Social vulnerabilities within hazards are defined as “the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard” (Maldonado et al., 2019). Social vulnerability is researched amongst communities that were affected

by hurricanes by understanding factors such as socioeconomic status and preparation influence recovery post-disaster. Understanding why one group within a community is more at risk than others showcases where the gaps in disaster recovery aid are and how political actors can play a role in minimizing the vulnerabilities they are faced with.

Socioeconomic Status

In 2017, Hurricane Maria left devastation in its wake with thousands of rural communities in Puerto Rico facing long-term consequences, while wealthy communities were able to recover quickly. A month post-Maria, 36% of households connected to the public water systems did not have access to water. Alongside the water shortages, a widespread food shortage caused FEMA to provide more than two million meals a day (García-López, 2018). The poorest populations, commonly in the rural and mountainous regions, felt these shortfalls for months after the initial landfall. The wealthy communities could pay for repaired amenities and recovered quickly due to having the funds to do so. Protestors and activists in Puerto Rico often chanted "hurricanes are natural, but disasters are political (García-López, 2018)." This is the main premise underlying vulnerability and which communities are most prone to long-term consequences. Wealthy communities, such as Condado, Puerto Rico, had electricity and were hosting parties and live music for the tourists, federal agents, and homeowners three weeks after Hurricane Maria made landfall. During this same time, there were still rampant reports of communities in the rural and mountainous areas that did not have reliable access to water or food (García-López, 2018).

Choosing to prioritize repairs in wealthy communities implies that poor and rural lives are expendable and do not deserve to have proper infrastructure. Even if these issues are recognized, local governments of these communities often do not have the funds and means to properly implement disaster response plans if they are not properly recognized and backed by federal aid. Although some financial aid is better than none, it still does not justify how FEMA prioritized communities over others (Checker, 2017). Although it is often lower income and minority households who are most at risk for damages following a hurricane, they are not the main beneficiaries of funding or insurance (Peacock et al., 2014). This is a major critique of governmental agencies, such as FEMA. Funding and aid are still structured to benefit the property, therefore putting renters at a large disadvantage. Though FEMA may allocate a large amount of funding to an area, it is usually distributed unequally (Howell & Elliot, 2019). Funding is favored most to single-family homes, despite multi-family households losing the most value in their property following a hurricane (Peacock et al., 2014). When comparing the property most damaged with Hurricane Andrew and Ike in the 1992 and 2008 and Hurricane Harvey in 2017, it is disheartening to see how this funding distribution has been an issue for many years, and yet the rental households still have not had much improvement in reducing their disparities in this regard (Howell & Elliot, 2019; Peacock et al., 2014; Flores et al., 2020b).

In 2005, following Hurricane Katrina, a similar event occurred., There was a movement to develop coastal Mississippi as a ‘blank slate’, involving the displacement and disinvestment of low-income African American neighborhoods (Derickson, 2014). Racial barriers to recovery are long standing, and often it is these low income and minority

community's property and land that are targeted for reconstruction and development projects. Understanding which communities are prioritized in post-disaster recovery is beneficial because it shows who does not receive proper aid and could most benefit from pre-disaster mitigation.

Pre-disaster Mitigation and Preparation

Researchers emphasize the importance of preparation and structural mitigation before a disaster strike. In a comparison survey performed between 2012 and 2017, respondents who reported higher degrees of pre-disaster mitigation prior to Hurricane Harvey in the Greater Houston region were associated with less physical effects, PTS syndromes, and adverse event experiences (Flores et al., 2020b; Grineski et al., 2019). Forms of preparation include preparation of structural infrastructure, as well as evacuations. Individuals who were early evacuees prior to Hurricane Harvey reported a 59% lower chance of experiencing immediate health problems. This both minimized their likelihood of exposing oneself to a bacterium or virus, and experiencing a catastrophic and traumatizing event that would contribute to experiencing PTS (Flores et al., 2020*a*).

2.2. Social Dimensions of Water Infrastructure

Water systems are the physical piped network infrastructures that distribute water from water facilities to households and businesses. Household water systems are potable and used for multiple usages, such as hydration, cooking, and cleaning (Cook & Bakker, 2012). Water systems play an important role in determining if households are water secure or not, as the compromised structural integrity of the system can influence the distribution

of the quality and quantity of water at the household scale, as evident in cases such as in Flint, Michigan (Pauli, 2020). Water systems and networks of pipes also hold influence beyond their structural wellbeing and can be symbolic amongst communities. In Bangalore, India, the act of paying for water services and the creation of water pipes offers a sense of identity and property-ownership and strengthens ties to land tenure (Ranganathan, 2014). Payment of these pipes offers more than a stable supply of water but can also instill a sense of community belonging. Landless residents around the urban periphery often feel as if they did not have ownership over land. However, by paying for the pipes there is now leverage in their sense of belonging, as their fees are helping construct the necessary water systems (Ranganathan, 2014). Water systems can hold multiple meanings to the community, and the benefits or disadvantages households feel towards water security from these systems is determined by both the quality of the system, as well as the cultural and social meanings behind them.

While water systems can be successful in establishing a sense of community, identity, and have cultural impacts, it is important to gain further understanding of how water systems can be disadvantageous to certain communities. Research on water system failures and water insecurity have traditionally been viewed as an engineering issue. The literature heavily emphasizes the physical system failures themselves, as opposed to understanding the social factors that contribute to their failures (Coleman et al., 2020; Ranganathan & Balazs, 2015). There is a need to view these water system failures through a contemporary lens of how social factors contribute to the patterns over which water systems are more

likely to fail over others or why proper functionality of some systems can be near-impossible.

Small Drinking Water Systems (SDWS)

Water systems provide drinking water for households and have various characteristics and traits amongst them. They can vary in sizes, the governance type responsible for the system, as well as the number of systems found within a region. The size of the water system is determined by the population it serves. The number may vary depending on the county but drinking water systems are on average classified as having the following classifications: very small (25-500 connections), small (501-3300 connections), medium (3301-10000 connections), large (10001-100000 connections), and very large (100000+ connections) (Pierce et al., 2019). Of the various sizes, small drinking water systems (SDWS) tend to have the most deficiencies in their ability to provide adequate water to households for a multitude of reasons that are outlined below (Edwards et al., 2012; McFarlane & Harris, 2018; Pierce et al., 2019; Scott et al., 2017).

Financial Stress

Of all the system sizes, small drinking water systems perform the worse in the categories of quality, accessibility, and affordability. SDWS are prone to a higher likelihood of contamination and unsafe consumption (Pierce et al., 2019). Faced with low funding avenues, they are more prevalent to intense failures (McFarlane & Harris, 2018). The issue of low funds is at the core of many issues with small drinking water systems due to the low number of household connections. SDWS tend to be non-municipally owned, and therefore does not receive funding from the state. All forms of funding are

sourced from fees that household residents who are connected to that system pay and contribute to the maintenance, upgrades, and personnel hired to upkeep the water system (Pierce et al., 2019). With a SDWS, the number of connections can range from 1 to 3,000. If only fifty households were connected to a system, compared to if 1,000 households were connected to a system, the fifty households are already at a disadvantage because the sum of the total fees will be less. The capital cost of investment for SDWS is often too high for it to be profitable and discourages these small populations from receiving equal accessibility to quality water services. In fact, research has found that larger drinking water systems are more likely to invest in water system infrastructure and upkeep maintenance and constant upgrades, especially if found of violations, simply because they have the higher fiscal capacity to do so (Scott et al., 2017). SDWS often cannot maintain their systems to the same capacity, especially when coupled with responsibilities of paying any fines due to violations of protocols.

Funding for small drinking water systems is crucial because of the varying forms of pressures these systems are continuing to feel. As climate change continues to shift towards increased frequency and intensity of weather events, the need for improved water systems is necessary so that they can withstand this, and damage is not catalyzed. As water and sanitation laws continue to change across all scales, the need to ensure water systems meet the new standards and requirements is also crucial. Along with this, general infrastructure updates are needed for old water systems that date back to World War II, as systems built in this era are naturally degrading and need to be replaced within the next 25 years (Mack & Wrase, 2017). All these updates on water systems are incredibly

difficult without the proper finances to do so, contributing further to their neglect and inability to provide adequate drinking water. To promote funding within SDWS, there is a call of action to promote water systems that are "planning-ready", meaning that they are in the early stages of planning how to upgrade and finance their systems (Balazs & Ray, 2014). By assisting in these types of upgrades, it can ensure efficiency and beneficial outcomes to the associated households.

Drinking Water Advisories

As mentioned previously, small drinking water systems tend to have higher levels of contamination and improper water conditions for household uses. Drinking water advisories are distributed by local governments with the goal to communicate information regarding household drinking water, including any potential hazards, contaminants, and updates. These advisories serve the purpose of informing residents of any health risks that the water may contain. SDWS tend to be on these advisories both more frequently and for longer intervals of time when compared to larger water systems (Edwards et al., 2012). As expected, funding plays a large role in this, as there are not enough finances to upkeep the water systems, leading to increased potential to exposure of contaminants within those water system boundaries. Secondly, a large contributor to this is the type of governance actor that is responsible for overseeing the duties of the water system. The two most prevalent governance actors within water systems are municipal governments and private water utilities, although county water district and mutual water companies are also semi-common (Edwards et al., 2012; Pierce et al., 2019). Of the differing forms of governance actors, there is a variety amongst who are the least likely to be on the advisory list.

Municipal water systems tend to be a more hands-on approach and are seen as more active in dealing with issues concerning water systems (Edwards et al., 2012; McFarlane & Harris, 2018). Municipal water systems receive better funding from the state and local governments and serve higher populations due to proximity to urban areas (Edwards et al., 2012; Pierce et al., 2019). This naturally allows the municipal water systems to respond and recover from water advisories at a faster rate, while private water utilities are not able to respond as effectively.

Spatial Distribution – "Water System Sprawl"

Water system sprawl is the ongoing phenomena of the over-dispersion of water systems and the increase of their numbers across a global scale (Pierce et al., 2019). Water system sprawl helps showcase the ongoing fragmentation of water systems and how it contributes to the ongoing difficulty of cooperation amongst water facilities to implement similar policies. Water system sprawl demonstrates how the geographic spatial distribution of what communities are more prone to what type of water system is evident. Similar water systems tend to be clustered in the same areas, such as the prevalence of small drinking water systems amongst low-income neighborhoods. This demonstrates the geographic remoteness of these systems, as they are often located either outside the periphery of urban areas or in complete rural locations (McFarlane & Harris, 2018). If water systems are located outside an urban area, it is often too distantly located to connect to an existing urban grid for access from municipal operators (Ranganathan, 2014). It must rely on the creation of a new water system and private water operators. However, if the water system is not near an urban area and is remote and rural, it still goes through the

issues of needing a private water system because it is smaller and not incorporated into an existing connection grid. Water systems are typically more expensive through private providers, such as due to an increased pricing necessary for a smaller population (Pierce et al., 2019). As mentioned previously, these SDWS tend to be agglomerated in low-income neighborhoods, and this vicious cycle of vulnerability and inability to afford adequate water services is often prevalent and ongoing for low-income residents.

Infrastructure and Disasters

Within the disaster literature, there has been a decent amount of research showcasing the effects that various disasters have on infrastructure, ranging from electrical infrastructure to infrastructure pertaining to the energy and refinery sectors. There has been an increase in natural-technological (na-tech) disasters, which are disasters "...in which a natural hazard event directly or indirectly produces technological failures (Flores et al., 2020d, p.280)." In the case of the refinery sector, Hurricane Harvey in 2017 devasted the petrochemical industry and failures to shut down the facilities prior led to leakages and pollution all throughout the Texas Gulf Coast (Flores et al., 2020d. In the case of Hurricane Maria in 2017, Puerto Rico lost almost 90% of their power grid upon immediate landfall (Garcia-Lopez, 2018).

Research has only exponentially grown in the hurricane literature that describe how socioeconomic barriers influence factors such as insurance coverage, disaster assistance, and infrastructure disruptions (Mitsova et al., 2019). While research involving infrastructure and disasters has increased, there is still a gap in the literature on research that pertains specifically on water infrastructure and the effects that disasters have on them

from a social perspective. While much of the current literature on water infrastructure comes from engineering perspectives, there has been an increase in the inclusivity of sociodemographic factors that contribute to infrastructure decline following a disaster.

In Balaei (2019), the author chronicles the relationship between social networks improving the pace of recovery, as well as other social factors that negatively influence water recovery rates. Using Chile and New Zealand as a comparison, both had catastrophic levels of water infrastructure loss after earthquakes damaged large portions of pipelines. However, despite both affected communities gaining 90% of restoration of their water infrastructure after 45 days, the pace of New Zealand was much quicker than Chile's. This is attributed to the social factors that slowed the pace of restoration - including outbreaks of community violence in Chile that prevented engineers and water operators from fixing the pipes (Balaei et al., 2019). In the United States, the American Society of Civil Engineers (ASCE) gave a 'C' grade to all water system infrastructure in 2013, and following Hurricane Katrina in 2005 it was estimated that the US would need $460 billion to upgrade all water infrastructure within the next 20 years (Copeland, 2005; Farahmandfar et al., 2017). This was attributed to the lack of funding to upgrade these systems (Farahmandfar et al., 2017). The inclusion of socioeconomic factors in understanding water infrastructure failure and disasters is also seen in the work of Coleman (2020). In their research, it was concluded that low socioeconomic status was correlated with higher levels of water disruption rates in Houston following Hurricane Harvey. Individuals who were racial minorities younger than 10 years of age, had mobility issues, and have not resided at their residency for years were the most exposed to water

service loss (Coleman et al., 2020). It is fantastic to see the rise of more socio-economic perspectives while looking at disaster impacts in the literature, as this was a large research gap.

2.3. High-Income Economies and Water Insecurity

Having access to a reliable and uncontaminated stream of drinking water is a luxury that some do not realize that they are privileged to have. Water insecurity is an ongoing issue that encompasses both the quality and quantity of available water for potability purposes. A community is water insecure if there is not an uncontaminated and stable supply of water to households for drinking, cooking, and cleaning (Cook & Bakker, 2012). While water insecurity at the household scale is often associated with proper hydration, it also includes the availability of water for sanitation and proper plumbing practices (Deitz & Meehan, 2019).

Water insecurity can erroneously be misclassified as being an issue that is only predominate in the Global South and not an ongoing issue in the Global North (Balazs & Ray, 2014; Ranganathan & Balazs, 2015). There is no debate that although water insecurity in the Global South is proportionally higher with nearly 1.1 billion worldwide that lack safe drinking water, that does not negate the prevalence of water insecurity in some of the most vulnerable communities in the Global North (Jepson & Vandewalle, 2015).

A misconception that contributes to the idea that water insecurity is not prevalent in developed countries is that numerous pipelines are correlated with accessibility (Balazs

& Ray, 2014). However, this mentality is futile in that it downplays the role that social and political actors play in contributing to the ongoing water insecurity. As mentioned previously with water systems, concentrating solely on the availability of pipelines and the engineering is vain (Ranganathan & Balazs, 2015). There are six common myths to water security that are often thought to be true in the Global North but have proven to be untrue: universal access to water, water is clean, affordability of water, water is trustworthy, uniform governance, and modern water is the best option (Meehan et al., 2020). Instead of viewing water insecurity as a technical issue or due to natural declines of water tables, understanding the social and political patterns is necessary before policies are implemented to help these communities (Truelove, 2019). Approximately one third of residents in the United States are not properly hydrated, with the most cases in low-income, African American, and Hispanic communities (Patel & Schmidt, 2017). These patterns of what communities are most vulnerable to having an inadequate supply of water are evident, and certain communities are more prone to water insecurity, such as obstacles in affordability of water services, minority communities, overall trust of water facilities, and housing locations (Jepson & Vandewalle, 2015; Mack & Wrase, 2017; Pauli, 2020; Pierce & Gonzalez, 2017; Pierce & Jimenez, 2015; Truelove, 2019).

Vulnerable Communities

Water insecurity is rarely distributed evenly, and certain communities are more prone to it than others. Households that are water insecure tend to be in an unfair hierarchy of power relations and are often also at a disadvantage with other insecurities, such as health and food accessibility (Wutich & Brewis, 2014). Communities with higher risks of

facing water insecurity in high income economies are low-income, minority groups (Truelove, 2019). Even within being a member of a minority community, there are other factors that increase the likelihood of water insecurity. While understanding the socioeconomic factors are also important in understanding water insecurity, it is crucial to not pay attention solely on the social and economic indicators, but also the cultural and political disadvantages some communities face over others, such as immigration status (Deitz & Meehan, 2019; Jepson & Vandewalle, 2015).

While immigrants are often also at a disadvantage socially and economically, separating the cultural and political significance is necessary in cases where there are disparities within socio-economic minorities, as evident in the disproportionate disadvantage foreign-born Hispanics have in receiving disaster aid compared to US-born Hispanics (Maldonado et al., 2019). Although Hispanics as a community receive lower degrees of disaster aid compared to other racial groups, understanding the language barrier and fears over immigration status shows how even within Hispanics, there is a division in who are the most vulnerable.

Other factors, such as housing status, play a role in water insecurity. Households living in mobile homes tend to have higher risks of inadequate and contaminated water supply, due to both the infrastructure and implemented policies. Water systems tend to be small at mobile homes and as mentioned in previous sections, small water systems are low on funding and cannot be properly maintained. This leads to unsafe drinking conditions and higher likelihood of water shut offs (Pierce & Jimenez, 2015). As well as infrastructural issues, mobile homes face further disadvantage due to the land they are

located on may follow water and sanitation codes that differ from areas that require stricter standards (Jepson & Vandewalle, 2015). Having lower standards for water and sanitation, combined with poor water systems, only contributes to the dangers of contamination for residents in mobile homes.

Along with residents in mobile homes, the homeless are also at an higher risk of water insecurity, as they do not have a reliable or stable source of water. Even at public shelters, often there is not enough water to distribute an adequate amount. These shelters are often located in low-income neighborhoods that are often already struggling with water security (DeMyers et al., 2017). If even amongst the public shelter there is not enough water to properly hydrate the homeless population, they must rely on either public drinking water, like fountains or purchase water bottles. However, beyond the homeless population, the purchasing of water bottles itself is an issue within the affordability of water in the Global North.

Affordability of Water

Affordability of water can go beyond simple infrastructural issues and can pertain to implemented policies and those who these policies benefit. The price of water is increasing at a rapid pace, alongside the inability to afford water bills within households. At the time of publication in 2017, an estimated 11.9% of households were estimated to not afford paying their monthly water bills. Within the next five years, the number is expected to jump to 36.5% of households who are unable to afford water (Mack & Wrase, 2017). There are a multitude of factors contributing to this increase, ranging from water quality standards changing, infrastructures becoming slow to upgrade facilities,

population growth of cities decreasing, along with the suburbanization of communities (Mack & Wrase, 2017; Pierce et al., 2019). The communities most likely to be effected by water affordability issues are urban areas, as declining populations of cities contribute to the rise of water prices with fewer people living in the city and paying for the water bills.

There are also currently no protection options enforced by federal policies or statutes that can help low-income households that have difficulty paying for water bills and any assistance comes at the decision of the individual water provider. If a household cannot pay, water shut offs and the water debt is paid are some of the few options available (Mack & Wrase, 2017). As affordability of drinking water is rising, there has been an increased reliability on finding other sources of water that were not from water systems, often in the form of bottled water. However, an increase in reliance on water bottles only pushes the growth of bottle industries and serves as only a temporary solution to the issue of water accessibility (Pacheco-Vega, 2019). Relying on water bottles does not solve the issue of the inflated prices households must pay for water services.

Distrust of Tap

Although the reliance of water bottles has grown, it is not always for the sole purpose of affordability. Whether it is due to mistrust of governmental officials or cultural reasons, the issue of water insecurity can also stem from distrust of tap water. As mentioned in the above sections, understanding immigration status and cultural aspects that prohibit water consumption is necessary. Often immigrants from Latin America tend to mistrust tap water because they immigrated from countries where it is unsafe to drink (Patel & Schmidt, 2017). This could be a potential contributor to why immigrants,

specifically immigrants from Latin America, may have a higher tendency to be water insecure.

Immigrants, minorities, and low-educated individuals are more prone to distrusting tap water. Although a portion of this is shaped due to cultural factors, avoidance of tap water in households is also due to mistrust that has formed between the households and government and water facility actors (Pierce & Gonzalez, 2017). Trust between communities and government can be broken due to repeated offenses of water security, such as in Flint, Michigan. The failure of the pipes in Flint and lack of initial responses from governmental officials broke the community's trust. Despite continuous efforts to reverse the damage many still avoid the tap water, therefore leading to an increased reliance on water bottles (Pauli, 2020). Avoidance of tap water is contributing to the ongoing issue of water security because the water is perceived to not be of standard quality and is only further influencing the reliance of bottled water, which then also plays into the issues of affordability of water.

2.4. Research Gaps

Within water security research, understanding the role and importance of water systems is extremely crucial. Water systems can be owned both publicly and privately, with public water systems usually controlled by municipal governments (Pierce et al., 2019). These water systems can vary in the mechanism used to distribute water, the usage for the water, and the size of the system. There are many factors that contribute to efficiency, but a big indicator of the success of the system is the size of the water system and how large of a population it serves (Edwards et al., 2012). Research has shown that

the smaller the water system, the more likely it serves a small low-income community. Because such systems do not serve large populations, a small water system likely does not have proper maintenance performed on it periodically, is not connected to a central water system, and does not have the proper means to upkeep itself (Edwards et al., 2012; McFarlane & Harris, 2018; Pierce et al., 2019). The size of the water systems plays a role in which communities are already at a higher risk of water insecurity. Further research must be done to understand what other characteristics of a water system can influence which communities are vulnerable over others.

In disaster research, there is a relationship in how minority groups and lower - socioeconomic status preparation capabilities play a role in the status of recovery of communities. However, there is not currently an emphasis on research pertaining to the relationship between household drinking water and hurricanes. Although many articles emphasize how water is disrupted by hurricanes, such as in Puerto Rico, it is often mentioned as a supporting point to the number of devastating effects hurricanes have and is rarely the focal point of the paper (García-López, 2018). Although there has been some preliminary research aiming to better understand the social intersections of how water is effected by hurricanes, future research should aim to draw comparisons between the two fields (Coleman et al., 2020). By understanding which communities are more likely to be vulnerable to water insecurity, such as those comprised of mobile homes, urban areas, and minority groups, parallels can be drawn with which communities are most vulnerable to hurricane damage and prolonged recovery to assess if there is a relationship or similar factors between the two (Jepson & Vandewalle, 2015; Pierce & Jimenez, 2015; Truelove,

2019). The goal of the current research on understanding hurricanes and their influences on water systems is attempting to fill the gap investigating how Hurricane Harvey made notable damages to southeast Texas and how these water systems have failed, rebuilt, and recovered. The research objectives for this study include:

- Objective #1: Describe the effects Hurricane Harvey had both during and post-impact on water systems.
- Objective #2: Analyze how water systems failed, recovered, and rebuilt since post-Harvey.

3. METHODOLOGY

The goal of this project is to illustrate how Hurricane Harvey affected water systems in southeast Texas and understand how the systems have rebuilt and recovered through qualitative research. The original research design included travel to the Golden Triangle and conducting surveys with water operators and community members. Focus groups were to be held between various actors involved with Hurricane Harvey recovery, along with interviews on the household level. By gathering a large collection of data through the various means of surveys, focus groups, and household interviews, the project was a field-site study that allowed a wide range of both operational and personal perspectives of Harvey on drinking water.

The initial data collection was intended to begin in April 2020 and continue through August 2020. However, three major external events changed the nature and timing of the research project. First, in March 2020 the United States began nationwide shutdowns due to the spread of the SARS-CoV-2, or COVID-19 virus. During the timeline of the intended data collection, the Centers for Disease Control and Prevention (CDC) enforced guidelines in attempts to prevent the spread of COVID-19. Some of these guidelines included no unnecessary travel, standing six feet apart, mandated masks in some states, and minimal indoor gatherings (AJMC, 2021). These restrictions made it improbable to continue my original research design, and in a short time span the project transformed from a field-site research design, to primarily a desk-study. The amended research design no longer included surveys, travel to the Golden Triangle, or focus groups and household interviews. The project now relied on virtual interviews with water

operators and a few community organizations and creating a narrative through a newspaper analysis. In addition, three major disasters- Hurricane Laura and Delta in August and October 2020, and winter storm Uri in February 2021 - created additional setbacks to the timeline of data collection (Garnham, 2020; Healy,2021; PA News, 2020; SBG San Antonio, 2020).

This chapter will include sections detailing the rationale and contribution towards the overall research design. The first section will describe the methods utilized to address the research question for the project, as well as the objectives to attempt to answer the research question. The second section will describe the case study site, the Golden Triangle, and the significance of the region for Texas. The third section describes data collection using the newspaper collection and semi-structured interviews. The final section details the challenges more specifically on how COVID-19 changed the research project.

3.1. Research Question and Objectives

The research project seeks to explain how natural disasters catalyze the decline of water system infrastructure and the potential for these systems recover and continue to provide secure water for the communities they serve. This project has two major objectives that will address this question:

- *Objective #1: Describe the effects Hurricane Harvey had both during and post-impact on water systems.* This is a crucial objective in that before the research

process begins on identifying how water systems failed and experienced recovery, it is important to understand what happened to the systems that caused their failure. This objective marshals a combination of secondary and primary data collection, through a newspaper article analysis and semi-structured interviews with water operators and community organizations.

- *Objective #2: Analyze how water systems failed, recovered, and rebuilt since post-Harvey*. While the first objective closely details on the water systems during the initial impact of Hurricane Harvey, the second objective will describe the rebuilding and recovery phase of the water systems. This objective centers on garnering perspectives on the administrative side of the water system and involves interviewing water operators.

3.2. Study Site

The study area for this research is on southeast Texas, in a region labeled as the 'Golden Triangle' - Port Arthur, Beaumont, and Orange. These three towns are in two separate counties, the first two in Jefferson County and the latter in Orange County. In August 2017, Hurricane Harvey had significant destruction along the coast of Texas and for three day brought torrential rainfall and catastrophic degrees of flooding to this region (Teitz, 2017a). The Golden Triangle's name stems from the three cities forming a triangle when connected on a map, as shown in the figure below:

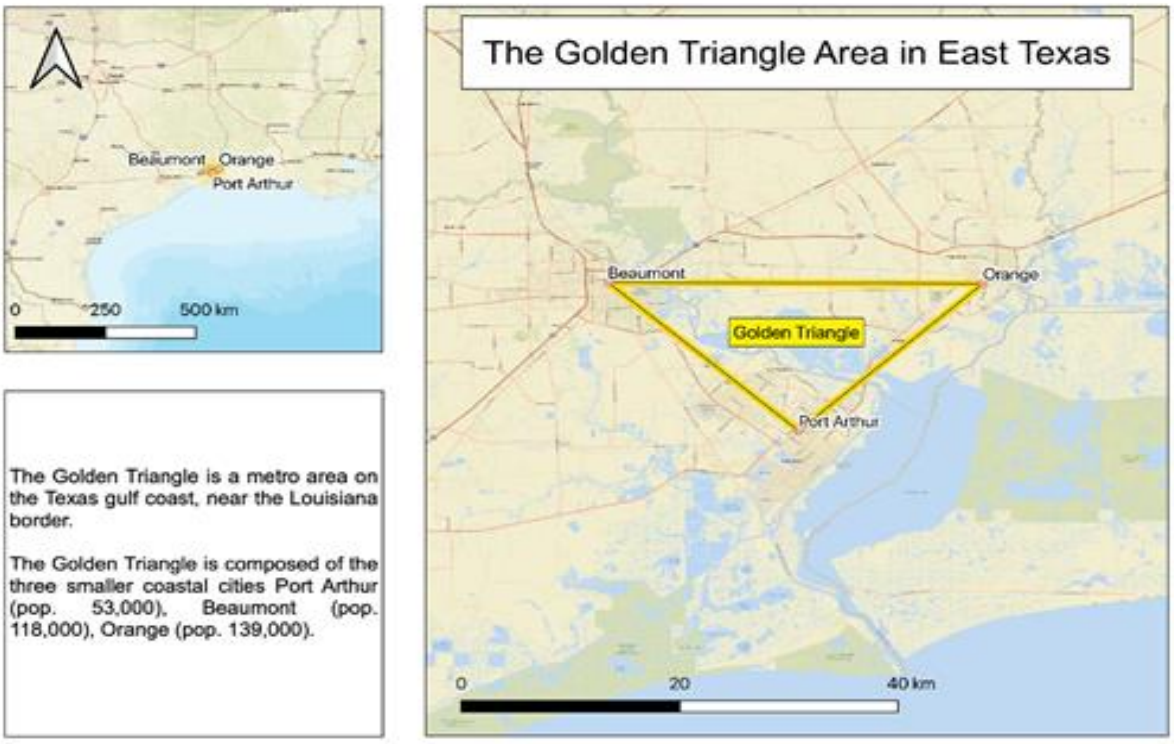

Figure 1: Map of the Golden Triangle in Southeast Texas

These three towns are significant in southeast Texas due to their importance as housing major refinery industries within their borders. There are multiple reasons that Hurricane Harvey and the Golden Triangle are selected for this research project. For one, academic literature and research have grown in the since 2018 regarding Hurricane Harvey. There have been many articles that detail the social vulnerabilities of communities in Houston, the harmful effects of petrochemical plants in southeast Texas following Harvey, and the influence of language barriers on preparation (Flores et al., 2020c; Flores, 2020d; Maldonado et al., 2019). The social vulnerabilities that Flores (2020c) discusses in their article is related to the petrochemical plants in Texas. The low-income

communities in Houston face chronic environmental injustice, due to their prolonged and frequent exposures to leakages and contamination in their water. Other social vulnerabilities are prevalent in southeast Texas due to the high Hispanic populations. There are often language barriers that arise both pre- and post-disaster, as these minority communities do not receive equal communication. This lack of communication contributes to lack of resources and funding, as well as preparation prior (Maldonado et al., 2019).

Although there is growing literature in the long-term recovery efforts of Hurricane Harvey, there is still a noticeable gap regarding research where drinking water following a major disaster is the focal point. The failure of water systems is often reported as engineering failures, but there is a need to pivot the research to the social dimensions of these systems. As mentioned previously, Hurricane Harvey caused the worst flooding instances throughout southeast Texas, and such destruction presented a clear threat to the region's water systems. While Hurricane Harvey's destruction equally affected the region, not all Harvey-affected communities benefited equally from various programs to recover and rebuild.

The Golden Triangle is also poorly researched. Despite Beaumont and Port Arthur making up half of the Golden Triangle's population, they both received significantly less funding for repairs per person. The Southeast Texas Regional Planning Commission (SETRPC) allocated $3.2 million in government funding to Beaumont, but due to their 120,000 population, it only contributes to $40 per resident. Meanwhile, in surrounding towns with a population of only 900, $1 million dollars in funding contributes to $40,000

per resident (Capps, 2018). Many were left without proper funding and repairs on their homes for many months, and 52% of residents in the Golden Triangle expressed needing assistance for housing and repairs (McCausland, 2017). These disparities in the experiences are all necessary to help understand further the issues revolving around drinking water. However, it is necessary to first establish the effects Harvey had on the region. Although Hurricane Harvey did flood many parts of the Golden Triangle, the floods damaged these water systems differently, based on many factors such as funding availability.

Due to the geographic proximity of the Golden Triangle to Texas A&M University, combined with the growing literature surrounding Hurricane Harvey, it seemed the most plausible hurricane to research. The Golden Triangle's proximity to a major city (Houston, Texas) also provides benefits from increased reporting and coverage compared to cities that are extremely small and rural. Through a combination of events, including the documented injustice that the Golden Triangle receives in funding and governmental aid, as well as both the growing literature on Hurricane Harvey in Texas and the slow-growing literature on the social dimensions of water systems and disasters, the Golden Triangle was selected as the case study site.

3.3. Structure of Water Institutions

The water systems that will be analyzed in this study are public water systems that were collected from the Texas Commission on Environmental Quality's Safe Drinking Water Information System (SDWIS) database. It is originally based off of the EPA's database but documents water systems at a state level and reports on all public water

systems (PWS). As mentioned previously, water systems are the pipelines that provide water to associated connections with the water systems. The requirements to be considered a PWS are minimal can be met through either the population size served or the number of household connections. The water system must either offer water through its pipelines to 15 service connections or serve a minimum of 25 individuals for at least 60 days out of a year (EPA, n.d.). The size of a PWS can also vary from very small to very large. It is difficult to quantify specific numbers of populations served or household connections served to categorize the water systems as there are many different classification metrics, but for this project it will utilize population served with the following categories associated: very small (25-500 connections), small (501-3300 connections), medium (3301-10000 connections), large (10001-100000 connections), and very large (100000+ connections) (Pierce et al., 2019).

There are then three classifications of water systems: community, non-transient non-community (NTNCWS), and transient non-community water systems (TNCWS). NTNCWS are systems that supply water for the same individuals at least six months at a time, and include hospitals, schools, and factories. TNCWS include systems that do not supply water to the same individuals for long periods of time and include campgrounds and gas stations (EPA, n.d.). For this project, I will only be looking at the community water systems, which are systems that supply water to the same populations all throughout the year.

Although these are PWS, a key classification is the difference between public and privately operated systems. Public water operators are typically under the supervision of

operators employed with their local municipalities, while private operators are typically investor-owned, non-profits, or corporate owned. Depending on the operating ownership, the structure of the systems can be slightly different. Public operators work through governing boards, and may have stricter regulations to abide by, while the private operators are able to fluctuate their rates without a governing board (Kopaskie, 2016). For this project, a combination of public and private water operators were interviewed.

3.4. Secondary Data: Creating a Narrative Through Newspaper Analysis

Newspaper coverage provided critical empirical information on Hurricane Harvey's events and timeline. The academic or secondary literature is limited in this regard, and, moreover, newspapers have the advantage of reporting immediate and daily updates that bring attention to what the community needs are in the present. After downloading 1031 articles for this project, I kept 389 relevant newspaper articles to help create timeline of Hurricane Harvey events with concentration on the water systems of the Golden Triangle, and how the communities have been able to recover since the disaster.

The first step in the collection of this secondary data involves sourcing a database for newspaper collection. To maximize efficiency in collecting hundreds of articles to create this narrative, newspaper databases allow access to large archives of articles. Newsbank was selected as the main database for this project, as it is both open-sourced through Texas A&M University and archives articles from Texas-specific newspapers. The three selected newspaper sources include the Houston Chronicle, Port Arthur news, and the Beaumont Enterprise. All three were chosen due to their location either within or near the Golden Triangle, as well as their abundant number of sources when key words

including a variation of "Harvey" and "water" were found. All search criteria focused the date from "2017 - 2020." Using a variety of boolean operators and key terminology, the main search criteria produced a variety of results. Below is a table of a summary of the key details, such as the source, years published, search terms used, along with the number of results for each:

Table 1: The search criteria on News bank for all newspapers

News Source	Years Available	Search Criteria	Results (N= #)
Houston Chronicle	Aug 2017 - Aug 2019	Port Arthur AND Harvey AND water	55
Houston Chronicle	Aug 2017 - Jan 2020	Beaumont AND Clean AND water AND Harvey	17
Houston Chronicle	Aug 2017 - Jan 2020	Water AND system AND Fail* AND Harvey	85
Houston Chronicle	Aug 2017 - Aug 2018	Water AND infrastructure AND Harvey	170
Beaumont Enterprise	Aug 2017 - Nov 2017	Water AND fail* AND Harvey	32
Port Arthur News	2016 - 2019	Water AND fail* AND Harvey	29
Baytown Sun	2016 - 2019	Water AND fail* AND Harvey	20
Port Arthur News	2016 - 2019	Water System NOT Damon AND Recover*	35
Beaumont Enterprise	2016 - 2018	Water System AND Recover*	20
Beaumont Enterprise	2017	Water AND Suppl* And Harvey	77
Port Arthur News	2017 - 2020	Water AND infrastructure AND Harvey	60
Port Arthur News	2017	Water AND Suppl* And Harvey	76
Beaumont Enterprise	2017 - 2020	water AND harvey NOT flood	101
Port Arthur News	Aug 2017 - Sept 2017	water AND harvey NOT flood	62
Houston Chronicle	2017 - 2020	Drinking water	6

Port Arthur News	2017 - 2020	Water system AND harvey	83
Houston Chronicle	2017 - 2020	Water system AND harvey AND Beaumont	10
Port Arthur News	2017 - 2020	Water Treatment AND Harvey	9
Beaumont Enterprise	2017 - 2020	City water supply AND harvey	25
Beaumont Enterprise	2017 - 2020	City water service AND harvey	9
Beaumont Enterprise	2017 - 2020	Running water AND Harvey	34
Beaumont Enterprise	2017 - 2020	Boil Notice AND Harvey	16

The articles were saved under the format of: *newspaper source acronym_search terms_ years published*. As an example, all 55 articles found in line 4 of table are from the Houston Chronicle, and the file names were saved as HC_PortA_Harvey_Water_2017-2019. This is done with the intent of preserving their search criteria and efficient categorization of the article origins, in the case that the article search needs to be replicated. A record of the search criteria and newspaper sources that produced limited necessary articles was also kept minimizing repeated searches. As the search terminology was kept broad, some of the articles were not necessary or relevant and were weeded out of the files. Some instances occurred where the same article was downloaded for two different search criteria. Under those circumstances, the repeated article would only be recorded once and labeled under the first criteria that it appeared in. Based on the common themes found within the articles as well as extracting the necessary information to narrate the forces of Harvey, the articles were split into three main subsections: (I) Overview of Harvey, (II) The Golden Triangle and Hurricane Harvey, (III)

Drinking Water in the Golden Triangle. This created the narrative to help show exactly what sort of damage Hurricane Harvey had in Texas in general, but most importantly, the Golden Triangle in both short-term and long-term.

3.5. Primary Data: Semi-Structured Interviews

After developing a detailed timeline of events leading to the landfall of Harvey and water resources and water systems in the region, I sought to interview water operators. , I conducted semi-structured interviews with water operators and community organizations based in the Golden Triangle. The goal of the interviews was to get a broad perspective on what Harvey did to water systems, services, and security at both the operational and community level.

Developing Sample Frame

I used the Texas Commission on Environmental Quality's (TCEQ) Safe Drinking Water Information System (SDWIS) database to collect the contact information of water operators in the region. This database is similar to the EPA's database on public water systems (PWS), but by utilizing TCEQ's it was much more efficient due to being Texas-specific. On their database (https://dww2.tceq.texas.gov/DWW/), the user can set the parameters for what specific public water systems that are of interest. I left all the parameters untouched, except for two, to allow for the most possible water systems. Under 'Water System Type' I opted for "Community" as opposed to "Non-Community" and "Non-Transient" water system types and searched specifically for Jefferson and Orange County. This leaves 49 systems remaining, but after removal of a few non-plausible ones for this project, such as a Federal Correctional Complex of Beaumont and hotel resorts, I

was left with 14 in Jefferson and 30 in Orange County. I created a spreadsheet of the PWS contact information listed on the 'Summary Sheet' for each system that included their name, phone number, and address. Of the combined 44 water systems, there are 28 remaining with unique contacts, due to some water systems having PWS contacts who operated or owned multiple systems in the county.

I contacted the 28 unique contacts and secured an interview with eight water operators. Of these eight, one was a referral from another operator that was interviewed. Although the actual water systems themselves were community systems, the water operators interviewed were a combination of public servants who worked directly for municipalities, and private contractors hired to oversee the systems.

The community organization contacts were solicited from a Port-Arthur native staff member at Texas A&M University, who I worked closely with to collect background information and contacts for organizations. Of the six I received, unfortunately there were only three respondents who were able to make an interview. One was a supervisor for an organization dedicated on providing water filters and accessibility to non-bottled water following disasters. Although this organization is originally based in North Carolina, there is a Texas A&M University chapter based in College Station, Texas. The other interview is with a religious organization in southeast Texas, that specifically has a disaster response team and are frequently assisting in hurricane recovery. The final interview was with an individual responsible for the shelters of evacuees and distribution of resources in one of the municipalities within the Golden Triangle. Total, between the water operators and

community organizations, I had eleven total interviews. These participants will have a correlated number, and this table can be used to reference the role of each participant, whether they are a private or public operator, and their associated number:

Table 2: Classification of interviewees

Role of Participant	**Private or Public Operator**	**Participant Number**
Water Operator	Private	#1
Water Operator	Private	#2
Water Operator	Public	#3
Water Operator	Public	#4
Water Operator	Public	#5
Water Operator	Public	#6
Water Operator	Private	#7
Water Operator	Public	#8
Community Organization	-	#9
Community Organization	-	#10
Community Organization	-	#11

Semi-Structured Interviews and Codebook

The interviews were conducted virtually over Zoom due to the COVID-19 pandemic making it improbable to hold in-person interviews. These interviews were scheduled in a two-week time frame, and approximately 30-45 minutes in length. With

oral consent from the participants, both the auto-transcription was turned on and audio was recorded for a final transcription. The interviews followed a semi-structured format, where although a set list of questions did exist for each interviewee to potentially discuss, not all interviewees received the same questions due to the natural progression and flow of the interview. However, each interview covered the basics of each theme, such as Hurricane Harvey, recovery, governmental roles, and trust.

To analyze the interviews, I imported the transcripts into MAXQDA for qualitative analysis and coding. To do this, I created a very basic codebook for the different themes that my interview questions covered. I used deductive coding and developed my codebook prior to the interviews by structuring my interview questions to address the common themes surrounding water systems and hurricanes that appeared in the existing literature. Deductive coding was selected as it allowed myself to set criteria goals during the interviews on what the specific goals of each question should include. It also allows for consistent coding and evaluation to be performed amongst all eleven interviews. The table below provides a brief overview of the codes that were selected, as well the as the literature that helped guide the selections:

Table 3: Codebook used for MAXQDA

Code Used	Why was this code picked?	Citations
Preparation	This code was picked to demonstrate how interviewees prepared for Hurricane Harvey. Preparation has shown to impact the varying degrees of disasters post-impact, and can include preparation for infrastructure, personnel, or resources.	(Grineski et al, 2019)
Hurricane Harvey Impacts	This code is to help pull the personal experiences of the water operators and organizations and what degree of impact that Harvey may have had on them.	(Wright, 2017d; Branham, 2017)
Community	Following a disaster, community relationships tend to strengthen and community resiliency follows a disaster. This code is to help demonstrate the ways the communities assisted with one another, both in general but also with water	(Patel et al., 2017)
Role of Government	This code is to demonstrate the roles of the differing levels of government - local, state, federal - following Harvey. The code is also to showcase the satisfactory rates and experiences the interviewees have had with the varying degrees of government	(Checker, 2017)
Funding/Aid	The funding/aid code is to demonstrate what forms of assistance these interviewees received following Harvey, as well as whether the various forms of aid were considered satisfactory or not	(Peacock et al, 2014)
Technology and Infrastructure	This code is to better understand the technological and infrastructural changes that have taken place following Harvey, especially with the water systems	(Copeland, 2005)
Trust	As trust can be shaped by funding, government, or technology, this code is to demonstrate the level of trust that the interviewees have with these other factors. The aim is to better understand where the trust or mistrust stems from	(Pauli, 2020)
Barriers to Improvement	This code is to understand what barriers, if any, that the interviewees believe are preventing them from either feeling recovered from Harvey, or adequately prepared for the next disaster that may occur.	(Pierce & Gonzalez, 2017)

From there, the codebook helped in analyze the similarities and differences between the experiences of the different water operators and community organizations.

3.6. Research Challenges

The original research project was created in the Fall of 2019, with intentions of the full research process to begin in early summer. However, in January 2020, the SARS-CoV-2, or COVID-19 for short, began to become a widespread global pandemic. By March 2020, COVID had finally made it's largely expected impact on the United States, prompting a national shutdown and mandatory quarantine period. During this time, schools were shut down, businesses were ordered to remain closed unless deemed essential, and travel was highly prohibited unless an emergency, in attempts to control the furthering of the spread of COVID-19. Despite some people's best efforts in the early months, the virus continued to be highly contagious and negatively influence the economy, people's livelihoods, and education. Since the initial shut down in March 2020, as this project is currently being performed, the nation has not fully reopened, and certain guidelines are still in place. At the time of the interview process of my research, the CDC still did not recommend unnecessary travel and masks were still mandated in some states, and vaccines had just recently begun to be available for the public (AJMC, 2021).

COVID-19 Adaptations

These mandates have made catastrophic alterations on a variety of research, in particular qualitative projects. This project is extremely qualitative in respect to gathering primary data, and many adaptations have had to come about in the last few months. Some of the major challenges include altering interviews and getting rid of focus groups, limited

travel allowed, and limited accessibility to individuals due to social distancing guidelines. Due to no in-person interviews allowed because of social distancing guidelines, it has altered the style of qualitative work this research will include. While previously the project was reliant on in-person interviews that were to be audio-recorded and transcribed, the new method was switched to being strictly virtual over Zoom. This has limitations, as not everyone is well-equipped to do interviews over Zoom, whether it is because of lack of computer and stable internet connection, or simply the barrier of having a harder time understanding how Zoom works. There may be a learning curve for some of the older participants who are wary to be interviewed over a new virtual platform. The meetings will have to be recorded and transcribed using other software as well. Since the interviews are not virtual, focus groups have been eliminated as well.

As mentioned previously, there are many difficulties and barriers to virtual interviews that are not present in-person, and it is difficult to coordinate large groups to meet virtually and ensure a productive meeting and will therefore not be utilized. Although the Golden Triangle is located only a few hours from Texas A&M University, travel is restricted and eliminated due to the possibility of spreading COVID-19 amongst different communities and is another contributing factor to making it all virtual.

Due to these ongoing challenges and adaptations to the original research design, it caused a substantial shift in the timeline of the research. While the IRB process and interviews would have begun in early-May, due to uncertain nature of the virus, all research plans were put on a temporary hold until early-August, when there is a better assessment of how the virus will likely play out to the end of the year. In the original

timeline, the research gathering process was to end by August, and with the shift, it did not even start until August, causing a 3–4-month shift in the entire timeline. Instead of having separated times for data gathering, analysis, and writing the results, the shift in the schedule had caused it to be performed all at once.

Hurricane Season 2020 and Winter Storm 2021

Due to the timeline shift, a new obstacle came to take place. Hurricane season begins in June, and its peak activity is during the months of August and September. While previously the original timeline did not have research conducted overlap with when the Golden Triangle is not at risk of being targeted by a hurricane, it was now simultaneously being done when they are most at risk. This is an obstacle in that it is impossible to determine if the Gulf of Mexico will have hurricane impacts in southeast Texas, let alone how intense of one. Extra attention must be paid to the current activities of hurricanes, as there is always a possibility of having to shift the timeline and research goals if the Golden Triangle were to be majorly hit once again. This was almost necessary, as Hurricane Laura was projected to make landfall in the southeast Texas and Louisiana border as a major Category 4 storm (Garnham, 2020; SBG San Antonio, 2020). Although the Golden Triangle was not a direct hit for the hurricane as originally projected, the rapidity in which a second threat of a strong hurricane, Delta, was threatening to strike the region made it clear that it would be incredibly difficult to get in contact with water operators. Trying to perform Hurricane Harvey research during the peak of a new hurricane season is tricky, as there is the possibility of a new hurricane that can drastically change the purpose of this research project.

The final limitation of my research project was the Texas winter storm and freeze that impacted the entirety of the state in February 2021. Due to unprecedented freezing temperatures all throughout Texas, many water systems and pipes were frozen and faced widespread damage through burst pipes (Healy, 2021). Due to all the setbacks that occurred as mentioned earlier, the timeline of my thesis turned into the data and interview process not being feasible until February. However, due to the winter storm, I was not able to reach out to water operators until late February, early March, as most water operators were extremely busy handling the damages to their water systems and simply did not have enough time to interview with me.

Adaptations

As mentioned previously, the major adaptations were due to COVID-19 preventing travel and conducting interviews in person. Due to the combination of timeline shifts and inaccessibility to meet with interviewees in person, the decision was made to alter my research design so that I only had two research objectives. The third objective was (3) Evaluate whether water recovery efforts have improved water security for households and communities. However, this was no longer plausible, and all aspects of household interviews were no longer included in the research design. This created a need to emphasize water operators and the utilities perspective of Hurricane Harvey more than the community perspective, as the household interviews and focus groups was where the core of the data was originally going to stem out of. Despite all these challenges and setbacks, with the project needing to be reshaped, but I was still able to have ten interviews to help offer perspectives on water systems and recovery following Hurricane Harvey.

4. NEWSPAPER ANALYSIS: A NARRATIVE OF HURRICANE HARVEY

This chapter reviews Hurricane Harvey event and post-recovery timeline for the region to provide a detailed context within which to situate the hurricane's impact on water resources and drinking water systems. As mentioned in the previous chapter, to answer the research question over the relationship between hurricanes and water systems objectives one and two must first be met. Objective 1, 'describe the effects Hurricane Harvey had both during and post-impact on water systems', is accomplished through the newspaper analysis that was detailed in chapter 3. Prior to conducting interviews, it is crucial to narrate the events of Harvey to contextualize the gravity of the effects that the hurricane had on the state of Texas, let alone on the Golden Triangle. Creating a narrative of the extent of the damages from Harvey also helped guide the questions that were formulated for the semi-structured interviews for more specific details on how the water systems and drinking water was affected and provided the foundation for the themes that would emerge in the interviews.

This chapter is split into three main sections. The first two sections will consist primarily of the summaries of the newspaper articles. Section one provides an overview of Hurricane Harvey, narrating the catastrophe and the devastation the hurricane left in its wake throughout the Texas coast. Section two will then describe how Hurricane Harvey tore through the Golden Triangle and the regional recovery efforts that followed. The third section will then provide an overview of communities within the Golden Triangle had their drinking water affected. This includes both newspapers and interviews, as the newspaper can provide a broad understanding of the drinking water impacts while the

interviews can provide personal anecdotes and experiences from both the water operators and community organizations.

4.1. Overview of Harvey

The Atlantic Ocean and Gulf Coast face hurricane threats every summer and fall. The hurricane season of 2017 recorded catastrophic hurricanes, and it is one of the most costly years for hurricane reparations, totaling a near 294 billion dollars (Smith, 2018). Hurricane Harvey made an initial landfall near Rockport and Port Aransas, located in South Texas, in the late evening on August 25th, 2017, and had 130 mph winds and 10-foot storm surges (Foxhall, 2018). In Rockport alone, the damage cost nearly $221 million dollars for a full recovery.

Hurricane Harvey affected the majority of the Texas coast, beginning in south Texas and moving north along the coastline, towards Louisiana). Intense rainfall lasted nearly 7 days, from the original landfall on August 25th and ending on the 31st, displacing over 30,000 residents. More than 13 million Texas were directly effected by the storm and rainfall associated with Harvey reached more than 100 miles inland (Tompkins, 2017b). Nearly 6.9 million people experienced over 30 inches of rain, and 1.25 million experienced more than 45 inches. Of the regions that were most effected, 11,000 received over 50 inches of rain (Salinas, 2018). Beaumont recorded 26 inches of water in 24 hours, and had five feet of rain over five days (Teitz, 2017a). Annually, Port Arthur records close to 60 inches of rainfall per year. However, in the days immediately following Harvey, the town recorded close to 50 inches, almost totaling the yearly average in a single rain event

(Wright, 2017b; Branham 31 Aug. 2018). Hurricane Harvey was unprecedented in that it was the rainfall and subsequent flooding that contributed to the colossal damages. Compared to prior strong hurricanes, such as Ike in 2008 and Rita in 2005, that left marks in Texas, their damages stemmed from wind events (Meaux, 2017). As damage came from unprecedented rainfall, there was a higher rate of infrastructure damage and increased cost in repairs as cities were not prepared for the flood levels. Harvey is the 3rd consecutive year of historic flooding for the city of Houston and was the second hurricane to make landfall in the last decade (Diaz, 2019).

In total, Harvey was one of the costliest disasters in the United States, only behind Hurricane Katrina in 2005 (Stickney, 2019). Hurricane Harvey is associated with extreme economic loss and extensive damage for the state of Texas. It is estimated to have cost $125 billion in damage and repair costs. Some of the most damaged infrastructure included roads, bridges, railroads, and the energy industry (Eaton, 2017a; Collette, 2018). In both South and Southeast Texas, Harvey temporarily forced the closure of much of the states and nation's energy and petrochemical sector (Blum, 2017).

Hurricane Harvey left thousands in need of assistance. More than 500,000 residents applied immediately for federal aid, ranging from housing shelter, food, water, and medical aid. FEMA approved $114.7 million to be distributed amongst 161,000 people, and of this amount, nearly $33.6 million was directed to housing assistance to help assist with the 300,000 homes and businesses that were destroyed (Barned-Smith, 2017; Wallace, 2017). FEMA played a pivotal role in the recovery efforts, such as the

distribution of 180,000 meals following Harvey (Chronicle, H., 2017). However, nearly 75% of Harvey's survivors had FEMA requests denied due to lack of funding availability (Chronicle, H, 2017).

Hurricane Harvey impacts differed depending on the region. Southeast Texas was met with rainfall and floods, while south Texas was met with extreme wind damage. However, one common theme in the effects of Harvey was that it exposed the state of Texas's weak spots in the energy supply industry (Eaton, 2017a). The Gulf of Mexico is home to many refineries and oil industries. In preparation for Harvey, 1/4th of all refineries in Texas temporarily shut down operations (Eaton, 2017b). Nearly 25 tankers that held 17 million barrels of crude oil were not able to offload their supplies (Eaton, 2017a). Although the crude oil sector was hit hard, the petrochemical sector was even more dramatically harmed, with nearly ½ of all ethylene production temporarily shut down. During normal operations, 2.4 million barrels of crude oil are turned into petroleum on a daily basis (Eaton, 2017a, 2017b). After a state of disaster was declared on August 23rd, some industries waited more than three days to suspend their operations (Stuckey, 2018). This lack of procedure and coordination of action from these plants shows that Texas's energy sector has much to improve on in relation to the actions plans taken during a disaster. Arkema Inc.'s chemical plant eruption and volatile chemicals that leaked from their facility made the local residents in Crosby, Texas susceptible to pollutant exposures. Due to floodwaters, important cooling systems went forcibly taken offline, leading to contamination leaks and forcing residents who lived within a 1.5-mile radius to evacuate (Barned-Smith, 2017). In Galena Park, Texas, a leak occurred at a nearby gasoline facility.

However, it did not get immediately made public that the spill had occurred, and for days residents reported their eyes burning and a strong odor outside. In fact, it took six days, when it was mostly cleaned up, that it had become public that a spill had even occurred (Eaton and Blum, 2017).

Despite these pollutants and leakages, on August 28th Texas Governor Greg Abbott suspended all environmental violation reporting, including to the Texas Commission on Environmental Quality (TCEQ) (Stuckey, 2018). This was done so that industries could concentrate on rapid preparation and repairs, to further minimize any leaks and spills. This had the unintended consequence of underestimation of pollution that occurred immediately following Harvey, as companies failed to self-report many pollutant leakages. It is currently estimated that there were nearly 100 different toxic spills that were widespread on land, water, and air pollution (Stuckey, 2018). After nearly 8 months, the environmental violation reporting was once again reinstated, but by then there is prolonged inaccuracy in environmental data. In Galena Park, despite the obvious pollutants that the residents were exposed to, it took 295 days for TCEQ to send the initial notice of violation (Stuckey, 2018. Due to more than a predicated 150 million gallons of sewage and industrial discharge that had spilled throughout Texas, the waters were heavily polluted (Stuckey, 2018). One of the most disturbing aspects of this is that this estimate of 150 million gallons of sewage is predicted to be a gross underestimate due to lack of reports (Stuckey, 2018).

Hurricane Harvey also showcased the importance of community resiliency. Many nonprofits and organizations rallied to donate labor in assistance efforts, such as Catholic Charities US, who coordinated 500 volunteers to travel to southeast Texas (George, 2017). While the US military and first responders were coordinating rescue missions, community-based rescues were also ongoing using a popular mobile app, Zello. This allowed users to report and plot locations themselves of where known hurricane victims needed assistance. The users themselves can put their location on a map. An ad-hoc volunteer group called the Cajun Navy organized the usage of Zello for rescue missions and created a channel called "Texas Search and Rescue" (Atkins, 2017). Having a public medium for the app encouraged community resiliency and was a relatively easy forum for other individuals to assist and help alleviate any pressure that the first responders faced.

Hurricane Harvey affected various bodies of water - from rivers and levees, water pollution, and drinking water. In Houston, the Addicks and Barker Reservoirs were overflowing from the intense rainfall. The reservoirs were at risk of collapse, and to prevent the flooding of a major highway, water was intentionally released into the nearby Buffalo Bayou. This action contributed to the flooding and destruction of nearly 4000 homes in the path (Barned-Smith, 2017; Carroll, 2017). Due to the damages that the Addicks and Barker Reservoirs experienced, there have been ongoing rehabilitation and construction through the A&D Dam Safety Project, with the intent of also improving infrastructure to minimize the risks of collapse in future rain falls (Powell, 2018). To prevent future failures, solutions to future infrastructure failures must be extensively researched (Collette, 2018).

Many levees and reservoirs were damaged during Hurricane Harvey, primarily from flooding. A consistent issue with infrastructure repairs is the inability to fund all necessary repairs in a timely manner leading to a delay in repairs. The slow-paced release of that disaster funds to Texas for Hurricane Harvey is only further exacerbated from an already-existent $4 billion backlog of funding for civic work projects that were to be distributed over the course of a decade (Diaz, 2019). In 2018, Congress passed the Bipartisan Budget Act, with the expectation of some funding to be distributed for the US Army Corp of Engineers to repair Harvey-related damaged infrastructure from (Powell, 2018). Although the Bipartisan Budget Act was passed, the question of how the funds are allocated and to what specific regions are receiving the money is highly contested. In Harris County Flood Control District will take the lead in the planning of the repairs, and the Army Corp of Engineers providing insight (Powell, 2018). However, in 2019 federal funds for storm protection funds were yet again threatened. There was speculation that some of the federal funds would be re-allocated to the Trump administration's border wall funds, and the remainder of the funding would then go to the Army Corp of Engineers for levee repairs (Diaz, 2019).

As mentioned previously Hurricane Harvey caused astronomical financial damage to Texas. It left many individuals without a home through mandatory evacuations. 34,000 people evacuated to churches, schools, parks, and convention centers. Hotels temporarily suspended hotel tax collection, and 24,000 had their hotel rooms covered by the Federal Transitional Shelter Assistance program (Zelinski, 2017). Governor Abbott opened up state parks to become evacuation centers and many suspended all fees. More than 5,000

people in 39 parks took refuge in camping sites, with Garner State Park housing the most (Tompkins, 2017a).

4.2. Texas during Harvey

Hurricane Harvey had differing lasting shocks on the different regions of Texas. Southeast Texas was met with extreme flooding and rainfall, while south Texas was met with extreme wind damage. However, one commonality in the effects of Harvey was that it exposed the state of Texas's weak spots in the energy supply industry (Eaton, 2017a). The Gulf of Mexico and all throughout the Texas coastline have dozens of both refineries and gas tankers operating. In preparation for Harvey and upon-impact, 1/4th of all refineries in Texas had to temporarily shut down operations (Eaton, 2017b). Nearly 25 tankers that held nearly 17 million barrels of crude oil were not able to offload their supplies (Eaton, 2017a). Although the crude oil sector was hit hard, the petrochemical sector was even more dramatically damaged, with nearly ½ of all ethylene production temporarily shut down. The drastic events of crude oil and petrochemical industries being shut down is showcased best when put into context of how typically 2.4 million barrels of crude oil are turned into petroleum daily (Eaton, 2017a, 2017b). After a state of disaster was declared on August 23rd, some industries waited more than three days to suspend their operations (Stuckey, 2018). This lack of procedure and coordination of action from these plants shows that Texas's energy sector has much to improve on in relation to the actions plants will take during a disaster.

Although much of the oil industry was shut down in preparation for Harvey, there were many issues regarding pollution and leakages caused by damage from impact. Residents in Crosby, Texas, were subject to Arkema Inc. 's chemical plant from erupting and causing volatile chemicals to leak out of the facility. Due to floodwaters, important cooling systems were forcibly taken offline, leading to the leaks and forcing any residents who lived within a 1.5-mile radius to evacuate (Barned-Smith, 2017). In Galena Park, Texas, a city within Harris County, a leak occurred at a nearby gasoline facility. However, it was not immediately made public that the spill had occurred, and for days residents reported their eyes burning and a strong odor outside. In fact, it was not until six days later when it was mostly cleaned up that it had become public that a spill had even occurred (Eaton and Blum, 2017).

Despite these pollutants and leakages, on August 28th Texas Governor Greg Abbott suspended all environmental violation reporting, including to the Texas Commission on Environmental Quality (TCEQ) (Stuckey, 2018). This was done so that industries could concentrate on rapid preparation and repairs, to further minimize any leaks and spills. However, this has brought into question whether some industries then felt encouraged to downgrade the amount of pollution that may have occurred at their facilities, contributing to the overall underestimation of pollution due to Harvey. It is currently estimated that there were nearly 100 different toxic spills that were widespread on land, water, and air pollution (Stuckey, 2018). After nearly 8 months, the environmental violation reporting was once again reinstated, but by then there was very little TCEQ could do, as mentioned previously many industries may not have reported accurate numbers as to what pollutants

left their facilities. In Galena Park, despite the obvious pollutants that the residents were exposed to, it took 295 days for TCEQ to send the initial notice of violation (Stuckey, 2018).

Hurricane Harvey saw the emergence of community resilience and showcased the best of humanity and how all over the US people came together to help with rescue missions, volunteer at shelters, and donate any necessary resources. Many nonprofits and organizations rallied to donate labor in assistance efforts, such as Catholic Charities USA organizing nearly 500 volunteers to southeast Texas to help assemble hygiene kits and distribute them (George, 29 Sept. 2017). While the US military and first responders were working around the clock to aid in as much rescue missions as possible, Hurricane Harvey also saw the increase in community-rescue missions through the usage of Zello. Zello is an app on mobile devices that allows users to report and plot locations of where known hurricane victims are that need assistance. The users themselves can put their location on a map or a third-party can do it for them. An ad-hoc volunteer group called the Cajun Navy organized the usage of Zello for rescue missions and created a channel called "Texas Search and Rescue" (Atkins, 2017). Having a public medium for the app encouraged community resiliency and was a relatively easy forum for other individuals to assist and help alleviate any pressure that the first responders faced. The pivotal and crucial role that the Cajun Navy played will be further explained in section 4, "Golden Triangle."

As mentioned in section 1, Hurricane Harvey caused astronomical financial damage to Texas. It left many individuals without a home and forced many to evacuate

their homes with very little places to go. At the peak of Harvey, more than 34,000 people evacuated to churches, schools, parks, and convention centers. Post-Harvey, so many houses were destroyed that more people were left without a home (Zelinski, 2017). Hotels temporarily suspended hotel tax collection, and more than 24,000 had their hotel rooms covered by the Federal Transitional Shelter Assistance program (Zelinski, 2017). Governor Abbott opened up state parks to become evacuation centers and many suspended all fees. More than 5,000 people in 39 parks took refugee in camping sites, with Garner State Park housing the most people (Tompkins, 2017a).

4.3. The Golden Triangle and Hurricane Harvey

Initial Impact

Although the Golden Triangle is a refinery region of Texas, many residents in these towns are low-income, blue-collar workers, who are often disproportionately offered less financial aid compared to their neighboring city, Houston (Capp, 2018; Tabuchi, 2020). Port Arthur was heavily obstructed by flood waters, with nearly 35 inches of rainfall in 27 hours (Dranham, 2018). In Beaumont there was 26 inches of rainfall in 24 hours. Within five days, an unprecedented five feet of rainfall was recorded (Teitz, 2017a). Floodwaters overwhelmed the Neches River Saltwater Barrier and to prevent collapse, the water from the Sabine Reservoir was forced to be released (Teitz, 2017a).

In Port Arthur, residents who did not evacuate hung sheets out of windows for responders and rescuers to identify what houses needed aid. Hurricane Harvey rainfall began by Tuesday, August 29th, and by the 30th, 150 boats were preparing to brace against

the floods to begin rescue missions (Hartman, 2017). The Cajun Navy dedicated their rescue missions in the Golden Triangle and utilized the Zello app to help identify individuals in need. Of the 150 boats ready on the 30th, 100 of them belonged to the Cajun Navy. Within 7 hours of Harvey's power, they had already begun their rescue missions (Hartman,2017; PA News, 2017). Total, in two weeks the Coast Guard assisted in more than 10,000 rescue missions (Rincon, 2018). In Port Arthur, more than 3,100 boat rescues were performed in the first day (Harrison, 2017). However, the shelters that the evacuees were taken to quickly reached capacity. By August 31st, two of the largest evacuation sites, Port Arthur's Bob Bowers Civic Center and Lumberton's Parkway Life Church, began to flood and evacuees once again were forced to relocate (Teitz, 2017a).

The estimated cost of repairs in Port Arthur is estimated to range from 500 million to 1 billion dollars for all repairs. A year after Hurricane Harvey, Beaumont still had 6% of their infrastructure damaged, totaling to around 2250 structures. Despite a year passing, two-thirds of these structures still required funding for repairs (Foxhall, 2018). In Port Arthur 85% of all infrastructure were damaged by flooding. By May 2018, Port Arthur disbursed $22 million dollars on Harvey recovery but continued to be met with funding issues (Salinas, 2018).

FEMA and Governmental Aid

The Golden Triangle has needed an extensive amount of assistance since Hurricane Harvey made an impact on August 29th. FEMA's presence has been prevalent in both funding for infrastructure damage and providing shelter. FEMA had been working extensively with the Texas Division of Emergency Management to bring temporary

housing options to residents of displaced community members. Hundreds of residents were forced to evacuate outside of the Golden Triangle region, going as far as Garland and Dallas, Texas (Meaux, 2017b). Floating barges that could house 300 people were initially proposed to assist residents whose homes were inhabitable but was later suspended due to failing regulations with the Coast Guard (PA News, 2018). Initially, much of Jefferson County was overlooked on receiving disaster housing assistance due to the abundant number of hotels in the county, but what was not taken into initial consideration was how much damage the hotels themselves endured and their inability to house evacuees. After federal agents reevaluated their decision, it was overruled, and more housing assistance was provided (Meaux, 2017b). In total, FEMA approved more than 32,000 registration applications for Individual Assistance in Jefferson County, with almost 600 receiving direct housing assistance, and 3,700 receiving small-business disaster loans (Salinas, 2018). Despite various forms of FEMA funding for housing, there were still many who did not receive the funding that was needed to recover and felt difficulty in both applying and receiving these FEMA funds.

Hurricane Harvey's sheer wind forces uprooted vegetation and destroyed infrastructure and property. The combination of these damages led to over 1.2 to 1.5 million cubic yards of debris to be scattered around Port Arthur (Ball, 2017a). FEMA agreed to assist in funding 90% of the debris cleanup costs, leaving municipal governments the responsibility to fund 10% of the cleanup (Wallace, 2017). However, tensions arose among municipal government officials in smaller towns when Texas Governor Greg Abbott hand-delivered a check paid through the governor's funds to

Houston that fully covered their 10% cost (Wallace, 2017). Amongst some drawbacks, Governor Abbott visited Port Arthur and also delivered a check from the governor's fund to cover 5% of Port Arthur's portion. In total, Port Arthur's costs were to be an estimated 25 million dollars. With Governor Abbott's assistance, Port Arthur was left with only having to pay 1.2 million dollars (Wallace, 2017).

Community Resiliency

Following Hurricane Harvey, the Golden Triangle was home to a wide variety of volunteering effort and showcased the best of community resiliency. Although aid came from both the state and federal level, volunteers gathered from all over the nation to help the Golden Triangle. Some non-profits, such as the United Way, collaborated with nearly 21 different agencies to help fundraise and bring supplies to the area and donated over 150,000 supplies (Meaux, 2018). Different organizations worked towards different resources, such as the Salvation Army serving more than 5000 meals through mobile kitchens throughout the Golden Triangle (Wright, 2017c). Due to the flooding and emergency evacuation of the Bob Bower's Civic Center, a bowling alley quickly converted their building into makeshift shelter. As they were not a registered Red Cross shelter, they were not equipped ahead of time with cots, blankets, and resources to distribute. However, the community donated supplies and helped this makeshift shelter become comfortable (Wright, 2017a).

Jack Brooks Regional Airport, located near Port Arthur, also found itself at the center of aid and recovery. Between August 30th to September 10th, more than 2300 flights took place, doubling the average air traffic in a six-month timespan. A variety of

operations were based at this airport, ranging from donations, evacuating more than 4000 individuals, or a mobile hospital set up in the parking lot (Bergeron, 2017). Jack Brooks Regional Airport proved to be an essential asset during disaster recovery, that the Nederland Economic Development Corporation began a development project, "The Landing." IIt was created with the intent to have a backup water storage facility. This was in part of efforts being implemented to increase storage capacity of water in the Golden Triangle in the future case that any disaster will once again impede community water supply anywhere in the region (Meaux, 2017c).

Energy Sector

The Golden Triangle is a region with a large refinery industry. Port Arthur is home to oil operations with numerous major companies, such as Valero, Chevron Phillips, and BASF. Port Arthur faced some of the worst of the environmental pollution due to compromised facilities. On August 29th, Flint Hills Resource Facility in Port Arthur began their facility shut-down process when one of the units lost control of their steam and released nearly 533,000 pounds of air pollution (Stuckey, 2018). Porth Arthur and Beaumont's BASF Corporation and TOTAL Petrochemicals & Refining USA facilities also faced leakages during Harvey, with nearly 149 million gallons of raw sewage becoming exposed to nearby communities. BASF's pesticide plant overflowed due to the extreme flooding, exposing non-hazardous process chemicals into discharge water (Stuckey, 2017). In some cases, such as Valero Port Arthur Refinery, there were damages that were minor, but post-Harvey turned into extensive damage. A breached levee near the refinery originally was a minor issue and would cost about 6 million dollars to repair, but

Harvey made the damages exponentially increase and now costs 730 million to repair (Ball, 2018). Port Arthur falls victim to the environmental damages and pollution that these failed infrastructures expose the residents to and toxins can be potentially dangerous following a hurricane.

4.4. Drinking Water in the Golden Triangle

The Golden Triangle may have had similar catastrophic levels of rainfall, but each town had experienced stark differences in the impression that this flooding had on the drinking water. While some regions, such as the City of Netherlands, did not experience disruptions in their water supply, other areas like Rose City experienced a prolonged period of water insecurity. The City of Beaumont is another example of a region that was not on polarizing sides of the spectrum, where drinking water was negatively impacted in the immediate aftermath of Harvey but recovered within ten days (Wallach, 2017). Similarly, Hurricane Harvey's differing effects are reflected in the interviews, where some expressed exhaustion over the lack of water, while others experienced minimum degrees of calamity.

The issues surrounding the accessibility of clean water following a hurricane have not been without warning. In 2017, Hurricane Maria impacted Puerto Rico and water systems went offline for the majority of the population. A month later, 35% of the population still did not have access to a source of clean water, and some resorted to using water from the Dorado Groundwater Contamination Site. Although Hurricane Maria was two weeks post-Harvey, Houstonians had been warned for years that the storage tanks for

petrochemical industries are vulnerable to storm surge, and harmful toxins can leak into the San Jacinto River (Chronicle, 2017). Although Hurricane Harvey did result in the leakage of toxins from refineries and petrochemical plants the extent was not as large as in Puerto Rico. However, Hurricane Maria and Hurricane Harvey exposed the desperate need for the government to build stronger infrastructure to protect these chemicals. The size of funding necessary to complete this project would have to be from the federal government. Although following Harvey residents did not have to resolve drinking water from a contamination site, the threat of toxins is colossal.

Population size did not disproportionately influence regional water systems. In the case of Beaumont and Rose City, a large and small city respectively, both faced negative impacts to their drinking water. While Beaumont has a population of nearly 120,000 people and Rose City with 500, there are similarities in the experiences that both the water systems and residents encountered following Hurricane Harvey (put in source w/ population size).

Beaumont relies on the Neches River and the Lawson pump station for 70% of their water source, and the remaining 30% of water from wells in Hardin County (Gstalter 2017a, 2017b). At the Lower Neches Valley Authority (LNVA) and Lawson pump, the flooding was extreme with almost 25-feet high water marks. Along the LNVA, all computer panels and two major pump engines were removed in anticipation of flood waters. By the evening of August 31st, the remaining equipment that was not removed was underwater and anticipated as unusable (Wallach, 2017). With the city's main water

underwater, there was immense urgency in supplying residents with water. By September 1st, Beaumont shelters were emptied due to the city's water outage, and evacuees were taken to Port Arthur or flown to Dallas (Teitz, 2017b). In Beaumont, the water treatment plant itself was never compromised by floodwaters and therefore did not have quality issues with their supply. However, the major issue surrounded the submerged pumps. Standstill water compromised water quality, making the water in the pipes unsafe for consumption (Wallach, 2017). Once the pumps were back online, water could then be safely supplied to the residents of Beaumont. A trickle of water was able to be pumped out of the Lawson pump, but not enough to supply all 120,000 of the population (Wallach, 2017). At the peak of emergency repairs, more than 70 people were working on the pump stations (Wallach, 2017). Exxonmobil collaborated with Echo and Tiger Industrial, two engineering companies, to assist in constructing temporary pumps for transportation to the treatment plants. The three temporary pumps each provided up to 5 million gallons per day to be delivered to the plants, compared to the usual 22 million gallons per day from the Lawson pump (Wallach, 2017). Another temporary pump was placed on a floating dock around the Loeb Ground Pump Stations, and the combined effort of all the temporary pumps allowed residents to have at the minimum a trickle of water, but still required a boil-water order (Gstalter, 2017a). After 10 days, the floodwaters receded enough to repair the pumps. The boil-water orders were lifted and the pumps were fully operational and able to maximize on 22 million gallons per day of water pumped (Wallach, 2017).

Located in Orange County, Hurricane Harvey had a greater bearing on Rose City and their water infrastructure. Two weeks post-Harvey, 500 residents were left without

running water. Similar to Beaumont, the pumps were overwhelmed by floodwaters. Rose City recorded eight feet of floodwaters and drowned all pipes and electric systems of the water systems (Taschinger, 2017; Teitz, 2017b). All eight pumps were destroyed, along with the laboratory at the water facility. Following Harvey, the entire system needed replacement, as well as all tanks and water lines required to be disinfected. For water, residents relied on donations of bottled water and two 5,000 gallon tanks of water located at city hall (Gstalter, 2017c). Overall, 270 businesses and homes in the town were destroyed, with only two buildings faced with minimal damage (Gstalter, 2017c). By December, nearly 3 months post-Harvey, Rose City continued to struggle with supporting a constant clean water supply. Although water supplies were back online, the water facility faced difficulty in sustaining the quality levels necessary to meet TCEQ standards for safe consumption. Leaking pipes and water lines were still decreasing the water quality, but the points of contamination were difficult to detect as many residents still had not returned to their homes (Gstalter & Teitz, 2017). The electronic equipment still needed replacements, leading to the water testing needing to be performed manually. This contributed to the continued delay in lifting the boil-water orders, as these tasks performed manually both took significantly longer, as well as facing inaccuracy (Gstalter, 2017c). On December 22nd, 2017, Rose City lifted the boil-water order, after nearly 3 and a half months (McCausland, 2017).

Although Beaumont and Rose City are two regions within the Golden Triangle that faced challenges to their water systems following Harvey, other regions had differing experiences that ranged from similarly catastrophic conditions and others that did not

experience much of a blow to their water. By December 2017, there were 13 different regions still mandated for a boil-water order. Spanning seven counties - Orange, Newton, Matagorda, Liberty, Kim Wells, Harris, and Angelina County - five of these counties were east of Houston. Nearly three-months post Harvey, 3,750 individuals throughout Harvey affected areas still did not have access to clean drinking water. Total, Hurricane Harvey compromised 2,200 community water systems (Gstalter, 2017c). As mentioned previously, the extent that Harvey impacted each region varied. While in Sour Lake, Texas high levels of E.Coli were tested in the drinking water in the immediate days following Harvey, other areas like Lumberton, Texas reported no issues with their city water operations (Gstalter, 2017a, 2017b). The city of Nederland is an example where the municipal water facilities never lost water supply, and their water systems were left fairly unaffected. The City of Nederland managed to avoid the worst of the flooding and partnered with Beaumont to supply water to Beaumont Baptist Hospital while they experienced water outages (Meaux, 2017a, 2019). Nederland supplied the hospital with nearly 100,000 gallons of water per day, compared to the hospital's typical 60,000 gallons utilized in a day. This ensured that all operations are fully functional at the hospital in the days immediately following Harvey (Wallach, 2017).

The flooding created massive issues for the water operators both during and after the hurricane. Hurricane Harvey disrupted many what? in its path through the prolonged rainfall and the subsequent floodwaters. This consensus over Harvey's shock on the water systems was made clear through the semi-structured interviews. All eight water operators reported major rainfall near their water systems, and all but one that the flooding disrupted

their water facility. The one water operator that did not describe any major flooding claimed the facility experienced minimal damage due to the elevation of equipment prior to Harvey. One water operator described how initially all their systems sustained extensive flood damage, but once a nearby reservoir was released, experienced catastrophic damages:

> **Water Operator, Participant 2**: "...there's a dam north of us, and we survived the storm. The storm wasn't the problem. The storm was over, and we were all celebrating prematurely. And then next thing you know, they released the dam, and we were underwater."

Four of the water operators went further to explain how the water systems were obstructed by Hurricane Harvey due to many electrical shortages and problems that ensued from the intense flooding. The systems either had to be manually turned off during the storm or were left running and were shorted and unsalvageable when inspected afterwards. For the systems that had to go offline temporarily, they were often only left offline for a few days. They are then 'temporarily fixed' so that the drinking water can be put back online immediately, but still require permanent solutions, such as new pipelines. The table below provides a closer analysis of the specific degrees of flooding and experiences that each water operator experienced:

Table 4: Brief overview of Hurricane Harvey Damages to the Water Systems

Water Operator Identifier	**Brief Description of Hurricane Harvey Impacts**
Water Operator #1 (WO1)	- Water facility overwhelmed with nearly 8 feet of flooding inside - All electric grids were short circuited and water lines were irreparable
Water Operator #2 (WO2)	- Did not disclose how much flooding they experienced, but stated almost all the systems were underwater due to the release of the reservoir
Water Operator #3 (WO3)	- Experienced 24 inches of water in the facility - Shut off operations for a few days because of water too close to electricity - Water systems not too negatively impacted, were already suspended 2-3 feet in air; most damage came from the building itself - nearly $700,000 in damage
Water Operator #4 (WO4)	- Did not disclose how high waters inside got, but high enough to flood pumpstations and short all motors
Water Operator #5 (WO5)	- Experienced 36 inches of water in facility - All motors and pumps underwater, damaged control panels and electrical units
Water Operator #6 (WO6)	- Experienced 50 inches of water inside facility - Already had some elevation and lift stations 6 feet above ground so damage not too bad - Generators able to run entire time, didn't lose water
Water Operator #7 (WO7)	- Did not disclose how high water inside got - Electrical systems destroyed
Water Operator #8 (WO8)	- Unsure how high water got, but was a few feet - Had to shut down plant so didn't risk electrical damage

The experiences of the interviewed community organizers slightly differed from one another, as they each had a different region of primary focus. However, despite the specific differences, all informants from the three community organizations described how rainwater and floods damaged the community.

Community Organization #1 (CO1) is a religious based organization, and they described how Hurricane Harvey altered their water supply availability. For four days, there was a lack of running water for the community. Many relied on external sources of water, such as water bottles, water tanks, and even pools to fulfill their needs. Similar to the experience outlined by Water Operator #2, they detail how flooding was not from the rainfall, but from the reservoir. Due to the reservoir floods, water infrastructure failed for at least four days. Once the floodwaters began to recede, ad hoc supplies such as bottled water were distributed to community members. These resources including anything from water to food to baby clothes. Community Organization #2 (CO2) is not based in the Golden Triangle but has many connections to the region. Following Harvey, they traveled to the area to donate water filters as an alternative to bottled water. The areas that required the most assistance in water were in the most flooded areas of Port Arthur. By requesting the help of the Cajun Navy and other volunteers who were on boats, the water filters were offered to individuals stranded by the flooding. Community Organization #3 (CO3) involved the evacuation center of Port Arthur. On the evening of August, 600 individuals gathered to take shelter from the floodwaters at their home. However, by the morning of the 31st, nearly three feet of floodwater entered the shelter. By mid-morning of August 31st, all evacuees had to be relocated to shelters located on higher elevation, as the parking lot had nearly five to eight feet of water in some areas. After the 600 individuals were evacuated, points-of-distributions (PODs) were established around the city to help distribute donated food and water to individuals in need.

Since Hurricane Harvey in 2017, various regions within the Golden Triangle have made strides towards improving the water systems and ensuring a safe supply of water following a disaster or major flood event. As mentioned previously, the City of Nederland partnered with Beaumont during their loss of water services by providing hospitals with water. In 2019, a partnership was formed between Beaumont and Nederland, where a memorandum of agreement was formed with hospital systems. In the case of an emergency, Nederland will assist Beaumont to provide an emergency supply of water, if Nederland still has a steady supply of water for their own residents (Meaux, 2019).

In 2018, the City of Port Neches received a 'Harvey Community Development Block Grant' from the Texas General Land Office. The purpose was to improve the infrastructure in the city, and the total funds were for close to $3 million dollars. The grant will be to replace the oldest water tower in the city, as well as create new water lines These new water lines will ease the flow of water throughout the city and allows easier accessibility following a disaster by the entire community (Jenkins 15 Feb. 2020). In 2020, Port Arthur continued to create disaster-response plans to mitigate the effects of flooding in the city. The city received federal funds to begin construction to create new infrastructure, such as a new pump station along Alligator Bayou, totaling $62 million dollars. The construction with this new federal funding will also emphasize on the drainage systems throughout the city, as previously built drainage systems cannot handle rain runoff as intense as Harvey. Regardless of the town, Hurricane Harvey had significant influence over the Golden Triangle. Despite the variation in extent of damage, all were crushed by floodwaters. Hurricane Harvey is not the first-time catastrophic flooding

damaged the area, but it did showcase just how ill-prepared the region is for intense rainfall.

4.5. Synthesis

Chapter 4 contextualized the widespread damages that Hurricane Harvey caused to the state of Texas. It demonstrated how although this project focuses on the Golden Triangle, the flooding and mass rainfall was an uncharacteristic phenomenon all throughout the state. It details how heavy of a reliance that the community had on governmental aid and volunteer organizations, such as FEMA and the Cajun Navy, to receive help in both the short and long-term. Despite providing a mass overview of Harvey, the newspaper analysis lacks in providing experiences of Harvey on a smaller scale and through specific communities. Although the third section did utilize semi-structured interviews in detailing the experiences of water operators and community organizations had with their drinking water, it did not go into further detail on how the water systems and drinking water accessibility was affected in the long term. Objective 2will utilize semi-structured interviews to further explain the factors that influence how certain communities were more prone to water system failures and what contributes in their favor in the recovery process from Harvey. The following chapter will provide and in-depth analysis of the results from the semi-structured interviews that is divided into sections based on the codes.

5. SEMI-STRUCTUED INTERVIEWS: RESULTS

In this chapter, results from the semi-structured interviews of water operators and community members will be outlined. As explained in the methodology section, water operators from Jefferson and Orange County were asked to participate through the listed contacts on the TCEQ's Public Water Systems database. Of the respondents, eight water operators are interviewed. Of the community organizations, however, only three partook in the interview.

This chapter will describe the results of the semi-structured interviews, based on their categorization into thematic codes in MAXQDA and will include eight different subsections. The first, 'Preparation', describes the protocols that are enacted prior to a hurricane. Literature has been published regarding communities and how different levels of preparedness prior to Hurricane Harvey affected their recovery capabilities in Houston (Grineski et al., 2019). This code will contribute to the understanding of how preparation affected drinking water accessibility and recovery following Harvey.

The second subsection will describe 'Hurricane Harvey Impacts'. This code will help outline the personal experiences of the water operators and community organizations. Similar to chapter 4, this code will outline what specifics of Harvey obstructed their drinking water and can help serve as an important tool in comparing any variations there may be in Harvey-impacts and the subsequent consequences that followed.

The third subsection will outline the effects of 'Community' following Hurricane Harvey. It is kept intentionally broad to demonstrate both the benefits and bonds of community amongst the interviewees and their local communities, as well with the communities that are formed amongst the water operators themselves. Community bonds are often strengthened following a disaster, and this community resiliency is crucial to understand how all members interact with one another (Patel et al., 2017).

The fourth subsection demonstrates the differing 'Roles of Government' involved following Hurricane Harvey. Similar to the 'Community' subsection, this is kept intentionally broad as there are many platforms that the government can get involved following a hurricane. This section details the differing roles that the local, state, and federal governments had on the interviewee, as well as describe the degree of satisfaction that the interviewees had with their government. This is to showcase how the different experiences with the government can alter the recovery of communities following a disaster (Checker, 2017).

The fifth subsection, 'Funding/Aid', is to display the different forms of assistance that each interviewee received and can include both monetary or non-monetary aid. By following-up and inquiring on whether this funding/aid was satisfactory or not, the intention is to demonstrate whether funding opportunities are presented equally amongst the interviewees, and if not, where the qualms may exist in unequal funding opportunities.

The sixth subsection is 'Technology and Infrastructure.' While coding, there was a distinction made in the beginning of the process to not include technology and

infrastructure during- Harvey, but to make the spotlight on how infrastructural changes have taken place post- Harvey. This distinction is necessary in order to gain a proper understanding of how interviewees have recovered and rebuilt, particularly involving their water systems, which is directly related to the second objective of this project.

The seventh subsection, 'Trust', is vague and can take the form of many differing levels of trust. This trust, or lack thereof, can be targeted towards funding, the government, or technology. This theme is necessary to demonstrate how the interviewees have been affected by Hurricane Harvey in the long-term and how they perceive hurricanes going forward.

The final subsection is 'Barriers to Improvement.' This section will discuss on what factors interviewees may or may not feel are preventing themselves from feeling fully recovered from Harvey or adequately prepared for another disaster. This section creates an overall image of each interviewee's experience with Harvey and the degree that they may still hold a negative connotation to the future of their community with hurricanes.

5.1. Semi-structured Interviews: Water Operators

Within the public water systems, the eight interviewees had a range of private and public contractors and water operators. Although the water systems themselves were public water systems, there were both public and private contractors involved in the maintenance of the systems. Total, there are four public water operators, of whom all worked with local municipalities, two private contractor water operators (one was investor-based, another a self-proclaimed "independently owned utility"), one nonprofit

organization, and one water operator who owned multiple water systems and utilized a combination of public and private contractors. The water systems ranged from small to medium size, the largest with just under 5,000 household connections, while one had as little as 60 connections.

Preparation

Prior to a hurricane, all water operators have a basic preparation protocol they follow. These protocols include assigned teams for post-impact that go over the responsibilities of each team, attending emergency preparation meetings, ensuring that water tanks and storages were filled to their capacity with water, and confirming there are enough resources to withstand a shortage of supplies. Some of these resources included chemicals, gas, diesel, food, and water, and one participant explained the length of time that is considered necessary for preparation:

> **Water Operator, Participant #8: "***Prepare. You prepare for probably about a month worth of off…off the grid I guess so to speak operating."*

There were mixed responses amongst the eight respondents on how they viewed their preparation for Hurricane Harvey. Three water operators expressed not feeling prepared enough for Hurricane Harvey, due to it being such a catastrophic event and unprecedented flooding:

> **Water Operator, Participant #1:** *"Hurricane Harvey, that was kind of the kick in the gut, if you will, because nobody was prepared for Harvey. Nobody anticipated the flooding, when we had the Hurricanes prior to Harvey. It was mainly wind damage you had some storm surge but not the catastrophic flooding that we did during Harvey. So, to be honest, there were no municipalities in our area that were prepared for Harvey, it affected everyone."*

One water operator expressed how they felt as if water system preparation was adequate, but the actual facility itself was not properly flood-proofed and received extensive damages. Two water operators were fortunate enough to flood-proof their water systems in the years prior through elevation of electrical equipment and the effects of flooding was not nearly as severe as it could have been. However, despite any form of preparation, there is only so much that is possible due to the unpredictability of a storm:

> **Water Operator, Participant #4: "***You know, we can…we can do the best preparation in the world that you do, but mother nature just seems that she says, "You think you got it? Let me show you this."*

Community

As stated previously, the community encompassed both the community that is experienced amongst the water operators and the general public, as well as within the water operator sphere. Of the eight water operators, one water operator reported having a negative relationship with their community, with minute complaints against the operators contributing to the tension felt between the two. They often feel immense pressure from the community. If any mistake occurred, an immediate response by the community would be to report it to state regulatory agencies for fines and demerits, creating a fear amongst the water operator to communicate openly with the public.

Of the remaining seven water operators, only one claimed to have an extraordinarily strong relationship with the community. They stated that the community is highly involved in the hurricane preparation process, such as assisting in tree trimmings and ensuring everyone has necessary resources, with the water facility and the community

having a strong line of communication with one another. Of the remaining six facilities, they did not state whether their relationship with the community was either positive or negative. There was frequent mention of having decent lines of communication via social media, text and email alerts, as well as local news. Two water operators specifically spoke of the 'older generation' of locals who often come by and ask if there is any need for assistance of any kind:

> **Water Operator, Participant #1: "***Well you know what's cool is every community has the little old organization of retired men that have lived longer and no more than anybody else. So they do a really good job at riding their scooters around, offering to impart knowledge that may help or disrupt whatever you're trying to do. So you always have that, which is, is a lot of fun. You'll have people every five minutes driving up, "you're gonna get the water on" or "Can y'all can we help you do anything", you know, in essence, they're not trained they don't know what to do.They have an eager heart. But we just kind of keep them at bay.*"

One water operator mentioned how nearby organizations, such as local church groups, were beneficial in providing food and water to the community members most in need. Generally, however, community involvement tends to be constricted to during the times of disaster. Without an immediate threat, the community does not stay actively engaged with the water facilities. The most effective mechanism for community involvement with the water operators would be through attending board meetings and local elections, but there is a notable lack of community involvement.

Interestingly when asked about community, the water operators voluntarily discussed their state-wide network and community within their own fields. Four of the water operators opened up about the strong connections with neighboring operators, with these connections both formal through official organizations such as Texas Water Utility

Association and Texas Rural Water Association, or simply through networking with nearby city operators. Both post- and pre- disaster, there was a large amount of open dialogue with support for labor, equipment, and materials. They all mentioned how tight knit of a community they are, and the support gained through these networks is extremely beneficial for post-disaster.

Role of Government

In terms of the government and the differing forms of government present as well as the operator's satisfaction with their experiences following Hurricane Harvey, there was a mixed response. Of the forms of government agencies available, six water operators mentioned federal government agencies such as FEMA and state agencies like TCEQ and the Texas Department of Emergency Management (TDEM) as being present following Hurricane Harvey and offering various forms of aid. This aid ranged from resource distribution in the short-term, as well as funding opportunities in the long-term.

When asked about the specific roles of the state government, four of the operators described them acting as a 'middle-man'. There is enormous coordination between the state agencies and FEMA on how resources and funding should be distributed to the local municipalities, and therefore the water facilities. When asked about the role of the local government, five of the water operators described a common theme. The local government tended to help the water systems by performing the administrative duties and assisting in the paperwork process for FEMA, as well as assisting in the grant writing process following a disaster. Of the six water operators who explicitly reported what governmental agencies were present, there was consensus that all scales of government are present

following a disaster. In fact, one water operator even discussed how they play a pivotal role in working with their local municipal governments as a form of advisor and aide on helping them create the best water policies for their communities.

The mixed responses continued when asking the water operators about their degree of satisfaction on their experiences with their government. Three respondents expressed very strong disappointment, two had very little opinion on their satisfaction, and three respondents were very satisfied with their relationship to governmental agencies. Of the three respondents dissatisfied, there was a general consensus that the government agencies were not there for actual assistance, but simply to 'show face' following disasters. In the case of Hurricane Harvey, two of the water operators had near-exact experiences with the governmental agencies who were in the area following Harvey:

> **Water Operator, Participant #1:** "*During that time, you have the Army Corps of Engineers, you have the EPA, you have the TCEQ which is our local regulatory agency. You have FEMA, you're going to have insurance representatives. And I even got to talk to ex-President Bush during that time. it's like when the spotlight. Yeah, when the spotlight is on something everybody wants a piece of that attention if you will.. But I'm just a dumb old country boy so you have to take this at face value, none of them were helpful. The most disappointing thing in my federal government, I learned so much during these natural disasters that the federal government puts on a great show. But when you have that many governmental agencies. One doesn't want to put forth their money until this one puts forth their money. And then all of a sudden you got a bunch of guys standing around with opinions but nobody's putting forth anything to help, right, so still the poor lonely city is left to their own resources to get their citizens some help."*

> **Water Operator, Participant #7: "***After the...the governor and the president comes down and looks at everything and says, "Oh, you poor people," and then leaves and then nothing, you know. We're still outta water."*

These three respondents who were not satisfied with the government roles expressed that the process for aid from the government was too slow, and assistance from the likes of FEMA had very little benefit in the immediate days following Hurricane Harvey. Two of these operators also expressed their disappointment in the lack of knowledge that the agents who are sent to assess their needs and report back their findings actually have on water and wastewater facilities. They were unsatisfied with the reports and believed it did not provide an accurate picture of the state of their water systems and the governmental agencies were therefore not given an accurate representation of the state of their facility.

Two of the respondents expressed very little opinion on the role of the government following Hurricane Harvey. There was acknowledgement that the process was indeed slow, but it was not at the sake of lack-of-care within the governmental agencies, but because of the urgency in other regions was much higher:

> **Water Operator, Participant #4:** *"...we know that the state is gonna be focusing on areas of higher population. I mean, if Houston goes down, they're gonna prioritize Houston because there's eight million people over there. They wanna we're over here. We got 5,000. So… Or 13,000. I mean, that's just something you understand that's normal operations."*

The remaining three water operators expressed feeling satisfied with their relationship with various governmental agencies and the roles they participated in during Hurricane Harvey. They felt as if they were able to work with all scales of governmental agencies and receive adequate funding. Two of these water operators explicitly stated the importance in communicating with the government, and how it created an even better line

of communication after Hurricane Harvey, due to the established relationship between them:

> **Water Operator, Participant #5: "***I come from working for the city. I retired about 21 years. And so, I knew, you know, dealing with cities, it's important to have that, I had that relationship when I came over here, you know. It's like we got to stay close with the city."*
>
> **Water Operator, Participant #6:** *"The state has done a lot more now to where, after every storm, they're in close contact with you ...they wanna know how you did during the store and if we lost water or anything of that nature. So, that's...it's a good thing 'cause I've always been the kind of operator that I like dealing...I like to be able to talk to the state. I'm not one of those operators that are scared of the state 'cause all they're all about is enforcement and all this stuff. I reach out to them on a daily basis and I talk to them and they help me through stuff. And, heck, sometimes they call me for help, you know."*

Funding/Aid

Following Hurricane Harvey, all eight water operators reported receiving grants and funding at some point following the hurricane, although the immediacy of this aid does vary greatly. The main agencies reported by these operators to offer funding and aid ranged from the federal level, such as FEMA, or through the state, such as TDEM, TWDB, and insurance companies such as the Texas Municipal League (TML). Just as much as the immediacy of aid varies between water operators, so does the amount of monetary assistance received, with some receiving as little as $10,000 to others at almost a quarter of a million dollars.

Although all eight water operators discussed having received some form of aid, there was split opinion on the satisfactory levels that the water operators had on their

experiences with Hurricane Harvey. For example, three water operators expressed dissatisfaction with the amount of funding they received and the forms that the aid came from. Of this subgroup, two of the water operators expressed similar opinions on how the agencies offering the funding operated. They felt as if the funding was all simply to 'show face' and were not for the benefit of the community but simply to increase profits for insurance companies, or were just simply not prioritizing these communities. The other water operator that expressed dissatisfaction also shared complaints in the government not being 'for-the-people' to say, but their main concern was the lack of speed in the funding being allocated to these small water systems that need the funding immediately and were suffering from the long-winded process. They go into detail how following Harvey, much of their equipment needed to be elevated for flooding mitigation, but due to lack of funding in their small city, they had to turn to state and federal agencies. However, the lack of speed in the funding agencies causes major issues:

> **Water Operator, Participant #7:** *"The government does not move fast …at all. And matter of fact, we still have a system that has not even gotten all of their money back from Harvey….They probably just got it repaired about five months ago."*

The extremely slow speed of governmental agencies is still noted amongst water operators who did express satisfaction over their funding:

> **Water Operator, Participant #8:** *"We're getting some recovery money now through things of that nature. They're getting some recovery money now. But it's…it usually trickles in way after the fact. And programs are just not available until, you know… It usually takes about two years to actually receive those actual funds to put to use."*

However, the remaining five water operators all viewed their funding in a much more positive light and stated feeling satisfied with their aid. Two water operators explicitly stated the perks of having insurance that helped tremendously in their recovery stages following Harvey and ease in getting replacements for their damages. All five water operators also expressed positive experiences with FEMA, while also acknowledging that it was a slow process and not a rapid solution. Two of these water operators also expressed the benefit they felt from having their local governments and state governments handle the paperwork and administrative aspects of applying for aid:

> **Water Operator, Participant# 5:** "*You know, for us, it's been a blessing to have the city be able to apply for those grants to get them for us. We have good engineers that help with it too. And so, just being a little water district, there's a lot of stuff that we can't, you know, do.*"

As mentioned previously, there was a water operator that was understanding over the slow speed of the funding from federal agencies. This understanding seemed to stem from multiple sources for the water operators who felt satisfied with their funding. One water operator described it as understanding their cities role as a smaller population and therefore not being as high of a priority amongst other cities, while another operator stated that they knew insurance and governmental agencies were working as rapidly as possible. There was also one water operator who held the exact opposite opinion as the dissatisfied water operators. While the other three believed that there was not enough funding available and accessible, they argued that there is plenty of funding available and there is so much these governmental agencies can assist in:

> **Water Operator, Participant #8:** *"At…at this point… and there's been so much funding through all the hurricanes. If you're not prepared by this point, there's probably no helping you at all."*

Technology and Infrastructure

Following Hurricane Harvey, every water operator described some form of technological change or improvement that took place afterwards. Four of the operators provided elaborate descriptions of their differing forms of elevation and flood prevention that took place. Equipment was raised a few feet higher, and these items ranged from catwalks to electrical components, generators, and control panels. This was done with the intention of trying to flood-proof the equipment and prevent electrical components of the equipment to be damaged. Two water operators emphasized the need to find electrical alternatives for future flooding events, with some solutions ranging from explicitly looking for gas and diesel pumps. An important component was also searching for generators that were of higher quality and better able to handle major disasters. A common theme found amongst water operators when asked about technological issues and improvements has been the emphasized role of electricity. The electric components are what needed to be elevated and generators are only increasing in importance as new disasters are experienced. As one water operator stated, they now shut off all electricity prior to landfall to prevent any damages that would be harder to clean following a disaster.

While the questions involving technology and infrastructure following Hurricane Harvey were directed towards within the water facilities, two water operators responded with improvements made outside their own facilities. One water operator discussed how the next goals for the region is to elevate the raw water stations to prevent any future

flooding. Meanwhile, the other water operator mentioned how the future of the infrastructure of the region was to focus on preventing the river and reservoir from overflowing into the community.

Trust

Not all the water operators discussed trust explicitly, but four of the operators did have some opinions on mistrust they have towards others. Three of these water operators felt their mistrust and wariness stemmed from their past negative experiences with government actors. Stemming from their past experiences, after Hurricane Harvey these water operators felt that the government agencies were not there to best serve the people, but to make a profit, show face, or offer support that was not in the best interest of the water operators. This lead one water operator to firmly believe that all disaster funds should be self-reliant, and water operators should work towards not needing the assistance of these government agencies to help post-disaster:

> **Water Operator, Participant #1:** *"I don't like to see people taking advantage of, because I know what it's like. I come from humble beginnings and I worked for everything that I have so I have an appreciation for those things that are earned. And I think that every hard work and citizen that pays tax money for these services deserves that same respect and someone looking out for them."*

> **Water Operator, Participant #7:** *"But one of the things is water and wastewater, and we...we found that you have to be prepared and reliable on your own. You cannot rely on the government to safely get you started back up."*

One of the water operators expressed mistrust at both the government agencies and communities. The mistrust with the government aligns with most of the above mentioned reasonings, but they view the community being just as guilty as the government agencies in adding pressure and making an unnecessary enemy out of them. The water operator

does not trust the government and community to be trying to express genuine complaints and concerns, but simply waiting for the best opportunity to voice all complains and hand out fines:

> **Water Operator, Participant #2:** *"I feel like I'm physically becoming ill dealing with these endless, endless events. The pressure from the customers. The pressure from the government. They're always waiting sort of, like, with a hammer to just hammer you if you don't do something right. It's thankless. The…the…the…it's just never ending. So, we've been doing this…I've been doing this water thing probably 30 years. I'm selling it. I'm selling it. I am getting the hell away from this just for health reasons."*

One water operator took a different approach in expressing their mistrust, by pointing it towards the constantly changing weather. There is always major concern and anxiety about the next storm and when the inevitable flooding will one day be as bad as Hurricane Harvey once again:

> **Water Operator, Participant #5:** *"There's always concern, you know, just...just with, you know, bigger rainfall, you know, a 6- or, you know, 10-inch rainfall which we've had those in the past too."*

There is constant worry and trust issues over the various stages of disasters and water, but it seems as if the major one for the water operators is targeted more towards the government.

Barriers to Improvement

One of the final topics discussed with all water operators was their perceptions as to whether or not they felt there were any barriers to improvement for their water systems after hurricanes, and if so, what they consisted of. Out of the five who responded to feeling

as if there were some barriers to improvements, it was a seemingly even combination of ones who felt they consisted of social or environmental barriers.

Of the water operators who believed the barriers to improvement were from social factors believed that the government was the biggest barrier to improvement following Hurricane Harvey. Within this subgroup, two of the water operators believed that these governmental agencies who were providing funding were only willing to fund enough to cover the costs of fixing the damage, but not offering funding to actually improve and prevent the same damage to occur again in similar circumstances:

> **Water Operator, Participant #1:** *"I'm smart enough to know that if that was not good the first time Why am I going to put it back the second time. If you're going to give me $100,000. Let me take that hundred thousand dollars and let's make improvements so that way we don't go through this again. And I had to fight every single agency there. And then finally, I told them I didn't need their help and I've done what I knew was best. It seems like these people are way too eager to waste money."*

Two of the water operators in this subgroup also mention how even when these government agencies, such as FEMA, do come and assess the damages, often representatives are sent that have very little knowledge of how water and wastewater facilities operate or are not consistent in sending the same representative if multiple visits are necessary. This creates confusion and miscommunication on both ends as to what parts are necessary and how the governmental agencies can be of assistance:

> **Water Operator, Participant 7: "***I think one system we went through five different people, and so we had to re-explain everything five times. And then the paperwork they did, the first guy said, "Do the paperwork like this." Second guy said, "No, paperwork needs to be filled out...out like this. Instead of doing it every single project, you need to group the projects." Then the next guy comes and says,*

> *"No, no, no, no. You need to do it by site. You need to group each of the projects by site and then put it..." I mean, it was crazy. We had to re-put, redo our application for money five different times because the people they send decided to do it differently."*

As mentioned previously in other sections, a major issue will always continue to be the slow pace of governmental funding that will be a major barrier to improvement. The combined social factors of recovery following a disaster will face these issues consistently:

> **Water Operator, Participant 7: "***I think it's always going to be that way because government changes too often, and rules change, and people change, and it never stays the same. But water and wastewater operators always stay the same."*

Of the remaining water operators, four mentioned the weather as being their main barrier to improvement. No matter how much hurricane preparation is taken into account, the shared opinion of the water operators was the acknowledgement of not being able to fully control the flooding, due to the pure geography of the region. For one water operator, a major river was only 500 yards away from some water systems and so it will always pose a threat. For another water operator, they described feeling as if they have done as much as they can to prepare for flooding, but with development happening in their surroundings, it can not be guaranteed to not happen.

Interestingly, there was one water operator who discussed both categories as a barrier to improvement. The nearby reservoir proves to be a constant barrier for improvement, as rainfall will always be an issue for the area. However, they also mentioned that the government is a major barrier to improvement due to their inability to

offer substantial help following a disaster and instead constantly badger them over updates:

> **Water Operator, Participant 2:** *"We can survive anything. We've been able to weather [Chuckles] the government regulations"*

There were a wide range of barriers of improvement amongst the water operators, but the consistent theme that was seen throughout the interview is that despite these barriers, there are still ways in which water systems and facilities can adapt and still persevere.

Lessons from Hurricane Harvey

Following Hurricane Harvey, the respondents had at least one takeaway that they have continued to apply for future disaster preparation, all involving flooding prevention. Three water operators explicitly stated that for future projects after Harvey, they did not even consider any form of plan that did not involve elevating the structures at least 3-4 feet in the air, at minimum. One water operator even said that they were now reconstructing their systems so that it is elevated at 8 feet in the air, so it is beyond what was experienced from Harvey flood levels. Within these three water operators, one water operator detailed how this construction of elevated equipment is part of their overall initiative to add flood protection during hurricane preparation. Prior to Harvey, they mostly wind-proofed their systems, but now include flooding protection, including transitioning to using more gas- and diesel-powered pumps so they did not have to worry about short circuits and inability to run power during flooding for safety reasons. A major lesson from the same water operator was that they learned to not gamble with the flooding

potential from a hurricane after Hurricane Harvey unexpectedly devastated their water systems, and now automatically shut down all electricity prior to landfall, and now incorporate that into their preparation steps for a hurricane. Two water operators also state the need to emphasize powerful generators, so they are not as reliant on the electricity. Along the same vein of flooding prevention, one water operator mentioned that they joined FEMA flood protection insurance, to protect their facilities in the case of another hurricane with an extreme flood event occurring.

Interestingly, when asked about the lessons learnt from Hurricane Harvey, two water operators talked extensively about the lessons they hope that others around them learned from Harvey, not necessarily themselves. One water operator commented that they hope other water operators realize how unreliable the government can be in offering aid following a disaster, and that establishing a disaster fund to repair water systems can be. Another water operator who was crushed by the release of reservoir water on their community stated that they hope that the government and people responsible for the decisions over the reservoir have learned from their mistakes and will be more cognizant of the reservoir water levels and release water at smaller increments beforehand, to prevent any major flooding from heavy rainfall in the future.

Although the interview questions were tailored to Hurricane Harvey in particular, one water operator mentioned how it was the lessons from two of the previous hurricanes that had major landfall in the area that taught them the most lessons - Hurricane Rita and

Ike. Without these past experiences, Hurricane Harvey would have much a much larger impact:

> **Water Operator, Participant #8**: *Like I said, every hurricane is a…a new learning experience. I mean, as soon as you think you got one figured out, you get a different level of challenge. But I will say in going back, Rita was the real eye opener to how vulnerable we were. And, you know, a lot of people use that as a tool or a learning tool. And here come Ike, just two years later, and just the sheer preparedness that people had in those two years was…was pretty phenomenal.*
>
> **Interviewer:** *Right. Right. So, if Rita and Ike hadn't been a thing then everything with Harvey would have been much, much worse.*
>
> **Participant 8***: Absolutely. Absolutely.*

5.2. Semi-structured Interview: Community Organization

There were three community organizations that participated in the semi-structured interviews. One of the organizations is religious-based and centered their disaster response following Harvey on helping community members in southeast Texas get a stable water and food supply. Another organization is not based in southeast Texas, but often travels to the region following hurricanes to provide water filters for individuals to keep and utilize when their water supplies are contaminated. The final organization is an emergency and shelter response team that works for the municipality of one of the towns in the Golden Triangle, and they are responsible for monitoring the shelters and distributing the donated food and water to those in need. There are a broad range of organizations that are involved in the Golden Triangle, all with different foci for their organization's goals, but all served to help the community following Hurricane Harvey.

Preparation

In terms of preparation, only community organizer, participant #9 (CO9) and community organizer, participant #11 (CO11) discussed any preparation that went into place prior to Hurricane Harvey, as community organizer, participant #10 is not located in the Golden Triangle, but a few hours west of the area. CO9 discussed that their protocol prior involves ensuring both that there are enough employees to assist in distributing resources post-impact, as well as ensuring that they have safe shelter to operate out of and keep their families safe. There is a hotline that is set up for community members to call if they need help with any resources, and once it is safe, act as a secondary response in helping other organizations and agencies in distributing resources. CO11 is in charge of ensuring that the shelters are available and readily accessible for individuals to take refuge in both pre- and post-hurricane. After ensuring all supplies are there to house individuals for the short term and employees have a safe shelter for their families, there is not much left but wait in anticipation to assess the damages.

Community

All three organizations stated that the relationships among the community are incredibly strong. CO9 described how following Harvey, community members spending hours on their boats, going as far as needed to help another individual across the county evacuate their homes from flooding sit

> **Community Organization, Participant #9**: And there is all these beautiful stories that come out of that. I've seen a lot of communities kind of rebuild on their own for many different reasons. But a lot of those reasons, it's because they wanted to. They wanted to do it themselves. They wanted to help each other. They just needed the tools or the supplies to do it.

This theme of community resiliency is evident throughout all the interviewees. CO10 details how immediately following Hurricane Harvey, members of the organization immediately asked how they can help provide water to the affected communities and immediately traveled to the Golden Triangle to donate and demonstrate how to utilize the water filter systems effectively. Both CO9 and CO11 discuss how points of distribution (POD) for food and water were set up sporadically throughout southeast Texas, and the community helped spread information as to where these PODs were located, as well as assisting one another in traveling to these locations. The relationship between the organizations and the community are also strong, with constant communication between them and the community often reaching out to ask in what ways they can also contribute to the recovery efforts.

Role of Government

Between the three interviewees, there was not much government involvement with the community organizations. CO11 worked with the municipal government and operated their shelter evacuations, but as mentioned in chapter 4, the shelter flooded nearly eight feet and all evacuees had to relocate. This relocation process was then transferred to the state and no longer the responsibility of the municipality. All three organizations discussed how the National Guard assisted in their abilities to distribute resources to individuals in communities that were difficult to get in contact with due to the flooding. Although there was not much government involvement with the organizations, the roles that the government did play were met with general positivity, and were not prohibitive in their volunteer efforts.

Funding/Aid

Amongst the three interviewed organizations, there was a general consensus that that most aid following Hurricane Harvey was not monetary, but in the form of donated resources. Although there was some money donated to the organization for future use, the immediate aid came in the form of water and food supplies. Due to the catastrophic nature of Harvey, donations poured in from all over the nation, to the point that CO11 even mentioned the difficulty in distributing the resources quickly enough so that the water was not just kept in the warehouses for the next year and no longer safe for consumption. Donations came from a range of actors, including individuals, other organizations, and even some government agencies like FEMA.

Technology and Infrastructure

There was not much discussion about technology and infrastructure in the three interviews. The extent was with CO10 and the water filters that were distributed to individuals throughout the Golden Triangle. The organization assembled 200 water filters and bucket systems that were then distributed. This was an effective water alternative as it did not rely on stockpiling bottled water and offered a way to still utilize the tap water in their homes even if it was still under a boil-water order. The individuals could then keep the water filters and use them for any future water disturbance.

Trust

Between the three community organizations, none of the interviewees discussed any positive or negative connotations with trust.

Barriers to Improvement

Between the three community organizations, none of the interviewees discussed any positive or negative connotations with barriers to improvement.

5.3. Synthesis

After coding the semi-structured interviews of both the water operators and community organizations, patterns emerged that demonstrated the relationship between certain codes. For water operators, role of government, funding/aid, and barriers to improvement seemed to be influenced with one another, and within the community organization, the preparation and community were also related on one another. This will be further explored in the following chapter, where the two sections will outline the objectives and draw connections between the data on the recovery process and experiences of the interviewees.

6. DISCUSSION

Through the analysis of secondary sources, such as newspaper articles, as well as conducting semi-structured interviews with water operators and community organizations, I gained an understanding of how Hurricane Harvey affected the Golden Triangle of southeast Texas and the specific impacts to the drinking water. In order to create this narrative and demonstrate it accurately, I focused on answering the following two research objectives: (1) identifying and evaluating the effects Hurricane Harvey had both during and post-impact (2) analysis on how water systems failed, recovered and rebuilt since Harvey. The data collected through secondary sources and the semi-structured interviews are used to split these research objectives into two sections, in hopes of answering the question of how Hurricane Harvey impacted this region. The final section will include how the findings contribute to future potential policy implications and research.

6.1. Objective #1: Identifying and evaluating the effects Hurricane Harvey had both during and post-impact

Analyzing newspaper articles and semi-structured interviews confirmed the shared experiences of communities throughout southeast Texas. Unlike prior hurricanes, it was not the wind that caused the most damage, but the constant rainfall and subsequent flooding. The experiences of the flood has had prevalent influences in the actions of both community organizations and water operators. Over a course of three days, 50-60 inches of rain fell in some regions, contributing to catastrophic flooding (Wright, 2017b; Branham, 2018). There was widespread destruction of infrastructure, caused by both the

rainfall during Hurricane Harvey and the days following when the nearby reservoirs overflowed and needed release, causing high levels of flooding in certain areas. The damage from flooding devastated some areas, such as in Port Arthur where 85% of the infrastructure suffered flooding damage and more than $22 million dollars have already been spent on recovery efforts (Salinas, 2018).

Through the interviews with community organizations, the ways in which the flooding impacted communities were apparent. While interviewing one organization located in Beaumont, they described four days without access to running water due to the on-and-off release of the reservoir. The release of the reservoir was mentioned by both the community organization and a water operator as playing a role in water accessibility. The water operator (water operator #2) discussed how it was not the rainfall during Hurricane Harvey that disrupted the system, but the reservoirs releasing their waters into the community that forced their systems to go offline. The intentional release of reservoir-water is documented in newspapers and narrates the devastating effects on the nearby communities (Barned-Smith, 2017; Carroll, 2017). Another organization that was interviewed was the emergency management team for a city in the Golden Triangle. They described Hurricane Harvey being an unprecedented flooding event. The local evacuation center reached. By the morning, the flood was almost 5-8 feet deep in various parts of the parking lot and all 600 were once again relocated.

Whether reported in newspapers or through the interviews, it is undeniable the role the community played with one another to ensure access to lifesaving resources, like

water, was met. Although governmental agencies like FEMA can assist in providing funding, it often comes with the understanding that it is not an immediate response (Ball, 2017c; Salinas, 2017). This is where the importance of having strong community resilience is evident amongst the residents in the Golden Triangle. Many city halls, such as the City of Beaumont, opened up bottled water centers for those who lacked water (Foxhall & Gordon, 2017). One water operator (water operator #1) expressed their admiration over the community resiliency that they witnessed following Harvey. They explicitly stated the importance of the local church organizations that were the most active and organized in distributing food and water throughout the community. Interestingly, the religion based organization that was interviewed (community organization participant #9) also mentioned how active church organizations are following a disaster and how communities typically rely on them before they attempt government agencies:

> **Water Operator, Participant #1:** "Well, mainly most of the help come from church organizations that sent goods and sent things down for the, for the citizens. My federal government, as I said, was a little disappointing."
>
> **Community Organization, Participant #9**: "I would say the government is probably more financial, monetary needs. But that also depends on the size of the disaster. After Hurricane Harvey, the National Guard was out and about distributing food, and water and so that often happens. And that was mainly because of the…the size I believe of the disaster and the fact that a lot of local agencies weren't able to respond because they were impacted as well. But I think in this area, if you ask someone, you know, where do you go, if you need something, you know, after a storm, I…I believe [organization]'s name is gonna be brought up first or at the very least most often."

It is interesting to see how participants #1 and #9 both view the importance of community organizations in immediate relief following a disaster, and not necessarily relying on the government.

The sense of community is not just within organizations that were located close to the Golden Triangle. Another organization (participant #10) that offered vital assistance in the days immediately following Harvey is located three hours west of the Golden Triangle. Due to the organization's mission of accessible water to all, they distributed close to 200 water filters to various community members all throughout the region. Though not based in southeast Texas, organizations still feel a strong bond to offer varying modes of aid following a disaster. Due to the high flood levels, the organization was not able to bring these water filters to the heavily flooded regions without the help of organizations, such as the Cajun Navy who brought boats to help distribute supplies to the vulnerable populations (Hartman, 2017; News, P., 2017). In the chaos of the flooding, communities had to rely on one another for help distributing water to ones who needed it most, while water operators worked tirelessly to navigate through the floods for their systems to go back online. While Harvey had devastating immediate effects on the region, it had the effect of creating community resilience amongst one another, as seen through the perspectives of both water operators and organizations.

6.2. Objective #2: Analysis on how water systems failed, recovered and rebuilt since Harvey

While the first objective created a narrative of the events immediately following Harvey and the state of the water, the second objective is to comprehend how the water systems themselves failed, recovered, and rebuilt since 2017. The eight water operators

reported that the main failures from Harvey were due to the electrical failures and shortages caused by the flooding. The water systems and facilities experienced flood levels that ranged in intensity, from three to eight feet deep. Without the equipment elevated higher than the flood levels, the equipment was exposed to water. Although each water operator experienced flooding damage to the water systems, the degrees of damage varied. While one water operator (participant # 6) reported facing minimal damage from the floods, others mention how their entire facility was devastated and needed to be gutted (participant # 3). While all eight operators experienced some form of impact from disaster, each operator varied in the following recovery process.

After conducting the semi-structured interviews with the water operators, connections became apparent between the water operator and the water system, and how it influences the recovery experience following Harvey. Although all the water systems that the operators were responsible for were public water systems, the water operators themselves were not all public servants. The title of water operator is given to someone who is certified by the state to operate a system, but cities and municipalities can contract this work out to private companies. If not working for the municipality, the 'private' operators can vary between investor-owned, corporation, or even non-profit organization water systems. Regardless of the type of 'private' operator, there was a notable difference in experiences between the municipality and private operators.

Amongst the three contracted water operators, all noted feelings of not being able to receive the same opportunities for funding as the municipality operators. The biggest

complaint was the inability to receive adequate funding from organizations such as FEMA in an easy and accessible way. However, the other five water operators did not share this experience and oftentimes expressed satisfaction with the funding and opportunities they received. Despite the small sample size of eight water operators, there are preliminary connections between water systems and public vs. private operators. There is the possibility that the type of water operator contractor shows the likelihood of receiving satisfactory funding. The five municipal water operators expressed a consensus over the ease of funding opportunities, with some mentioning how the city and state helped them tremendously with writing the grants for funding:

> **Participant #5:** *"...it's, you know, for us, it's been a blessing to have the city be able to apply for those grants to get them for us. We have good engineers that help with it too. And so, just being a little water district, there's a lot of stuff that we can't, you know, do."*

Amongst the five municipal operators, there was acknowledgement of the benefits of working closely with the state government. The local and state governments often collaborated so that the local officials are responsible for grant writing and funding opportunities. Having a separation of the funding-duties split between the local officials and water operators improved the opportunities for funding, as this allowed for the water operators to not have to dedicate portions of their time to grant writing, and instead purely to the operations of the waters. In fact, amongst these five, one mentioned that Hurricane Harvey was not as terrible and catastrophic as it's potential, because they had adequate funding to elevate their equipment some years prior from Hurricane Rita and Ike funding.

The municipal water operators are able to receive more government funding, such as FEMA.

An observation from the data collected involved the size of the water systems. The water systems were all relatively small or medium systems, with small systems typically consisting of less than 3300 connections and medium less than 10,000 connections (Pierce et al., 2019). Of the operators interviewed, the size of the water systems varied from 5,000, to some as small as only 60 household connections big. Existing literature emphasizes the disproportionate disadvantages small water systems often face in quality, accessibility, and affordability (Pierce et al., 2019).

Despite all the water systems with this research project being labeled as small or medium sized, there are still disparities on how different systems recovered following Hurricane Harvey. Based on the data collected, it was interesting to note the tentative relationship between the water operators employed as municipality vs private partners and the degrees of satisfaction with recovery that each experienced. Despite a small sample size, it would be interesting to further explore this disparity amongst small drinking water systems. These small water systems are traditionally already at a disadvantage, but the preliminary findings of this project finds that public vs. private operatorship can contribute to differing recovery following a disaster.

Another key factor when analyzing the interviews is the number of water systems that the municipal vs. private operators are responsible for. Private water operators oversee multiple water systems at once, ranging anywhere from 5 to 14 different systems. While

municipal-owned operators may have a larger number of household connections per system, often were responsible for one or two systems. Although the private-water operators are responsible for multiple systems, they may not have much staff and field workers for assistance, contributing to the strain the operators experience following a disaster. When asked during the semi-structured interviews on how many are employed at the facility, the answers averaged to 5-8 workers. Following a disaster, an operator responsible for multiple systems may not be as quickly accessible to attend to the needs of all systems, such as the case in Hurricane Harvey. During a prolonged disaster, such as Hurricane Harvey which affected the area for three days, these private water operators struggled in having enough field workers to respond to the various challenges caused by the flooding emergency for such a prolonged period of time.

One private water operator (participant # 2) described how during normal operations, the employees consist of only himself and a secretary and would have to contract field workers. During cases of a widespread emergency, such as Hurricane Harvey, there is potential difficulty in having the resources to recruit all the necessary personnel. This would lead the operators to be forced into handling the situations alone. Another added pressure the operators experienced involved TCEQ policies. When a water system is under pressure or goes offline, TCEQ mandates frequent updates on the situation so they can also update their own databases (TCEQ 2019). This could potentially be overwhelming for private water operators, who may already feel overwhelmed by the lack of assistance and are attempting to get their water back online as quickly as possible:

> **Participant 2:** *"They slow me down. They bog me down... those departments will call me all day. Asking me to sit down and describe for them what's going on. Well, I can't even leave my house, first of all. You know, I'm flooded in. So, I have no idea what's going on out there. And then when I finally can risk, you know, life and limb to get out on the street then they're calling me the next day. They want an update. And the next day, they want an update. So, they drive me [expletive] crazy. They drive me absolutely crazy. 'Cause they're not here to help. And…and everybody…you know, every different department wants to know…wants me to give them the same information. Stop what I'm doing and talk to them for 30 minutes."*

Water operators face immense hurdles to recovery following a disaster when they struggle to access resources that are not equally accessible amongst the operators. Although more data is needed to better conclude if there is a relationship between the relationship between water operators who are municipal workers or private contractors for the public water systems and whether one is at a disadvantage for faster, more efficient and satisfactory recovery, the preliminary findings suggest that there may be some merit to this. The private water operators expressed more dissatisfaction in the government, lack in funding opportunities, and a general feel of mistrust due to feeling like those two factors act as a constant barrier to improvement from future hurricanes. The private water operators are both responsible for the operations of the water system and the administrative aspects of grant writing, while the municipal water operators could focus solely on the systems, as the local municipalities handled the grant process. The combination of the inequality in grant-writing access and the number of systems each operator is responsible for suggests that the recovery of the water systems can be evaluated.

6.3. Implications and Future Research

The connection between private and public water operators and the pace of the recovery process following Hurricane Harvey became evident following the semi-structured interviews. For future research, it would be interesting to further dive into this question of how private entities are impacted by hurricanes, and how certain solutions like public-private partnerships can potentially improve the disadvantages that these water operators may naturally experience.

The main issue pertains to the gap between the water system operators and their capabilities to repair following a disaster, due to the lack of capital and accessibility by the private operators. The unequal access to funding, due to the public water operators partnerships with municipalities to assist in the application process for governmental aid, means that the private operators must apply for grants themselves, spreading themselves thin in both applying for grants and handling the water systems.

The goal of water systems is to provide a safe and stable source of water for their customers. However, small water systems are already at a disadvantage from narrow profit margins (Pierce et al., 2019) . With small profit margins, upgrades and repairs can be difficult to fund during normal operations. However, once a disaster occurs, like Hurricane Harvey, there may not be much left for emergency funds. Due to the inability for equal access to government funds after a disaster, there is a potential larger argument for the municipalization of private water operators. In the case of the Golden Triangle, hurricanes are not their only concern for a potentially catastrophic disaster. In February 2021, an unprecedented winter freeze impacted the state of Texas, and many water systems in the area experienced widespread damage through burst pipes (Healy, 2021). Future policy

adaptations may need to become necessary so that all water systems may have equal opportunity to receive similar benefits as the public systems. This shift in policy and potential municipalization has to be considered and implemented before it leads to more communities to have their water security. compromised.

7. CONCLUSION

In an all-too-fitting way, this project came to light after a discussion with one of the individuals from the organization that was interviewed for this project. They brought forward attention on the state of the Golden Triangle, and how through personal experience and relationships, were aware of how they are still affected through Hurricane Harvey and are in danger for any future ones. Despite no longer being a resident, there was still passion and desire to look out for this region with any future hurricanes, and after having conversations with the interviewees, this feeling of mutual respect and desire to look out for one another was clear. Community members are some of the first to try and distribute supplies, and water operators truly wanted to do their best for all their customer all year long, but especially during hurricanes, but some simply just did not have the money to accomplish it to the best of their abilities. Issues of funding seems to be the common thread in acting as a barrier to complete recovery for some in both the literature and in the interviews.

This research project was not able to reach its full potential, due to the many changes to the research plan from both COVID-19 and the ongoing natural hazards throughout the fall and winter. To fully understand the depth of connection between municipal operators and private operators and the amount of aid they receive, and satisfaction levels is something that needs to be better researched. There may be future merit in arguing that these private operators need to be higher prioritized in the funding allocation process if they are consistently receiving less than their municipality counterparts, but unfortunately this project cannot draw that conclusion with only eight interviews. For any future work, it will be interesting to investigate further what barriers

both water operators and community organizations may experience in ensuring a steady water supply to all residents.

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