Towards understanding the level of communication between Water-Energy-Food Government Organizations in San Antonio

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ABSTRACT
San Antonio has one of the most rapidly growing populations of all cities in the United States. The city is also witnessing the rapid growth of its energy development in the neighboring Eagle Ford Shale play, and increasing agricultural activity in the areas surrounding the city. These growing municipal, energy, and agricultural sectors compete over common water, land, and financial resources in the area. Despite the tight interconnectedness between resource challenges, we know little about the levels of communication and coordination between San Antonio officials that make decisions that affect the management of water, energy, and food systems. Without sufficient communication, the region’s future could be subject to competing resource allocation strategies and policies that result in unintended negative consequences. This paper identifies the current levels of communication between San Antonio’s water officials and the officials at energy, food, and other water institutions in the San Antonio Region. Different factors that may impact and improve that level of communication are considered. The overarching research questions in this paper are: “What level of communication exists among water different institutions, and between water, energy, and food institutions in San Antonio?” and “What role could the awareness to future water challenges, and participation in engagement activities, play in improving those levels of communication? In other words, do water, energy, and food institutions really operate within “silos” in San Antonio? A questionnaire, titled “Water Management in San Antonio,” was mailed to 289 public water officials in San Antonio Region, as defined by Texas water planning regions L and K. We conclude, based on 101 survey responses, that the frequency of communication between and among water officials at different water and planning organizations is higher among those who reported participating in stakeholder engagement activities. We also conclude that there is not enough evidence to suggest that attending stakeholder engagement activities improves the frequency of communication of water players with food and energy players. On the role of concern regarding future water availability in the region, there is not enough evidence to allow us to conclude that people at water institutions in San Antonio would have a higher frequency of communication with other water, energy, and food players, as a result of being more concerned about future water availability. The creation of an institutional policy environment that incentivizes increased levels of communication, coordination, and cooperation is needed. This could be partially achieved through mandating integrative planning workshops and forums that bring representatives of different resource domains to the same table to engage in dialogue around differing viewpoints. Such activity would facilitate better understanding the reality of the resource challenges facing the region and of the innovative cross-disciplinary and cross-institutional solutions needed to ensure long term sustainability.
I. INTRODUCTION

As populations and economies around the world continue to grow, demand for resources is projected to increase. It is projected that by 2050, we will need 55% more water, 60% more food, and 80% more energy (IRENA, 2015). The challenge of meeting the growing demands for water, energy, and food is further exacerbated by the growing interdependence between the three resource systems. It is projected that by 2050, 80% of freshwater will be allocated for agriculture, while 15% of water withdrawals will be needed to meet energy production demands. It is also projected that 30% of the energy produced globally will be consumed by the agricultural sector (Figure 1). The pressures facing the resource systems and the extent of their interdependence, will vary from one place to another, and will emerge as different hotspots with varying characteristics, which will require unique sets of solutions in order to be addressed. Our growing understanding of these interlinkages, and the development of different methods for their quantification, is an initial step in our work towards reducing stresses on these resource systems, and on reducing their interdependence.

Different opportunities exist for addressing these challenges. One such opportunity lies in our choice of technologies. For example, desalinating 1 m$^3$ of water requires an average of 23.4 kwh using a Multi-Stage Flash plant, versus an average of 2 kWh using a Reverse Osmosis Plant (Al-Karaghouli & Kazmerski, 2013); more than 50% water savings could be made by switching from flood to drip irrigation for growing same crops (UNEP, 1998); switching to hydroponics from conventional growing methods for lettuce results in 11 times higher yield, yet with an 82 fold increase in energy requirements (Barbosa et al., 2015).

![Figure 1: Projected pressures on resource systems and increased interconnectedness among them. Adapted from IRENA (2015).](image)

Other opportunities could lie in raising public awareness towards conservation of these resources. In 2015, Sacramento recorded 20% water savings due to increased public awareness to the importance of water conservation, which was catalyzed by a drought that faced the city during that year (Sacramento City Express, 2015). Better management practices could also play a role in addressing these challenges; a 10% increase in corn yield was reported after growing corn for two years, followed by a year of alfalfa, as opposed to continuously growing corn (Roth, 1996). All of the above are interventions that have trade-offs, which also need to be assessed and quantified in order to make informed decisions. Those decisions could be made by different types
of players at different levels, including farmers, business owners, individuals at a household level, water utilities, and energy utilities, among others. All these players exist within an environment which could play a role in incentivizing a set of interventions and actions over others. It also could play a role in incentivizing improved communication and cooperation between those players. Decision makers within the public sector, who are given the authority to develop policies related to governing water, energy, and food, have an important role to play in incentivizing different actions which could potentially result in reducing pressures on these resource systems. Those could come in the form of subsidies, decisions to invest in different technologies, and change in trade policies, among others. By doing so, those decision makers need to be aware of the extent the policies they develop could conflict with others who use the same common resources. The following example illustrates the potential complexity of such interactions: a decision made to subsidize electricity for farmers at the national scale, could incentivize those farmers to pump more water in order to increase their food production. While this would create positive economic impact for farmers; it might also result in increasing the risk of groundwater depletion or degradation at the municipal scale. This ends up competing with other resources that are required for other activities. This decision to subsidize electricity for farmers could have an effect on the water aquifer which would jeopardize availability of water for a growing city.

![Electricity Subsidies for Farmers](image)

**Figure 2**: Example of the different systems affected with an electricity subsidy policy

Similarly, a decision to shift a State’s energy portfolio towards more wind and solar energy, would have a positive impact on reduced emissions, but might end up competing with land which could be used for meeting agricultural needs, or urban expansion. A growing body of technical literature has worked on quantifying these interconnections between water, energy, and food resource systems and evaluating the trade-offs between different interventions and resource allocation scenarios. It is commonly cited in the literature that current policies are often created within separate water, energy, and food domains, also known as “silos” (Liu, J. et al, 2015; Ringler, C. et al 2013; IWA, 2016), by public officials with defined authorities within each of the domains. The potential to coordinate across domains could be viewed as a function of the current perception of existing public policy and management officials to urgency of the resource challenges, and their interconnectedness. Further research allowing us to better understand the potential of translating those solutions into policies, developed in coordination across resource domains, which is consistent with the extent of their interconnectedness, and its effect of the long term sustainability of the resource systems is needed. This needs to be done with an understanding of the public policy process and its potential role in ensuring effective implementation of proposed policies, in a given environment with identified biophysical conditions, community attributes, rules, and action situations (Ostrom, 2011). This chapter will particularly focus on the water-energy-food hotspot in the San Antonio Region. It will first describe the hotspot from a bio-physical perspective, and will then test hypotheses that relate to: 1) the current level of communication between decision makers within the water, energy, and food domains, and the 2) impact of water officials’ perception of future water challenges, and their 3) participation in stakeholder forums related to resource planning, on that level of communication.
II. San Antonio: Resource trends

A. Overview of water in San Antonio
San Antonio is the largest city in South Central Texas located in Bexar County which is part of Region L as classified in Texas State Water Plan (16 regional water plans) by the Texas Water Development Board. According to the United States Census Bureau's estimates, the population of Region L was around 2,860,393 in July, 1 2015 (Census Bureau, 2016). The population is projected to reach 3.15 million by 2020 and estimated to grow to about 5.2 million by 2070 (TWDB, 2016). The growth in population will result in increased demand for water across sectors. The water demand projection for 2020 in Region L is 1,070,354 ac-feet/year (TWDB, 2016). On the other hand, water supply is estimated to be at 1,027,889 ac-feet/year (TWDB, 2016). Although, shortage seems evident (200,071 ac-feet/year), the Texas Water Development Board has put in place water management strategies to overcome the deficit (Figure 3).

![Region L Water Demands and Supplies](image)

**Figure 3**: Region L Water Summary

The city of San Antonio is one of the fastest growing cities in the U.S. (Forbes, 2017). Accompanied with its projected urban growth, is the fast development of the energy industry in the region, particularly hydraulic fracturing in the Eagle Ford Shale. In addition, growing irrigated agricultural activity is exerting further pressures on the water system. In 2015, Texas got out of a five year drought which put major stress on the water system and others interconnected to it. As the growth of the agricultural, energy, and municipal demands for water continues, competition over limited water sources are projected to escalate. That is only exacerbated by climate change effects, threatening the potential availability and distribution of water resources.

B. Overview of energy in San Antonio

The Eagle Ford Shale plays a major role in Region L’s economic progress. The economy and environment of southeast Texas have been transformed by the Eagle Ford shale play, after becoming one of the major producers of shale oil and gas. The average amount of water used per fracked well in the Eagle Ford Shale is 13.7 million Liters (Kondash and Vengosh, 2015). The state regulator, the Railroad Commission, does not require oil and gas companies to report on the amount and sources of water they use for production, making it hard to keep track of abstracted amounts with increased activity (Corey, 2014). Any reporting that currently occurs is voluntary. In the Eagle Ford Shale, 80% of the water used for hydraulic fracturing is fresh, while the remaining 20% is brackish (Nicot et al., 2012). Even though the water used for hydraulic fracturing is much less than the water used for irrigation, it is consumptive, and is removed from the hydrologic cycle. Flowback water recovered from the fracking process is less than 14% of water used at the beginning, and is hard and expensive to clean.
Close to 23% of the natural gas withdrawn and produced in the US takes place in Texas (Figure 4) (USEIA, 2017). A large portion of that natural gas production is in the Eagle Ford Shale with a large overlap with the San Antonio Region, above the Edwards Aquifer. Figure 5 shows the spatial distribution of permitted oil and gas wells over the Eagle Ford Shale as of October 2016. As this trend continues to grow, and as technology continues to advance, allowing greater lateral length drilling per well, more water will be consumed.

**Figure 4:** Natural gas gross withdrawals and production in Texas and US (USEIA, 2017)

**Figure 5:** Wells completed and permitted in the Eagle Ford Shale Play as of October 1, 2016 (Source: Railroad Commission)
C. Overview of agriculture in San Antonio

Agricultural activity is most dominant in the Wintergarden area, west of Region L. This area includes LaSalle, Frio, Dimmit, and Zavala countries. The Texas Water Development Board (2017) projects water for irrigation to increase by 47% between 2015 and 2020. However, the water stresses from irrigation are projected to decline by 8% in 2070 from 2020 because of the anticipated growth in irrigation efficiency (Figure 6). The main crops being grown in that region are wheat, barley, cotton, and sorghum (USDA, 2012). Direct competition occurs between agriculture and energy, as the eagle ford shale play overlaps the vegetable growing counties in the Wintergarden area as seen in Figure 7.

While San Antonio’s volume of crop production hardly compares to the counties in the Wintergarden region, urban agriculture is becoming a major contributor to the agriculture sector in Bexar County (such as urban farm around First Children’s Hospital, Gardens of St. Therese, Spurs Community Garden, among others). In addition, companies like Venture Labs and Local Sprouts are using advanced methods such as hydroponics which is a subclass of hydroculture where plants are grown without a soil medium with their roots being suspended in water containing nutrient solutions (Kako, 2014).

Food manufacturing in San Antonio has also grown over the years with growing population. The top food manufacturing companies in San Antonio are: Bimbo Bakeries, Flowers foods, Frito-Lay North America, H.E.B. Grocery Company, Lone Star Bakery, Texas Big Game Processing,
Amigos Foods. In the food processing industry, water is used for cleaning and cooling, and as an ingredient in a large range of products. The data is hard to find because companies don’t have to report it but in table 1 there is an example of animal based food processing water use (NWFPA, 2016).

Table 1: Typical Water Consumption for Beef, Turkey, and Broiler Processing (Source: NWFPA)

<table>
<thead>
<tr>
<th>Animal type</th>
<th>Water (gallon/animal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef</td>
<td>150-450</td>
</tr>
<tr>
<td>Turkey</td>
<td>11-23</td>
</tr>
<tr>
<td>Broiler</td>
<td>3.5-10</td>
</tr>
</tbody>
</table>

D. San Antonio: a resource hotspot

In San Antonio, the municipal, industrial, and agricultural sectors are projected to grow. Those trends are expected to exert pressures on limited water resources, mainly on the Edwards and Carrizo-Wilcox aquifers. As population grows and uncertainty in climate prediction rises, more pressures are felt within the water system, and others interconnected to it. Water, energy and food are highly interconnected resource systems. In order to properly plan future pathways for their development, without having one infringe on the progress of another, it would be important to better understand those interlinkages and quantify them.

Figure 8 shows groundwater wells in the San Antonio region. The green, red, and blue dots on the map represent groundwater well locations for agriculture, oil & gas, and municipal uses,
respectively. A clear competition exists between growing municipal, agricultural, and energy uses in this region. Addressing this hotspot requires a holistic, yet localized, transdisciplinary, and multi-stakeholder approach. Even though plans for strategic water reserves exist, they come at a high price tag. Looking into solutions for better resource allocation, building on our understanding of how these resource systems are interconnected have the potential to reduce that projected gap at a lower cost and reduced risk of lack of implementation.

Figure 9 introduces some of these main interactions which exist between water, energy, and food systems. Water is needed for growing food as well as energy generation, extraction, and cooling. Energy is required for pumping, transporting, and treating water. It is also needed for different processes related to food production. The three resources are also affected by various pressures, namely growing population and economies, climate change and governance. The way in which we define our system of systems is critical. While many externalities and parameters could be added and accounted for, there is a trade-off between being more accurate, and being practical, within the time, data, and resource limitations. It all eventually depends on the end use for the analysis and the need for more granular data needs, or detailed processes to be included. In the context of the San Antonio hotspot, as we work towards finding interventions and solutions to reduce pressures on interconnected resource systems, we need to be able to quantify the trade-offs associated with adopting different options forward.

Figure 9: Water, Energy, and Food interconnections (Mohtar and Daher, 2012)

In addition to the complexity of the multidimensional physical resource interconnections, one must deal with the reality that these common resources are consumed, regulated, and impacted by different stakeholders and decision makers. The concept of “Tragedy of the commons” was first introduced by G. Hardin (1968), where he described the “commons” to be any shared and unregulated resource. According to Collective Action Problem, people acting independently will result in a worse outcome than if they coordinate. Individuals will work towards maximizing their own utility, making everyone, including them worse off, compared to when they coordinate (R. Hardin, 1971; Ostrom, 1990). Further research in recent years focused on the importance of understanding the interactions between natural and human systems (Kurian et al, 2017; Lubell, M, 2013; Lubell et al., 2010, Scott, C.A, et al, 2015). Different players, within various resource domains in San Antonio, have the authority to make decisions that impact the way resources are
allocated, consumed, used, reused, and supplied. The resources they use are common and finite. Below is an example (Figure 10) which illustrates a set of possible actions by water, energy, and food players, and their implication (positive or negative) on the same resources.

**Figure 10:** Example demonstrating the implications of different actions made by water, energy, and food players on water, energy, land, finances, and carbon emissions

- **Water** (W) resources are finite, and are under increasing pressures resulting from decisions made by players within or outside of the water domain (including energy and food).
- **Energy** (E) is required for pumping, treating, conveying water. It is also needed for food production. Our choice of energy portfolio also impacts how much water, land, and financial resources would be required.
- **Land** (L) is also limited and is mainly shared among agricultural, energy, cities, recreational areas, forests and other public areas.
- **Financial** (F) resources would be needed for subsidizing, investing, operating, or maintaining different activities within water, energy, or food systems. These finances could be public or private sources; the focus here would be on public budgets which have their limitations, and which need to be prioritized over a various set of competing expenditures.
- **Carbon emissions** (C) would be produced or reduced depending on the different decisions being made by the players within the three domains.

Even though their decisions impact common resources, we know little about the level of communication and coordination that currently exists between entities across the three resource domains. The lack of necessary levels of coordination is argued to result in policies and strategies that might conflict and compete with one another. The remainder of the chapter will focus on identifying the current level of communication between water officials in San Antonio and others at other water, energy, and food institutions. It will also investigate different factors that might have an impact on improving that level of communication.

**III. Research Question and Hypotheses**
The overarching research questions in this chapter are: “What level of communication exists among water different institutions, and between water, energy, and food institutions in San Antonio?” and “What role could the awareness of future water challenges, and participation in engagement activities, play in improving those levels of communication?” In other words, do water, energy, and food institutions really operate within “silos” in San Antonio?
In order to address these research questions, the following hypotheses are investigated:

**Hypothesis 1:** People at water institutions in San Antonio Region are more likely to communicate with people at other water institutions, than with those at food and energy institutions.

**Rationale 1:** The rationale behind this hypothesis is that people at water institutions with public authority might be more likely to communicate with people at other water institutions regarding addressing similar goals or challenges facing water resources in the San Antonio region. This communication might take place at water planning meetings were representatives from different water institutions could be represented, or through different correspondences to coordinate towards common set regional goals, perhaps within the same water planning region, Region L. This communication might be less present with other food and energy institutions. Testing this hypothesis will give us an indication of the level of communication among water institutions, and how it compares relative to those with energy and food institutions.

**Hypothesis 2:** The frequency of communication of people at water institutions with others from water, energy, and food institutions is improved as a result of their participation at stakeholder cooperative planning efforts in San Antonio.

**Rationale 2:** The rationale behind this hypothesis is that people who attend such meetings have a higher chance to meet with people from other institutions within the water domain, or others from food and energy domains. It also assumes that people who get the exposure and training on the importance of integrative planning while dealing with water issues would see an increased value for having those communications. This might result in them being more likely to reach out to those from other water, energy, and food institutions when working on addressing the challenges within the mandate of their own water centric institutions.

**Hypothesis 3:** People at water institutions who are less concerned about future water availability are less likely to communicate with others from different water, energy, and food institutions in San Antonio.

**Rationale 3:** The rationale behind this hypothesis is that people who have a higher sense of urgency towards future water availability would be more aware of the need to communicate and coordinate with other water institutions. They are more likely to be aware that solutions to water challenges would not exclusively come from within the water system itself, but in coordination with others interconnected with it.

### IV. Methodology

A questionnaire titled “Water Management in San Antonio” was mailed to 289 water public officials in San Antonio Region. 81 responses were received by mail and online. Throughout this chapter, results from these 81 responses were used to test the hypotheses. Table 2 below identifies the specific questions from the Questionnaire which were used to test these hypotheses.

The 81 respondents were asked to indicate the frequency of their communication with individuals from other water (57 institutions), energy (14 institutions), food (10 institutions), and other “cross-cutting” institutions (12) in San Antonio. The “cross-cutting” category included offices whose mandate likely extends beyond water management. This category includes offices of state representatives, senators, texas railroad commission, among others. The questionnaire also included a list of major food and energy payers in the San Antonio region. Some players might be missing, but we made sure to include enough players to ensure a good representation. Respondents indicated one of the frequencies with which they communicated with each of the institutions:
1 = Once a week or more; 2 = Monthly; 3 = Once every 3 months; 4 = Once a year; 5 = Not at all

Throughout the rest of the chapter, the response to the questions that address the frequency of communication will be shown as percentages indicating “no communication” (5’s) and “some communication” (sum of 1, 2, 3, and 4’s).

Table 2: Hypotheses and questions from the Questionnaire used to test each Hypothesis

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Questions to test Hypothesis (Refer to Appendix I)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hypothesis 1</strong>: People at water institutions in San Antonio Region are</td>
<td>Q9, 10, 11, 15. Over the last year, as part of your job, how often have you communicated with any of these</td>
</tr>
<tr>
<td>more likely to communicate with people at other water institutions, than</td>
<td>organizations, or decision makers from these organizations, about water issues affecting the San Antonio Region?</td>
</tr>
<tr>
<td>those at food and energy institutions.</td>
<td></td>
</tr>
<tr>
<td><strong>Hypothesis 2</strong>: The frequency of communication of people at water</td>
<td>Q12. Over the last year, as part of your job, have you personally participated in any kind of stakeholder</td>
</tr>
<tr>
<td>institutions with others from water, energy, and food institutions is</td>
<td>forum or cooperative planning effort with organizations or agencies other than your own? with Q 9, 10, 11, and 15</td>
</tr>
<tr>
<td>improved as a result of their participation at stakeholder cooperative</td>
<td></td>
</tr>
<tr>
<td>planning efforts in San Antonio.</td>
<td></td>
</tr>
<tr>
<td><strong>Hypothesis 3</strong>: People at water institutions who are less concerned</td>
<td>Q13. Overall, how concerned are you about future water availability in the San Antonio Region? with Q 9, 10, 11, and</td>
</tr>
<tr>
<td>about future water availability are less likely to communicate with</td>
<td>15</td>
</tr>
<tr>
<td>others from different water, energy, and food institutions in San</td>
<td></td>
</tr>
<tr>
<td>Antonio.</td>
<td></td>
</tr>
</tbody>
</table>

Also throughout the analysis, the level of communication of a respondent with the different institutions in the questionnaire will be represented by the average of the responses to their frequency of communication with the different institutions. The more 5’s, the less communication a respondent has with other institutions. The average value representing that level of communication can be between 1 and 5. The closer that number is to 5, the less communication that person has with other people from the different institutions. The lower the average, the more communication.

When asked about their participation at stakeholder forums or cooperative planning efforts (Q.12), respondents had the option to answer with “yes”, “no”, or “not sure”. In order to test hypothesis 2, the level of communication for those who answered “yes” was compared to those who answered “no” to this question. When asked about their level of concern about future water availability in San Antonio (Q.13), respondents were given the chance to indicate that level on a 10 point scale (0 being not concerned at all, and 10 being extremely concerned). In order to simplify the analysis, those who answered 0-5 where considered to have “low concern”, as opposed to those who answered with 5-10, who were considered to have “high concern”.
V. Results and Analysis

In this section, each hypothesis will be tested by analyzing the questionnaire results.

A. Hypothesis 1: On the level of communication

**H₀**: People at water institutions in San Antonio Region have the same level of communication with people from other water, food, and energy institutions.

**H₁**: People at water institutions in San Antonio Region are more likely to communicate with people at other water institutions, than with those at food and energy institutions.

This hypothesis aims to learn two main pieces of information regarding the level of communication of the different players: one about the overall level of communication that exists between the 81 surveyed water officials, with other water, energy, and food institutions in San Antonio, and another about the likelihood of higher level of communication between water officials among themselves, as opposed to that of water officials with those from energy or food domains. The null hypothesis assumes a similar level or frequency of communication with water, energy, and food players. Throughout the rest of the analysis, the communication between the 81 surveyed people from water institutions with the other water institutions will be referred to as W-W; W-E, W-F, and W-C will refer to the communication of those water officials, with other identified energy, food, and cross-cutting institutions, respectively.

**Table 3**: Communication between the 81 surveyed water institutions with other water, energy, and food institutions

<table>
<thead>
<tr>
<th>NO Communication</th>
<th>W-W</th>
<th>W-E</th>
<th>W-F</th>
<th>W-C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>79%</td>
<td>92%</td>
<td>95%</td>
<td>81%</td>
</tr>
<tr>
<td>some communication</td>
<td>21%</td>
<td>8%</td>
<td>5%</td>
<td>18%</td>
</tr>
</tbody>
</table>

According to the questionnaire results (Table 3), low levels of communication are reported between water officials and other players in San Antonio. Only 5% of the responses indicate some communication with food institutions, 8% with energy institutions, and 18% with cross-cutting institutions. The highest level of communication was reported with other water institutions with 21% of responses indicating some communication. Figure 11 shows a breakdown of the different levels of communications reported.

It is noticed that even among those who reported some level of communication, most of them represented a low frequency (once a year). Nine percent communicated with other water institutions at a yearly frequency, 7% every 3 months, 4% monthly, and only 1% communicated at a frequency of once a week or more. Those percentages are lower for communication with people from energy and food institutions. A similar level of communication is reported between W-W and W-C; 9% of water officials communicate at a yearly and monthly frequency with other water and cross-cutting institutions.
In order to test the null hypothesis, we do a 1-way ANOVA to investigate if the means are the same or if there is any statistical significance between them. The p-value of the analysis showed to be 3.11177E-09 < 0.05. As a result, we reject the null hypothesis, which means that at least one of the means of the frequencies of communication is different. Detailed information on the statistical analysis could be found in APPENDIX II: Hypothesis 1 statistical analysis.

In order to identify if the frequency of communication among water institutions is higher (and statistically significant) than that between water institutions and other energy, food, and cross-cutting institutions, we conduct the t-test for each pair. Table 5 summarizes the p-values from the respective t-tests.

Table 4: P-value results for t-test for WW-WF, WW-WE, WW-WC averages

<table>
<thead>
<tr>
<th>Averages</th>
<th>Hypothesis</th>
<th>P-value (t-test)</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>WW-WF</td>
<td>H0: $\mu$ (ww)$\geq$ $\mu$ (wf); H1: $\mu$ (ww)$&lt;$ $\mu$ (wf)</td>
<td>1.17018E-09</td>
<td>Reject H$_0$</td>
</tr>
<tr>
<td>WW-WE</td>
<td>H0: $\mu$ (ww)$\geq$ $\mu$ (we); H1: $\mu$ (ww)$&lt;$ $\mu$ (we)</td>
<td>2.0044E-07</td>
<td>Reject H$_0$</td>
</tr>
<tr>
<td>WW-WC</td>
<td>H0: $\mu$ (ww)$\geq$ $\mu$ (wc); H1: $\mu$ (ww)$&lt;$ $\mu$ (wc)</td>
<td>0.084751</td>
<td>Fail to Reject H$_0$</td>
</tr>
</tbody>
</table>

According to Table 5, we can conclude that the frequency of communication among water institutions (WW) relative to that between water and food (WF) and energy (WE) institutions is higher with statistical significance, at 95% level of confidence. It is also worth reminding that a higher average ($\mu$) indicates lower frequency of communication. If $\mu$(ww)$<$ $\mu$(wf), this means that the frequency of communication among water institutions is higher compared to that between water and food institutions (the more 5’s: no communication, the higher the mean). We fail to reject the null hypothesis [H0: $\mu$(ww)$\geq$ $\mu$(wc)] for cross-cutting players. This indicates that the higher frequency of communication among water institutions is not statistically more, compared to that between water and cross-cutting institutions. This result was expected given the breadth of responsibilities and mandates of several of the cross-cutting players.
B. *Hypothesis 2*: On the effect of attending stakeholder cooperative planning efforts on communication

**H₀**: The frequency of communication of people at water institutions with others from water, energy, and food institutions is not affected by their participation at stakeholder cooperative planning efforts in San Antonio.

**Hₐ**: The frequency of communication of people at water institutions with others from water, energy, and food institutions is improved as a result of their participation at stakeholder cooperative planning efforts in San Antonio.

This hypothesis investigates the relation between attending stakeholder forums and cooperative planning efforts, and its effect on the frequency of communication. When asked if respondents personally participated in any kind of forum outside of their organization, 51.8% answered *YES*, 44.4% answered *NO*, and 3.8% were *not sure*. Out of the 42 people who answered yes, 77% of their possible interactions with different water, energy, and food players, showed no communication at all. That number was higher among those who indicated not participating in any stakeholder forum or cooperative planning effort as part of their job (total 36 who answered no).

<table>
<thead>
<tr>
<th>Table 5: Percentages of frequency of communication between water officials who have participated, and not participate at integrative planning workshops, with all players from San Antonio</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Participation</td>
</tr>
<tr>
<td>No Communication</td>
</tr>
<tr>
<td>Some Communication</td>
</tr>
</tbody>
</table>

We can see a 13 percentage point improvement in communication among those who attended cooperative planning workshops. In order to investigate if this change in statistically significant, we conduct a t-test.

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>P-value (t-test)</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₀: μ no participation = μ participation ; Hₐ: μ participation &lt; μ no participation</td>
<td>0.037709896 &lt; 0.05</td>
<td>Reject H₀</td>
</tr>
</tbody>
</table>

By rejecting the null hypothesis, we can conclude that the frequency of communication of water officials who have attended stakeholder forums, was higher than that of those who did not attend, with statistical significance, with a 95% level of confidence. More detailed information on the statistical test in **APPENDIX III- Hypothesis II statistical analysis**.

As we investigate to see if this is the case as we zoom in into the effect of communication between water-water, water-energy, water-food, water-crosscutting, we find the results below. In table 6 “WW-y & WW-n” refer to testing the change in frequency of communication between water institutions (WW), among those who indicated attending a stakeholder workshop before (y), and those who have not (n).
Table 6: Testing the impact of stakeholder participation on the frequency of communication for W-W, W-E, W-F, and W-C

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>P value (t-test)</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>WW-y &amp; WW-n</td>
<td>0.008413</td>
<td>Reject H₀</td>
</tr>
<tr>
<td>WF-y &amp; WF-n</td>
<td>0.286213</td>
<td>Fail to Reject H₀</td>
</tr>
<tr>
<td>WE-y &amp; WE-n</td>
<td>0.280868</td>
<td>Fail to Reject H₀</td>
</tr>
<tr>
<td>WC-y &amp; WC-n</td>
<td>0.0043</td>
<td>Reject H₀</td>
</tr>
</tbody>
</table>

According to the test done in Table 6, we can conclude that the frequency of communication of water officials, with other water and cross-cutting officials, is higher, among those who participated with stakeholder engagement activities, with statistical significance, with a 95% level of confidence. We also conclude that there is not enough evidence to suggest that attending stakeholder engagement activities improves the frequency of communication of water players with food and energy players.

C. Hypothesis 3: On the effect of concern towards future water availability on communication

H₀: People at water institutions who are less concerned about water future availability communicate with water, energy, and food players at a frequency that is at least equal to that among those who are not concerned.

Hₐ: People at water institutions who are less concerned about water future availability are less likely to communicate with others from different water, energy, and food institutions in San Antonio.

On a scale from 0-10, 0 being not concerned at all, 10 being extremely concerned, 32% of the 81 respondents answered 5 or less (low concern), and 68% answered 6 or more (high concern). For the 32% who indicated low concern about the future of water availability in San Antonio (≤5), the table below shows the percentage of those who indicated no communication with other water, energy, and food institutions (5). The 68% who indicated higher concern about the future of water availability in San Antonio (≥6).

Table 7: Percentages of frequency of communication between water officials with high and low concern, with all players from San Antonio

<table>
<thead>
<tr>
<th></th>
<th>Low Concerned</th>
<th>High Concern</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Communication</td>
<td>81%</td>
<td>79%</td>
</tr>
<tr>
<td>Some Communication</td>
<td>19%</td>
<td>21%</td>
</tr>
</tbody>
</table>

According to table 7, we notice a slightly higher level of communication among those with higher concern towards future water availability in San Antonio. In order to investigate if this difference in statistically significant, we conduct a t-test.

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>P-value (t-test)</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₀: µ High ≥ µ Low ; Hₐ: µ High &lt; µ low</td>
<td>0.384695637</td>
<td>Fail to Reject H₀</td>
</tr>
</tbody>
</table>

By failing to reject the null hypothesis, we learn that there is not enough evidence to allow us to conclude that people at water institutions in San Antonio would have a higher frequency of communication with other water, energy, and food players, as a result of being more concerned.
about future water availability. Similar to hypothesis 2, as we look at a relation between being more or less concerned on the frequency of communication between water-water, water-energy, water-food, water-crosscutting, we find the results below.

When asked about their frequency of communication with other water institutions, 78% of those with low concern towards future water availability reported no communication with other water institutions. The percentage of no communication among people with low concern grew when asked about the frequency of their interaction with other energy (92% no communication) and food players (95% no communication). Communication frequency with other “cross-cutting” institutions was higher than that of energy and food at 83% no communication (Table 8).

Table 8: Percentages of frequency of NO communication among water officials with high and low concern, with other water, energy, food and cross-cutting officials

<table>
<thead>
<tr>
<th>NO Communication</th>
<th>W-W</th>
<th>W-E</th>
<th>W-F</th>
<th>W-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Concern</td>
<td>78%</td>
<td>92%</td>
<td>95%</td>
<td>83%</td>
</tr>
<tr>
<td>High Concern</td>
<td>76%</td>
<td>90%</td>
<td>95%</td>
<td>80%</td>
</tr>
</tbody>
</table>

According to the tests done in Table 9, we do not have enough evidence to conclude that the frequency of communication of water officials, with other water and cross-cutting officials, is higher among those who are more concerned about future water availability in San Antonio, with statistical significance at a 95% level of confidence. More information on the statistical tests in Appendix IV - Hypothesis III statistical analysis.

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>P value (t-test)</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>WW-high &amp; WW-low</td>
<td>$H_0: \mu_{high} \geq \mu_{low}$</td>
<td>0.460622342</td>
</tr>
<tr>
<td>WF-high &amp; WF-low</td>
<td>$H_0: \mu_{high} &lt; \mu_{low}$</td>
<td>0.384989346</td>
</tr>
<tr>
<td>WE-high &amp; WE-low</td>
<td>$H_0: \mu_{high} \geq \mu_{low}$</td>
<td>0.275566523</td>
</tr>
<tr>
<td>WC-high &amp; WC-low</td>
<td>$H_0: \mu_{high} &lt; \mu_{low}$</td>
<td>0.470390457</td>
</tr>
</tbody>
</table>

VI. Discussion

To recap, the overarching research questions addressed in this chapter were: “What level of communication exists among water different institutions, and between water, energy, and food institutions in San Antonio?” and “What role could the awareness of future water challenges, and participation in engagement activities, play in improving those levels of communication?”

On the overall level of communication

- **We concluded that** the overall level of communication of water institutions with other water, energy, and food institutions low.
  - **We concluded that** people at water institutions in San Antonio have a higher frequency of communication with people at other water institutions, than that with people at energy and food institutions.

Reasons for low communication could be attributed to institutional, financial, or time limitations. Unless some agreements towards cooperation or coordination between different institutions exist,
water officials might find themselves unable to take steps towards improving levels of communication with other institutions. Limitations could also be connected with the volume of responsibilities water officials at different institutions have as part of their mandate, which leaves little time to engage effectively with others, through attending cooperative planning workshops, for example. This low level of communication might also be a result of the officials’ perception towards the limited role of increased communication on addressing the resource challenges they face.

On the role of stakeholder forums in increasing communication

- **We concluded that** the frequency of communication of water officials who have attended stakeholder forums, was higher than that of those who have never attended one, with other people at water, energy, and food institutions in San Antonio.
  - **We concluded that** the frequency of communication of water officials, with other water and cross-cutting officials, is higher among those who participated at stakeholder engagement activities.
  - **We conclude that** there is not enough evidence to suggest that attending stakeholder engagement activities improves the frequency of communication of water players with food and energy players.

One reason behind the increased communication among officials from water and cross-cutting institutions and not others, might simply be a result of the fact that such meetings are largely attended by people from water-centric institutions. Even though such workshops promote integrative planning, it largely remains to be done within the same “silo”, with weak agriculture and energy presence. Therefore making sure food/agriculture and energy are represented at such meetings could play a role in improving current levels of communication.

On the role of concern regarding future water availability in the region

- **We concluded that** there is not enough evidence to allow us to conclude that people at water institutions in San Antonio would have a higher frequency of communication with other water, energy, and food players, as a result of being more concerned about future water availability.

That could also be a result of not perceiving the resource systems and their challenges to be as interconnected as they are. That might cause these officials not to necessarily see the need for greater communication across different resource domains, regardless of their concern toward future water availability. Raising awareness and building institutional capacity towards the importance of cross-institutional and cross-sectoral cooperation and coordination on resource allocation challenges could play a positive role in improving those levels of communication.

Future research

This first hypothesis gave us an overall indication of the low level of communication among people from different institutions in San Antonio, and the relatively higher level of communication among water institutions, compared to that with other food and energy institutions. In reality, these 81 water officials come from different types of organizations, with different scope and scale of authority. Some of them come from groundwater districts, river authorities, counties, and cities, among others. Additional research could focus on investigating whether the results from the first hypothesis would look different once we zoom into responses of water officials at different scales. Further research needs to be done on the type and kind of communication that might result in cooperation or coordination between institutions. Also capturing the perspective of energy and food officials from San Antonio, could yield new insights to better describe the network and levels of communication.
VII. Conclusions

Given the tight interconnectedness between resource challenges that face San Antonio, a certain level of communication, coordination, and cooperation is needed between officials across these resource domains. Otherwise, the region might end up subject to future resource allocation strategies and policies that compete with one another, resulting in unintended consequences. The creation of an environment which incentivizes increased levels of communication, coordination, and cooperation is needed. This could be partly achieved through the organization of integrative planning workshops and forums which bring officials representing institutions from different resource domains to the same table. Such dialogue and exposure to different viewpoints would play role in better understanding the reality of the resource challenges that face the region, and the innovative cross-disciplinary and cross-institutional solutions that are needed to make everyone better off in the long term. The role of increased communication on cooperation and coordination is to also be further investigated.
VIII. References


