Water and Other Flows:

Mapping Policy and Governance in Texas Water

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Introduction

Water flows across all sectors of society and water governance challenges inherently involve multiple policy issues. Water is not the only flow in the interdependent web of policy and governance interactions that manage water in Texas. Water governance cuts across many policy issues, a wide range of institutions and actors, and many different contractual and regulatory mechanisms. In this research, we model and map the institutions and governance mechanisms of Texas water to elucidate and better understand the complex dynamics of the Texas water sector (Figure 1). To do so, we analyze the "governance" of the system, which consists of institutions (agencies, actors and types of users) connected by different policy/governance mechanisms (authority, funding, regulation, etc.) across interdependent policy issues or subsectors.

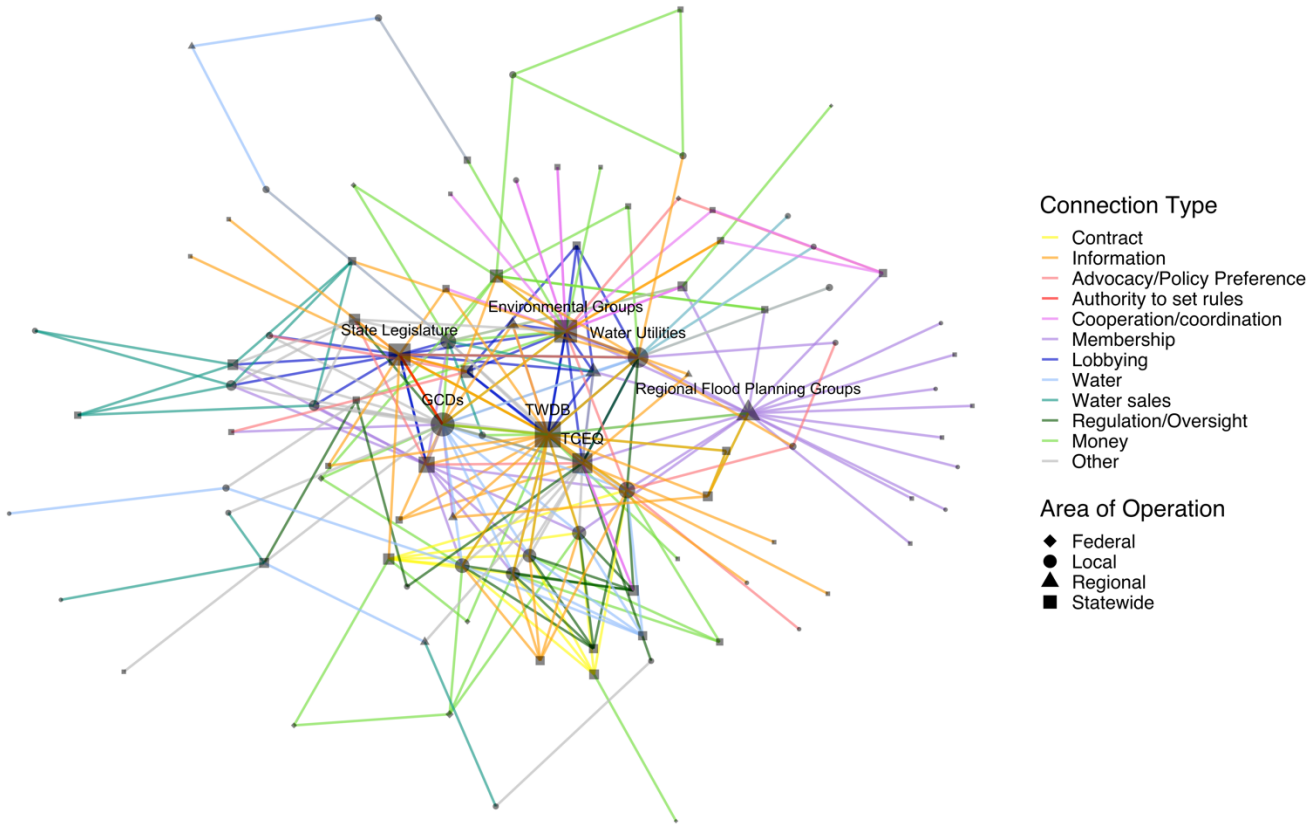

Figure 1. Policy and governance connections between institutions and agencies in the Texas water sector

Background

Broadly speaking, research in environmental policy and governance establishes the essential role of collaboration in addressing societal and environmental problems.[1] Collaboration, or collaborative governance, is essential because many challenges—such as the sustainable long-term management of water—span organizational, sectoral, and geographical boundaries. As a consequence, the challenges are fragmented into separate issues (or policy subsystems), to reduce the perceived complexity of problem solving, despite their interdependence.

Subsystems in contemporary politics have grown into incredibly complex webs of interaction with more linkages across issues and different types of actors than ever before.[2] Sometimes referred to as issue networks, the complexity of policymaking linkages spreads to outside agencies, interest groups, state and federal agencies, and other subsystems. Policy and governance interdependency is of growing interest because unravelling these dynamics can illuminate the core presumptions of different stakeholders, highlight collaborative opportunities, and (re)structure problems in ways that facilitate the development of scenarios and solutions.[3]

In an effort to explore and understand the complex dynamics of the Texas water sector system, we mapped eight subsectors (Table 1), the interactions within each sector (Figures 4-10), and the interactions across the sectors (Figure 1).

Table 1. Subsectors of Texas Water*

Subsector	**Focus Group Comments**
Agriculture	Includes irrigation, ranchers, water-food nexus
Energy	Oil and gas operations, hydraulic fracturing
Environment	Environmental flows, endangered species
Flood Management	Includes flood prevention and response
Groundwater Management	Includes brackish groundwater, aquifer storage and recovery, desired conditions/planning, landowners,
Innovation	Water supply development, desal, academic research
Municipal	Water supply and other urban use
Rural	Water supply, including rural use

*Our preliminary focus group also identified "human" and "industry" as distinct subsectors that are not included in this current study.

This technical report will proceed as follows. We will provide a high-level overview of the methods used for data collection and mapping. This will be followed by the results, including visualizations and descriptions within each subsector and between each subsector consisting of the policy and governance of Texas water.

Methods

The study uses a system mapping tool called Fuzzy Cognitive Mapping (FCM) to gain an understanding of complexity of the Texas water system. FCM combines insights from concept mapping and causal loop diagramming to map participants' interpretations of the complexity of the subject by combining their knowledge, preferences, and values with quantitative estimations of the perceived relationships between components within a particular context of interest.[4] The objective is to capture and to visually convey participants' perceptions and understanding of how water—both in physical flows and as the mechanisms of providing, using, and disposing of water—moves in Texas. Fuzzy cognitive maps are developed using expert knowledge and enhanced by combining the perspective of multiple, different experts.[5,6] Individual perspectives can be combined to create an aggregated map[5].

We began by convening a focus group of the leadership of five prominent, water-focused organizations in Texas and asking them to identify key subsectors within the state's water sector. The group identified 10 subsectors with descriptors as provided in Table 1. Using a key stakeholder and expert elicitation sampling strategy, we identified an expert from each subsector and arranged a time for an interview. We used a structured interview protocol to maintain consistency across participants and guided them through a process of "systems" mapping the subsector. We asked each interview participant to create on paper a sketch illustrating their understanding of how the subsector worked, using individuals, agencies, or other kinds of entities as nodes and connecting them with directional flows of water, money, information, political pressure, or other resources. We asked those interviewed to explain their drawing to us and asked clarifying questions for understanding. In these discussions, respondents often conveyed needed changes to the initial sketch and illuminated complexities in the relationships between actors. All interviewees consented to being recorded. After the interview, the recordings were transcribed and qualitative data analysis techniques were used to code the data and refine the maps.

The next step utilized the hand-drawn maps, discussed amendments, and transcribed interviews to build digital maps in Miro (a collaborative mind-mapping software). Miro "mind-maps" can be found in Appendix A. The map was then shared with the interview participant, who was asked to make any corrections or changes they perceived necessary.

Once the participating water subsector expert confirmed the final Miro map, the map elements – nodes and edges – were coded in excel. The nodes consist of the institutions/agencies/organizations and the edges consist of the connections between the nodes. The excel dataset was this used for computer generated visualizations and quantitative descriptive statistics as discussed in the results. We used R analytical software for this analysis. After each subsector was analyzed in R, we sought consultation with additional experts to validate the accuracy of the maps.[6] Figure 2 demonstrates the process in its entirety.

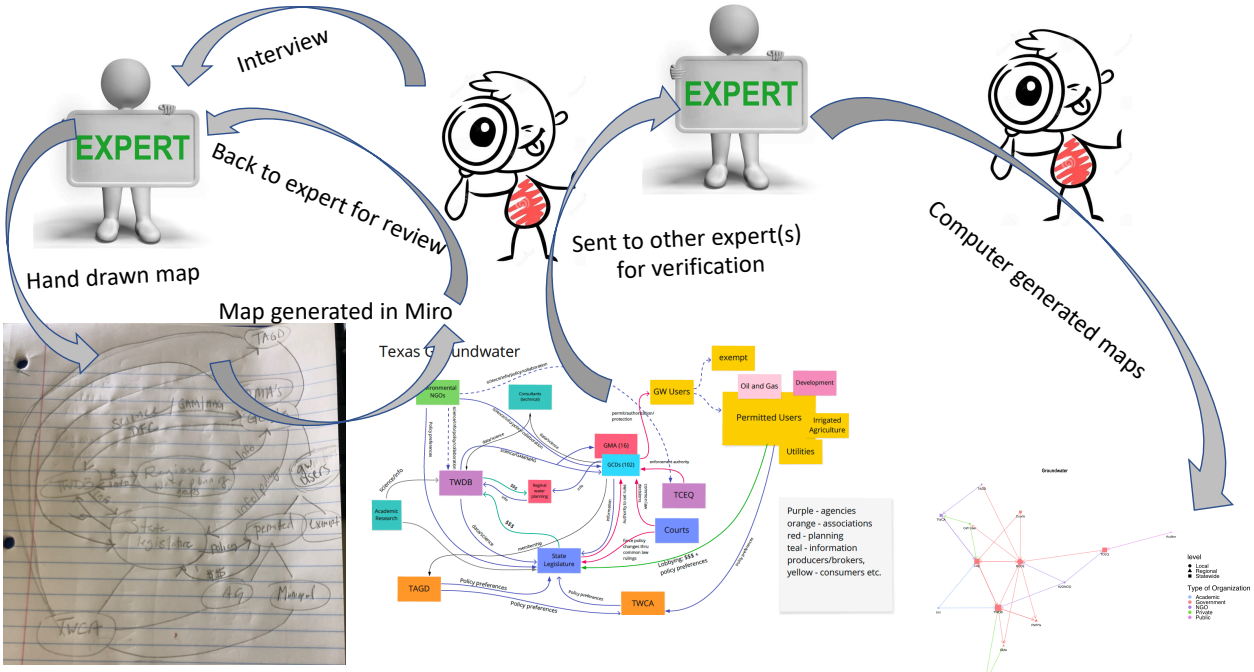

Figure 2. Data collection and analysis steps.

Results

Policy and Governance of Texas Water

The maps were developed from the bottom-up, employing the interview and mapping method with each individual sector. However, when combined we get an idea of the heterogeneity of institutions and agencies involved in water policy and governance across Texas, and the many types of "flows" through the system. In total, we identified 100 different institutions and/or agencies working on water in the state. For the most part, we sought to define these "actors" at an institutional level, e.g., groundwater conservation districts (GCDs) are considered as one institution rather than 98 individual GCDs. In some cases, a specific agency or organization—i.e., Texas Water Development Board or the Texas Water Conservation Association—played such a central role that they are noted separately rather than as part of a more generic institutional category such as "state agencies" or "water groups," respectively. Based on the total number of policy/governance connections, the top ten institutions are listed in Table 2 and visualized in Figure 3. The Texas Water Development Board (TWDB), GCDs, environmental advocacy groups, and Texas Legislature are the top four institutions based on number of connections to other institutions.

Table 2. Most central institutions in the Texas Water Sector

Institution	Number of policy/governance connections	Level of administration	Type of institution
Texas Water Development Board	46	Statewide	Government
Groundwater Conservation Districts	39	Local	Government
Environmental Advocacy Groups	35	Statewide	NGO
Texas Legislature	33	Statewide	Government
Water Utilities	29	Local	Utilities
TX Commission on Env Quality	27	Statewide	Government
Regional Flood Planning Groups	22	Regional	Government
Municipalities	18	Local	Public
Trade Associations	17	Statewide	NGO
Surface Irrigators	16	Local	Private

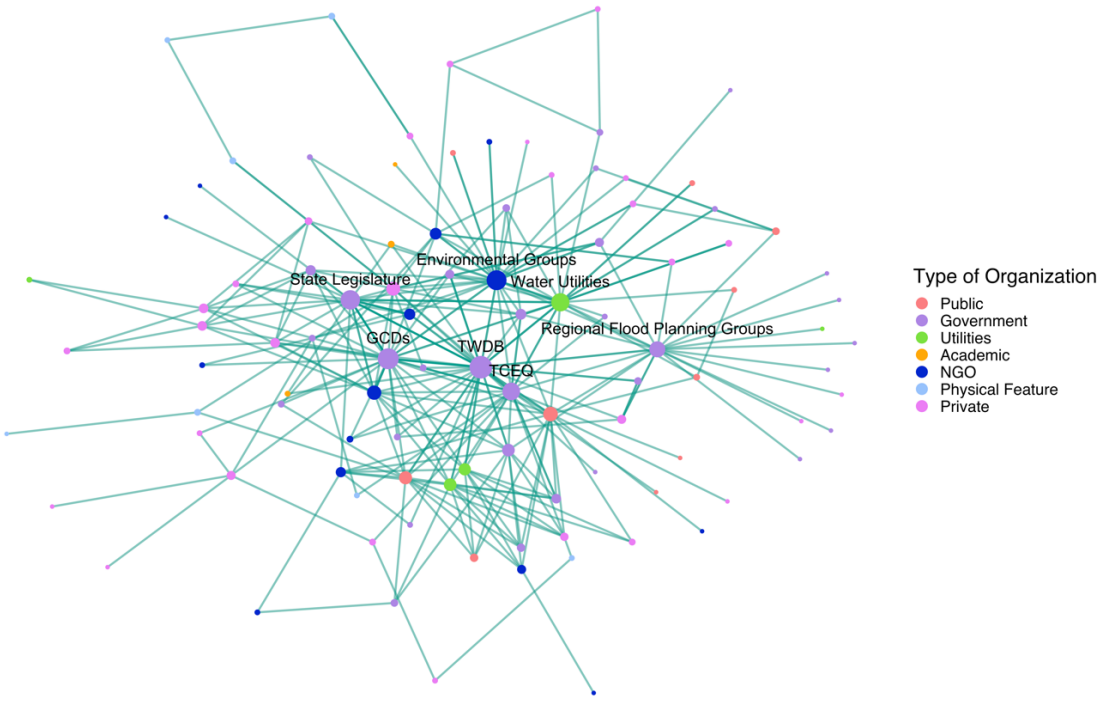

Figure 3. Institutions and connections in the Texas Water Sector

An edge, or link between two nodes, represents a policy and/or governance connection. Our research identified 20 different policy/governance links connecting different actors in the system. Figure 1 is an aggregate map that visually presents different connections. The frequency, or relative use, of the different connections are reported in Table 3.

Table 3. Policy and Governance connections across the Texas water sector

Type of policy/governance connection	Frequency of use	Percentage as total of all connections
Money	52	18%
Information	51	18%
Membership	30	11%
Lobbying	29	10%
Water	22	8%
Regulation/Oversight	18	6%
Advocacy/ Policy Preference	14	5%
Cooperation/coordination	14	5%
Water sales	13	5%
Permits/Authorization	12	4%
Contract	11	4%
Water rights/regulation of	6	2%
Authority to set rules	4	1%
Litigation	4	1%
Grants	2	1%
Water disposal	2	1%
Ecosystem Service	1	0%
Infrastructure services	1	0%
Litigation	1	0%
Water savings	1	0%
Total	**283**	**100%**

Each individual subsector is summarized in Table 4 and discussed below.

Table 4. System characteristics by subsystem.

	Number of institutions	Number of institution types	Number of connections	Number of connection types	Density of map
Agriculture	15	4	42	12	.20
Energy	15	5	*20*	9	.10
Environment	20	6	40	5	.11
Flood	23	5	27	3	.05
Groundwater	*14*	5	29	9	.16
Innovation	25	6	41	6	.07
Municipal	17	5	25	9	.09
Rural	*27*	5	*74*	8	.11
TX Water	**100**	**7**	**283**	**20**	**.03**

Agriculture[*]

The agriculture sector includes 15 institutions/agencies, including many of the most central institutions across Texas water: TWDB, TCEQ, the state legislature, ground water conservation districts, and trade associations. It is interesting to note that agriculture includes a number of actors that are somewhat well connected in agriculture, but who do not participate in any of the other sectors (hence their relatively small size despite being well connected in this map). They include: water marketers, surface irrigators, groundwater irrigators, and livestock producers. The sector map includes 42 total connections and an extensive diversity of policy/governance mechanisms (12), the most frequent of which is water sales (25%). The structure of the water sector is "cohesive" in that there is a higher density of connections between institutions than other sectors (20% of all possible connections are present between the actors, i.e. graph density of .20).

Type of connection	Frequency	% in sector
Water sales	10	25.64%
Lobbying	5	12.82%
Membership	4	10.26%
Litigation	4	10.26%
Advocacy/ Policy Preference	3	7.69%
Permits/Authorization	3	7.69%
Water rights/regulation of	3	7.69%
Money	2	5.13%
Grants	2	5.13%
Information	1	2.56%
Regulation/Oversight	1	2.56%
Authority to set rules	1	2.56%

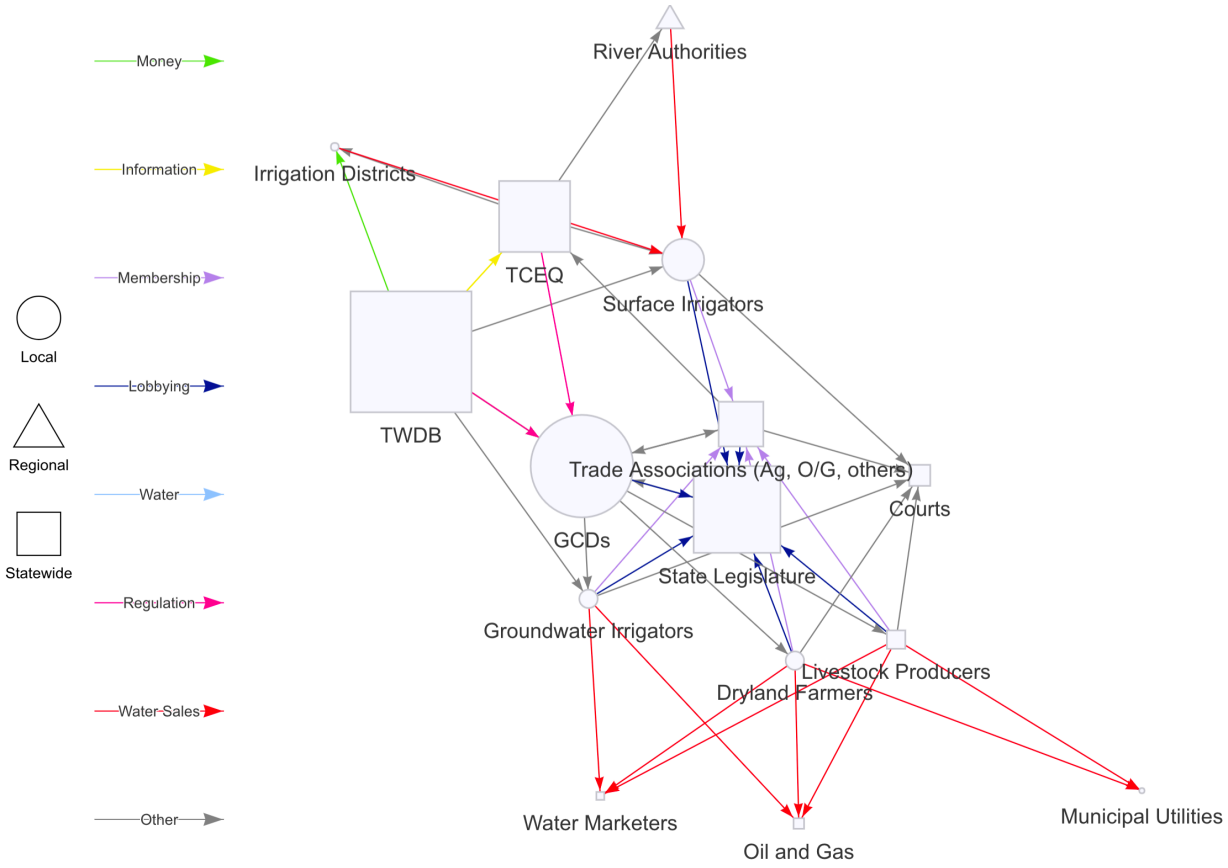

Figure 4. Agriculture sector of Texas water

[*] Subsectors are presented in alphabetical order.

Energy

The energy sector has 15 institutions/agencies and 20 policy/governance connections. The most frequent reported connection is information, followed by regulation, water sales, and permits. Water disposal is an aspect of this sector not found in others. The structure of the energy sector is unique as compared to the other sectors given the prominent "brokering" role of Oil and Gas Exploration and Production Operators (OG E&P Operator). Network brokers are characterized by being central in their "in-between" connections that serve as a bottleneck to others in the sector. This is characterized by a centrality statistic called *betweenness centrality*. OG E&P Operators are in the bottom quintile for degree centrality (number of connections) but in the top quintile for betweenness centrality across the entire Texas water system.

Type of connection	Frequency	% in sector
Information	4	22.22%
Regulation/Oversight	3	16.67%
Water sales	3	16.67%
Permits/Authorization	2	11.11%
Water disposal	2	11.11%
Water	1	5.56%
Water rights/regulation of	1	5.56%
Authority to set rules	1	5.56%
Lobbying	1	5.56%

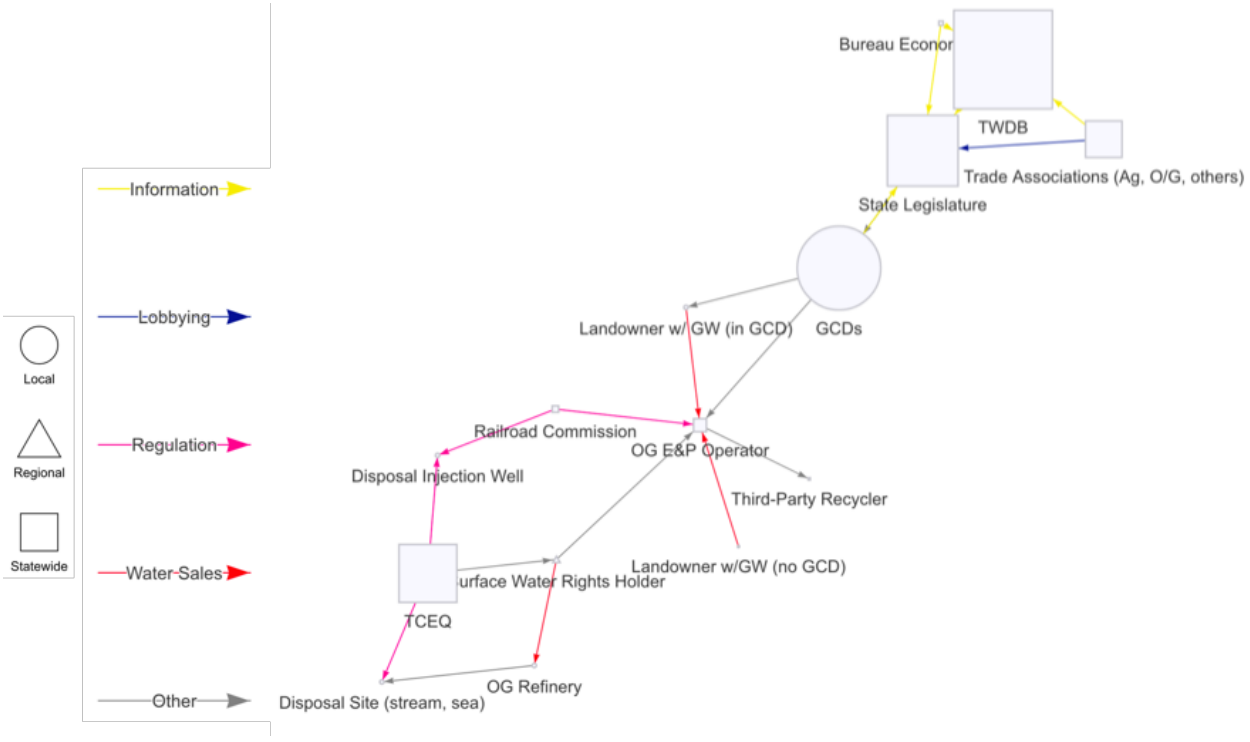

Figure 5. Energy sector of Texas water

Environment

The environmental sector prominently includes environmental groups involved in lobbying (80% of policy/governance connections) and relies on cooperation and coordination (40% of connections) much more than any other sector. In total, there were 40 policy/governance mechanisms recorded and 20 institutions/agencies included. As visualized, there are two types of "community" structures in this map. Primarily on the right side, there is cooperation/coordination, information, and advocacy between environmental groups and other types of groups and agencies (hub and spoke formation with environmental groups in center). On the left side, more central and formal institutions are involved in lobbying each other. The central role of environmental groups and the dense cluster of other institutions give the graph the highest graph centralization score of any sector (centralization = .55).

Type of connection	Frequency	% in sector
Lobbying	22	81.48%
Cooperation/coordination	11	40.74%
Information	4	14.81%
Advocacy/ Policy Preference	2	7.41%
Litigation	1	3.70%

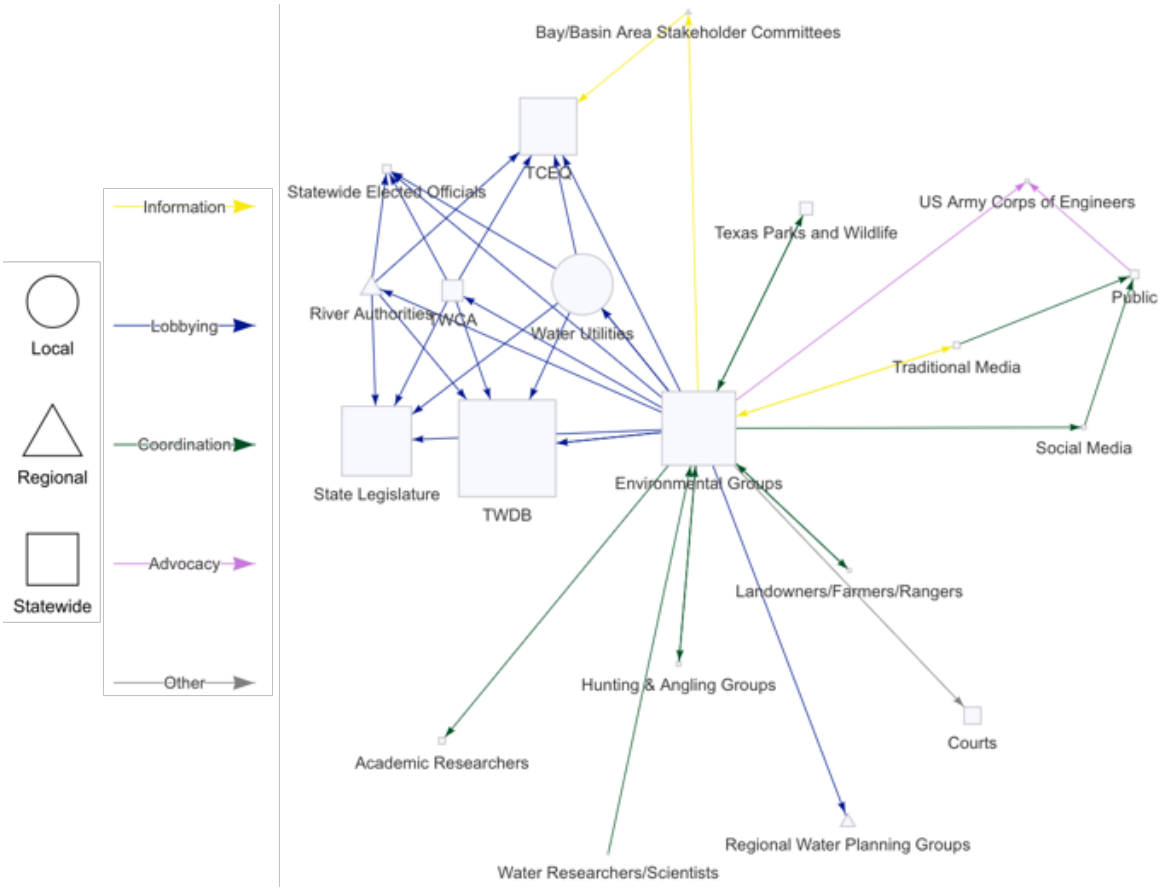

Figure 6. Environment sector of Texas water

Flood Management

As visualized below, the flooding sector reflects simple system organization (hub and spoke centered around regional flood planning groups) indicative of the nascent stages of formal planning and organization in the sector. That said, there are many institutions/agencies involved (23). Membership is the prominent type of policy/governance mechanism (70%), with money and information rounding out the types of connections. In total, 27 policy/governance mechanisms were reported.

Type of connection	Frequency	% in sector
Membership	19	70.37%
Money	5	18.52%
Information	3	11.11%

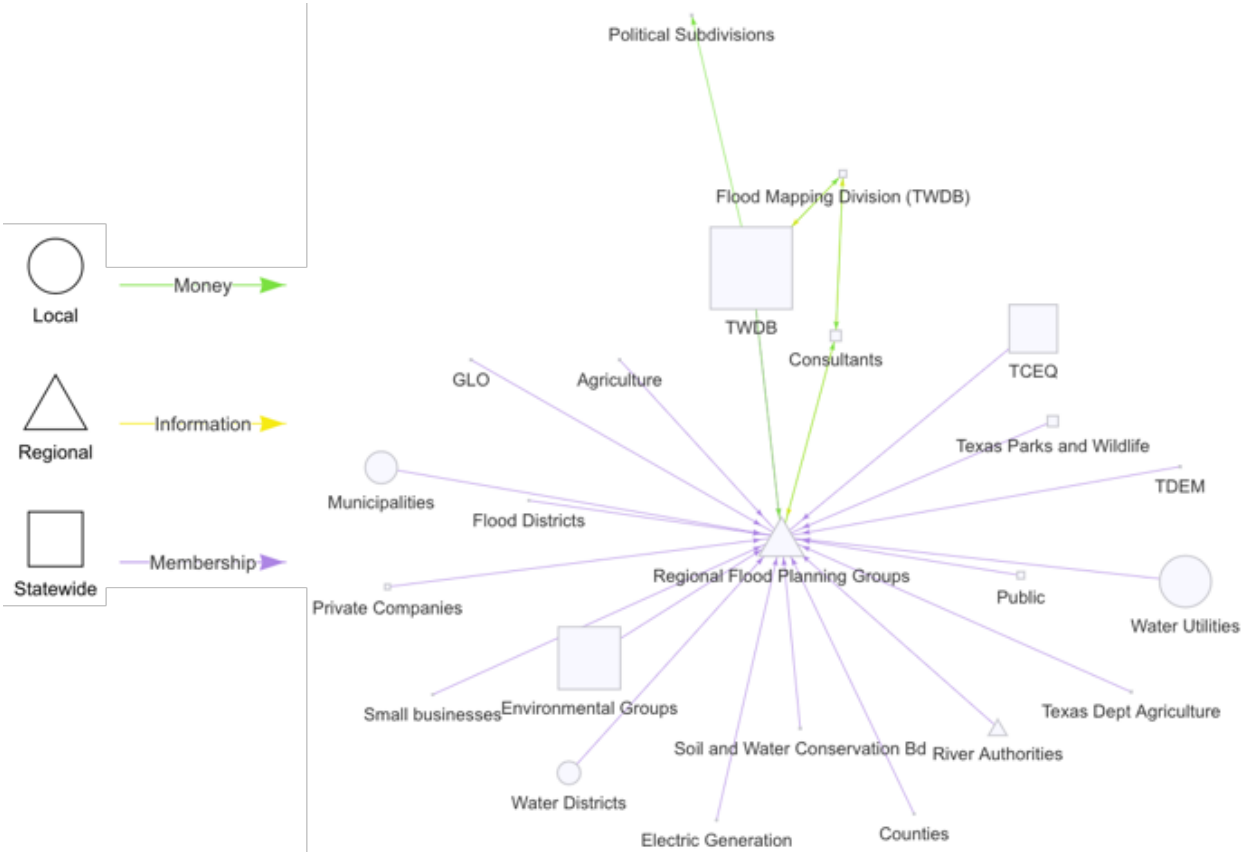

Figure 7. Flood management sector of Texas water

Groundwater

Groundwater is an information rich sector with nearly 50% of the reported policy/governance connections being information exchange. There are more statutory-related connections in groundwater (i.e., permits, authority, rights, and regulation) than other sectors. In total, there are 29 policy/governance mechanisms and 14 institutions/agencies. Groundwater conservation districts, the Texas Water Development Board, and the state legislature are central actors. Similar to the agriculture sector, this is a "cohesive" set of actors as indicated by the graph density (.17).

Type of connection	Frequency	% in sector
Information	13	48.15%
Advocacy/ Policy Preference	4	14.81%
Membership	2	7.41%
Money	2	7.41%
Authority to set rules	2	7.41%
Lobbying	1	3.70%
Permits/Authorization	1	3.70%
Water rights/regulation of	1	3.70%
Regulation/Oversight	1	3.70%

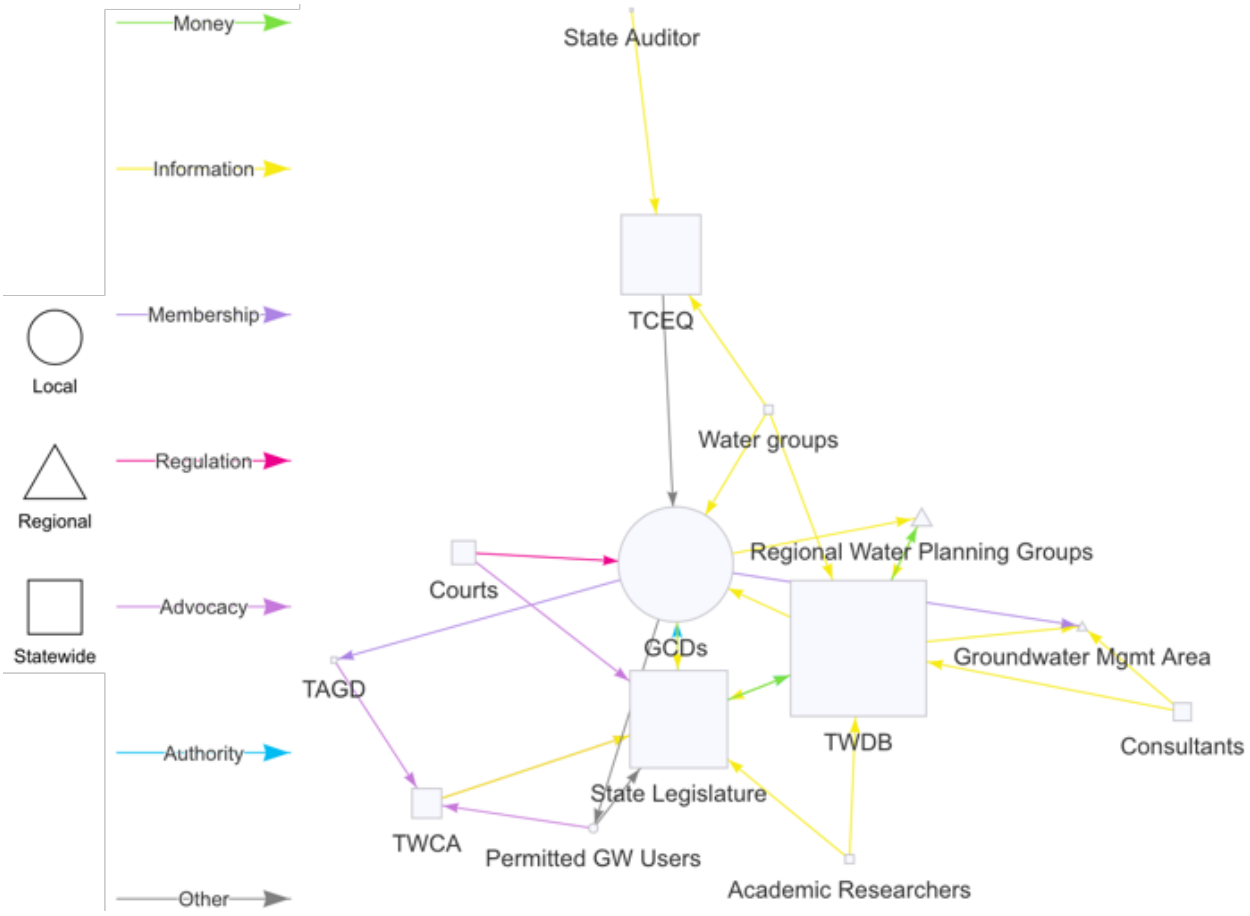

Figure 8. Groundwater management sector of Texas water

Innovation

Innovation in Texas water is about using creative funding and incentives to increase efficiency and move water to where it is needed most. To that end, a primary policy/governance mechanism is an exchange of money for water. Actors in the water innovation subsector, including well-established institutions/agencies from other sectors (i.e., TWDB, environmental groups, GCDs, water utilities, surface irrigators), are connected in new and original ways. The innovation sector also includes actors not considered in other sectors' maps, as innovators look to capitalize on flows not considered elsewhere. In total there are 25 institutions/agencies and 41 policy/governance mechanisms.

Type of connection	Frequency	% in sector
Money	24	58.54%
Information	8	19.51%
Water	6	14.63%
Water rights/regulation of	1	2.44%
Ecosystem Service	1	2.44%
Water savings	1	2.44%

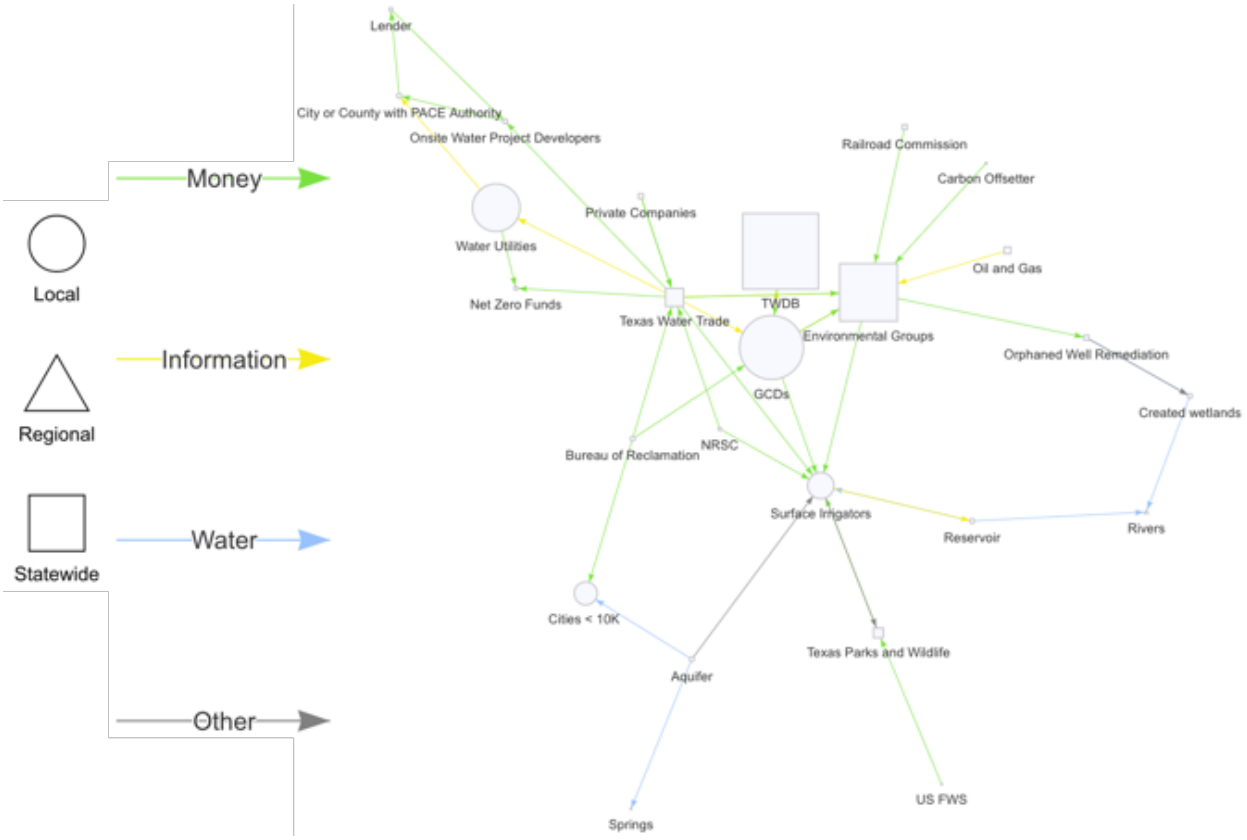

Figure 9. Innovation sector of Texas water

Municipal

Structurally similar to the environment sector, the municipal water sector consists of two main graph "communities": one clustered around water utilities and the other clustered around municipalities (with a high graph centralization score of .5). It has more parity in the distribution of policy/governance mechanisms that other sectors. Water flows to and from water utilities, and advocacy, money, information, and regulation connect the actors in the sector. There are 17 institutions and 25 policy/governance connections in the municipal sector.

Type of connection	Frequency	% in sector
Water	5	27.78%
Advocacy/ Policy Preference	5	27.78%
Money	3	16.67%
Information	3	16.67%
Regulation/Oversight	3	16.67%
Permits/Authorization	1	5.56%
Cooperation/coordination	1	5.56%
Contract	1	5.56%
Infrastructure services	1	5.56%

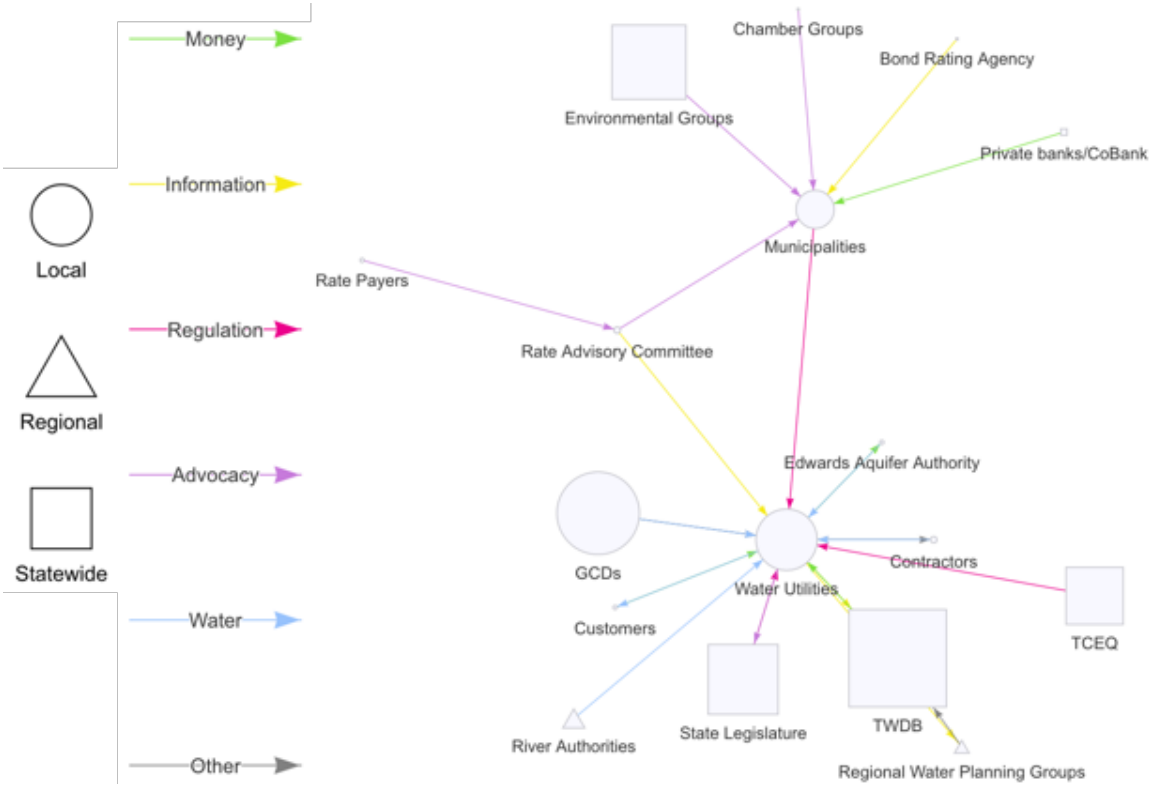

Figure 10. Municipal sector of Texas water

Rural

The rural water sector is the most active and expansive in terms of total number of institutions/agencies (27) and total number of policy/governance connections (74). Money and information are the two most frequent connections, followed by regulation, water, and contracts. In addition to central institutions such as TWDB, TCEQ, GCDs, and the state legislature, the rural sector includes some national level entities and federal agencies. This illustrates the complexity of ensuring a reliable supply of clean water to rural areas.

Type of connection	Frequency	% in sector
Money	16	21.92%
Information	15	20.55%
Regulation/Oversight	10	13.70%
Water	10	13.70%
Contract	10	13.70%
Permits/Authorization	5	6.85%
Membership	5	6.85%
Cooperation/coordination	2	2.74%

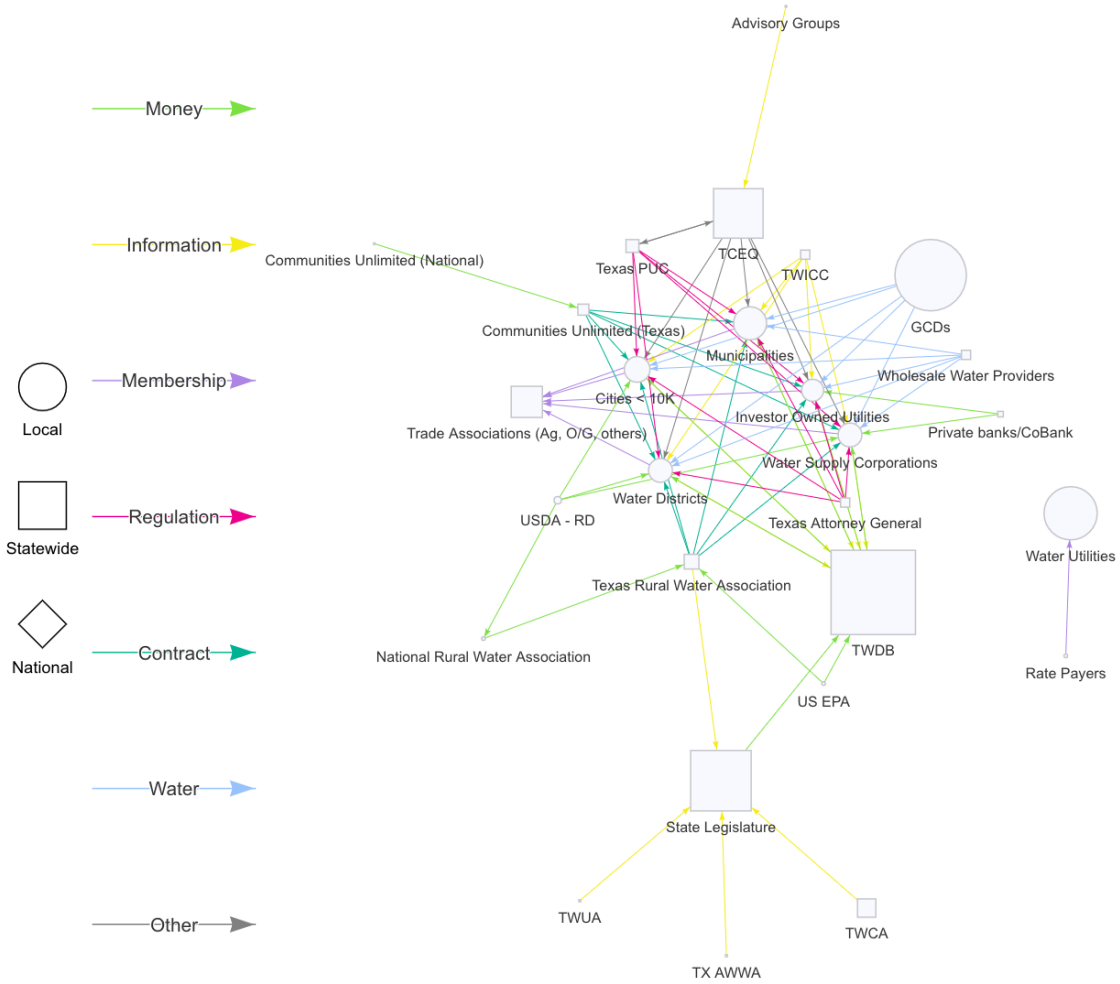

Figure 10. Rural sector of Texas water

References

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Appendix A: The Mind Maps

Each of the maps created in our interviews is provided below. Some of those interviewed felt their subsector was better captured in multiple maps (Figures A4-A6).

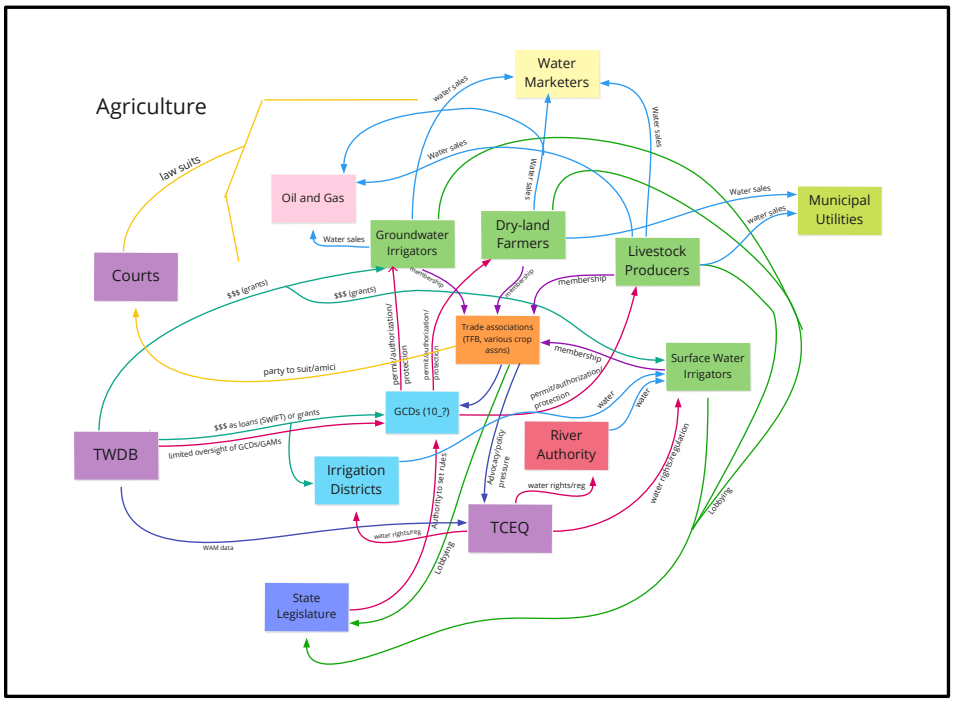

Figure A1. Texas Agriculture

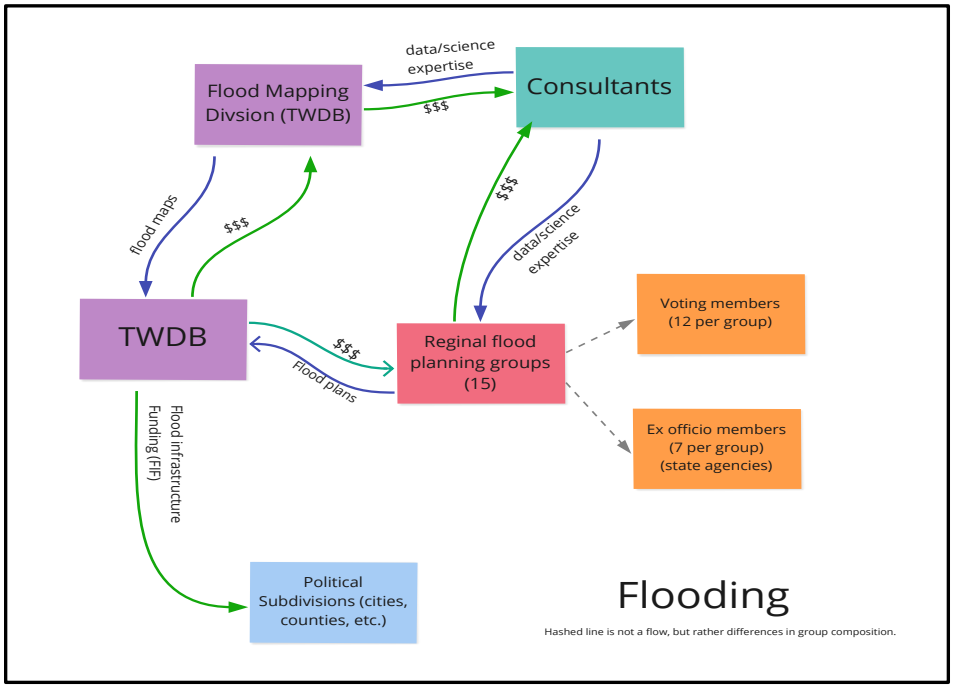

Figure A2. Flooding Prevention and Response

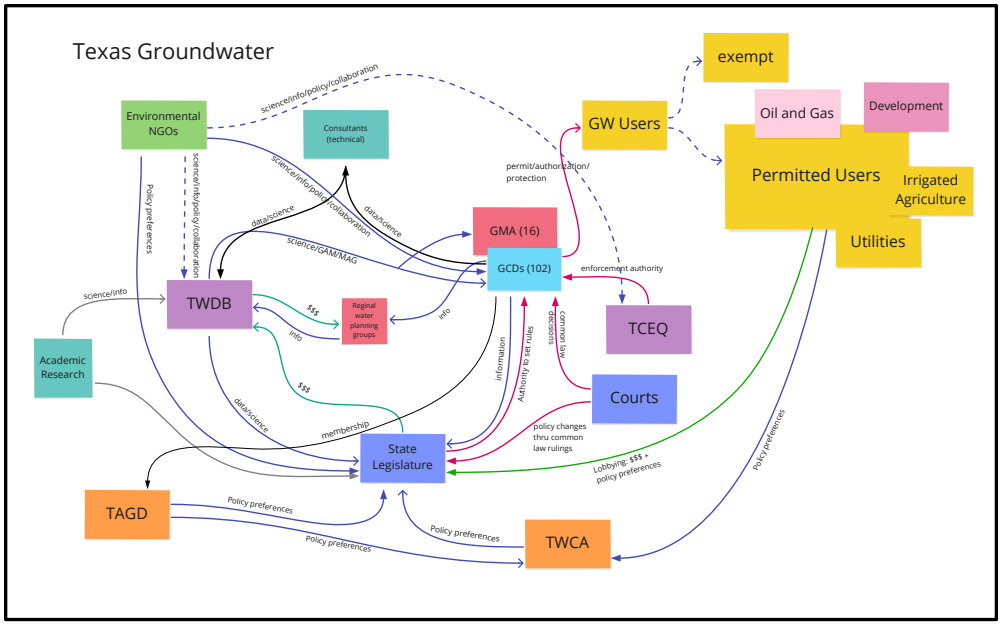

Figure A3. Groundwater

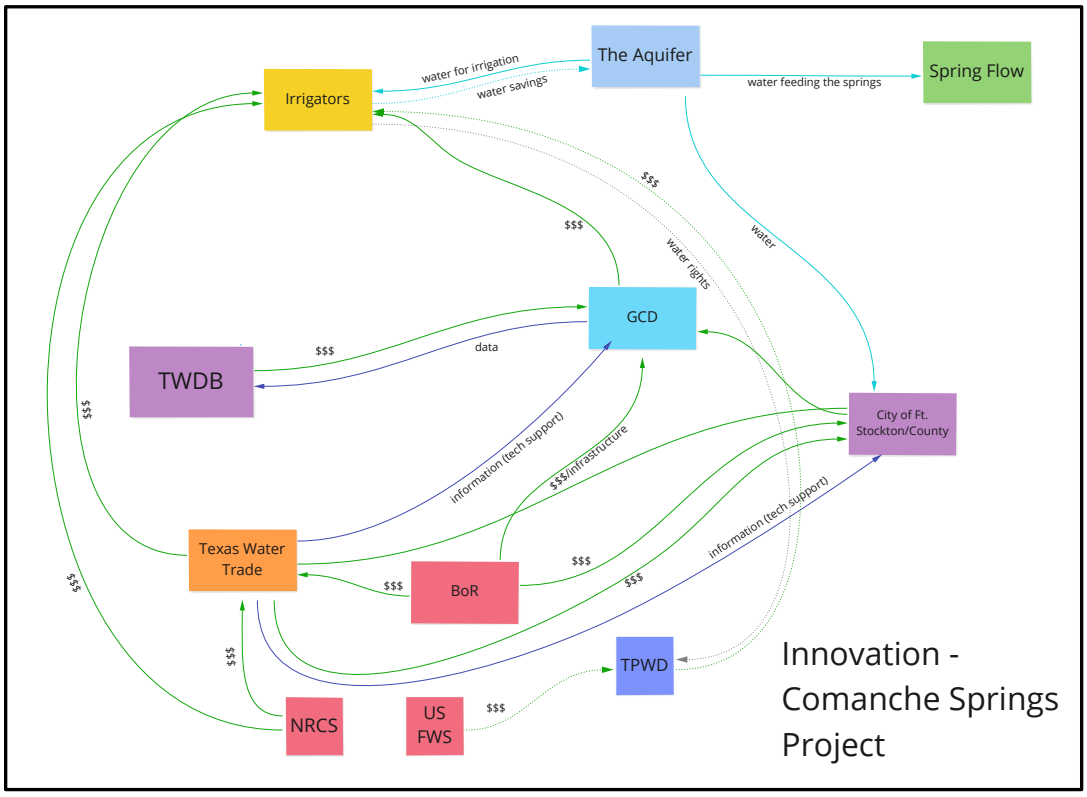

Figure A4. Water Innovation (Comanche Springs Restoration)

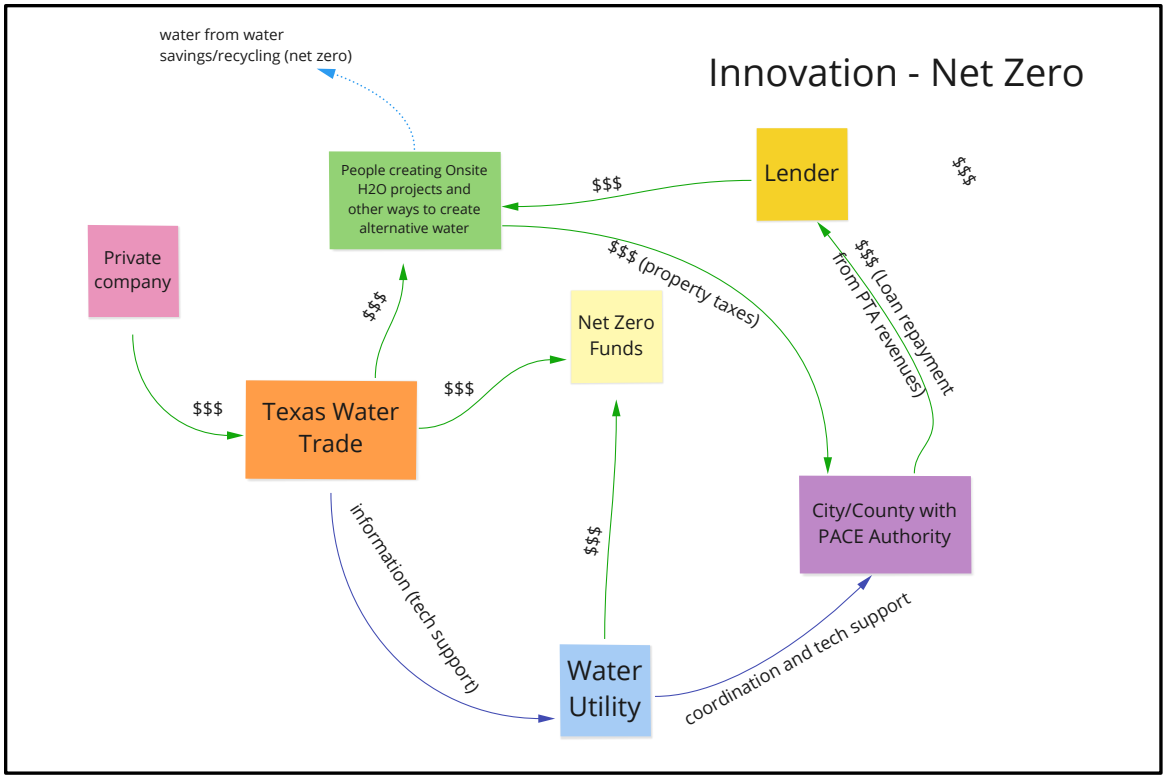

Figure A5. Water Innovation (Net Zero Projects)

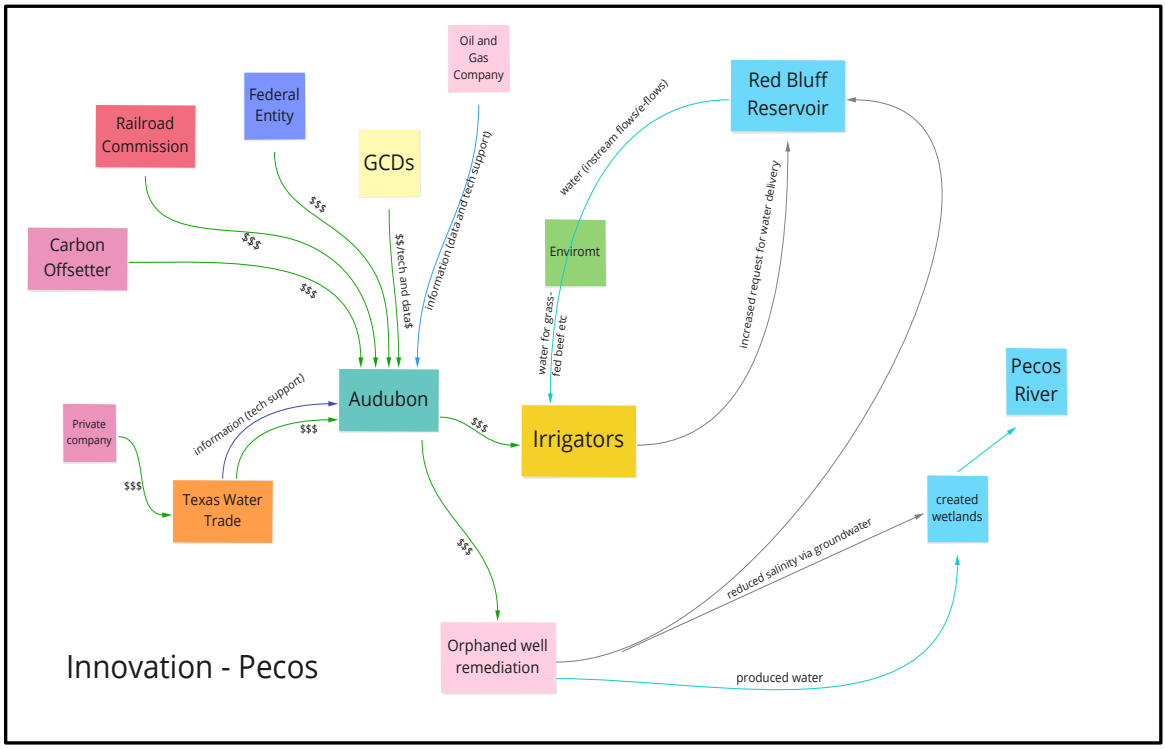

Figure A6. Water Innovation (Pecos River)

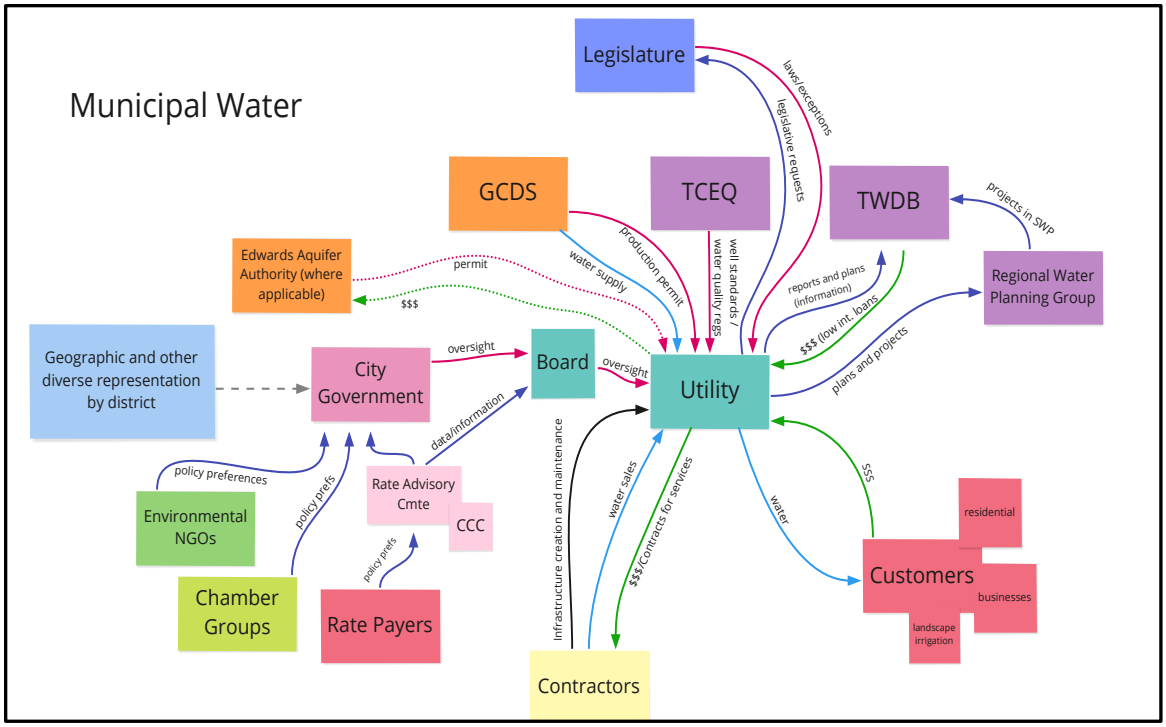

Figure A7. Municipal/Urban Water

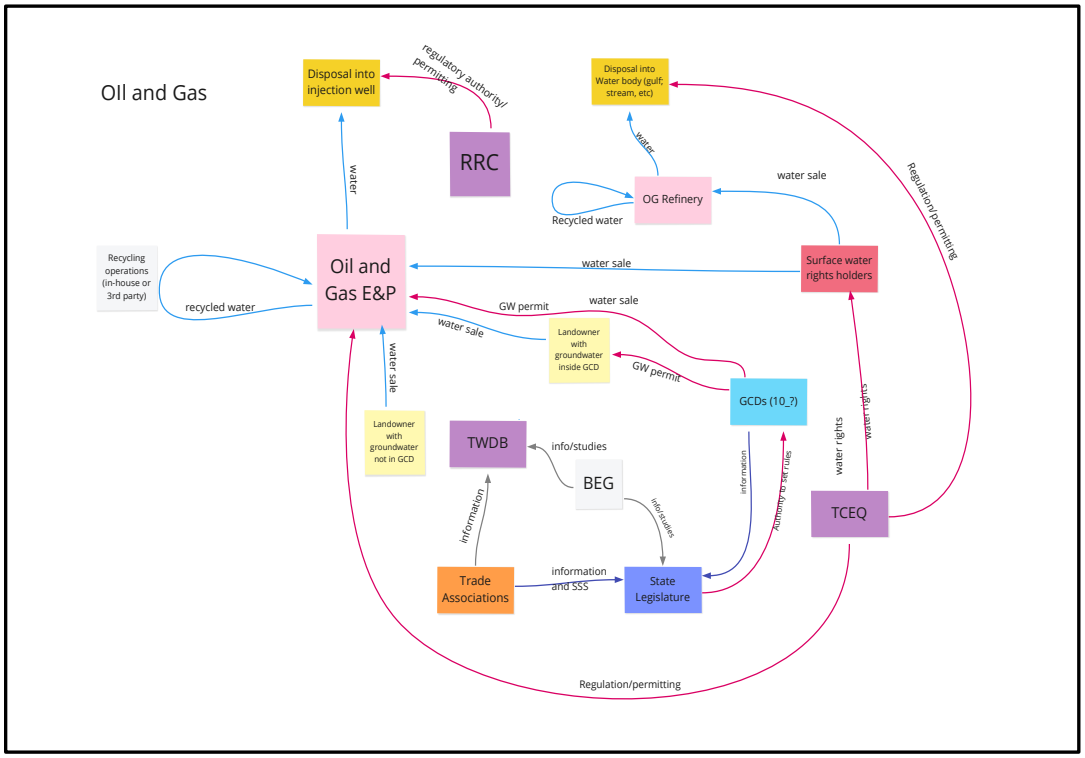

Figure A8. Oil and Gas

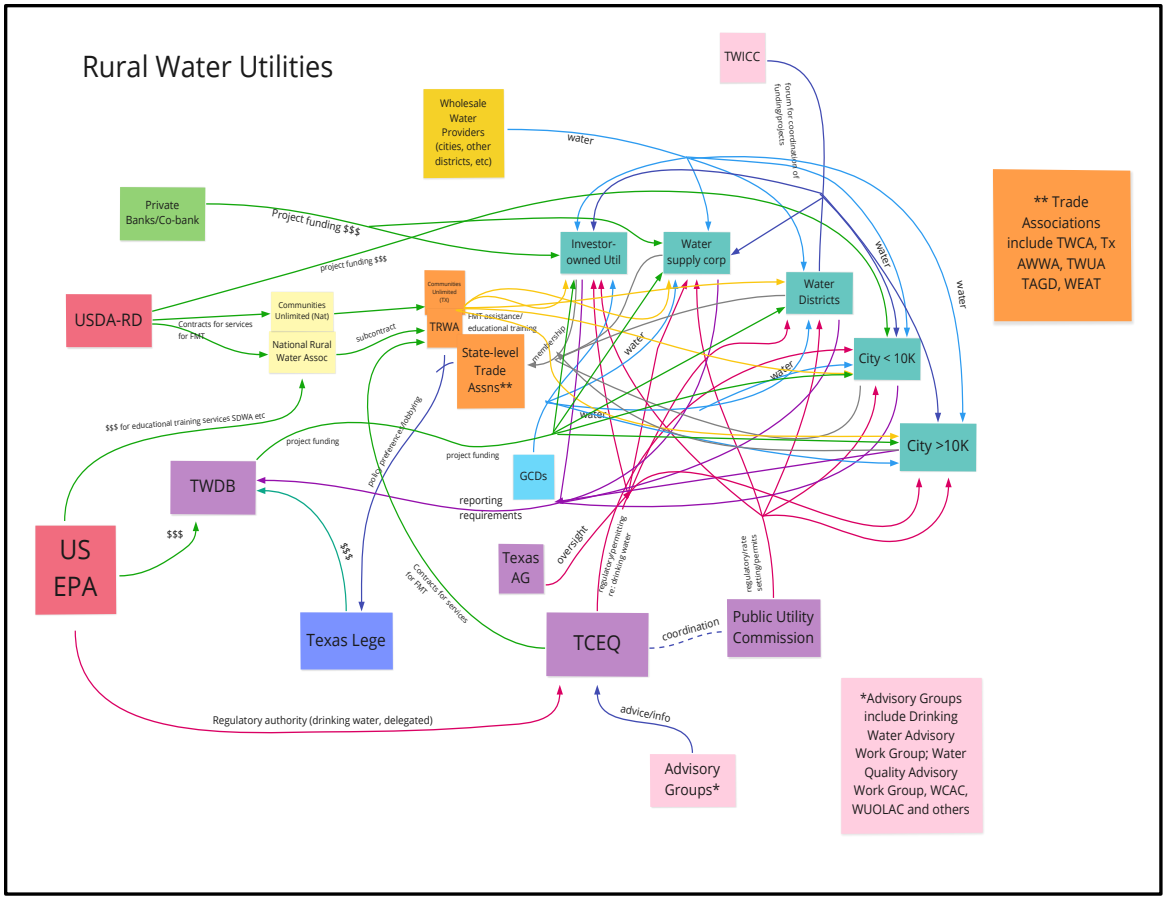

Figure A9. Rural Water Utilities