Surface Water Regulation in Texas: Problems and Solutions

Maria Vaca
Stefni Richards
Alexa Davis
Kylie Jackson
Nanag Timur
Fahad Manzoor
Said Azam
Robert Jr (RJ) Feltman
Dr. James Griffin (Faculty Advisor)

A Bush School Capstone Report to Hon. Glenn Hegar,
Texas State Comptroller of Public Accounts

The Bush School of Government & Public Service
Texas A&M University

Executive Summary

According to the 2017 Texas State Water Plan, Texas will experience an 8.9 million acre foot water shortage by 2070. The question is what role surface and groundwater will play in alleviating this shortfall. The 2016 Capstone project to Comptroller Hegar assessed the potential for ground water to meet these predicted water needs (the Brady et al. report). This report is a follow on report focused on surface water.

In several ways, surface water poses a more complex task because one cannot point to a single regulatory institution with simple fixes. Indeed, in many respects, surface water institutions in Texas are relatively sophisticated. From the extensive WAM modeling used by the Texas Commission on Environment Quality (TCEQ) to the comprehensive 50-year water plans produced by the Texas Water Development Board (TWBD), Texas is significantly ahead of other states in their water planning and management. However, our analysis has identified three major problem areas, the solutions to which are the focus of this report.

Our research concludes that the first major problem area is the water planning process and the potential problems of planning for an uncertain future. The second major probem area is that water is under-priced and inflexible during drought periods. This leads to waste and fails to incentivize conservation. The last major problem area is that water is trapped from flowing to its most efficient use. Significant regulatory and legal impediments exist for using surface and groundwater conjunctively, for moving surface water between river basins, and even for moving surface water within a river basin.

Solutions to these three major problems lead us to propose a variety of fixes. Regardless of other policy options, addressing the planning process should be the first step. We present three suggestions to improve the existing planning process. First, we need to ensure that state/federal regulatory barriers are taken into account when weighing the feasibility of new projects such as construction of new reservoirs. Second, there is a need to consider alterrnative scejarios in the water planning process. Specifically, alternative scenarios should consider (a) the potential for more severe droughts due to climate change and (b) the possibility that not all of the 2500+ new projects will be completed. Third, the conflicting criteria for project funding as applied by the regional planning groups and the Texas Administrative Code Guidelines utilized by the TWDB need to be reconciled. Using a common set of criteria and explicitly calculating the net present value cost-per-acre-foot will enable better choices among alternative projects.

Even though addressing the planning process will no doubt improve our performance in the future, Texas is underutilizing its existing water resources. We offer the following two basic alternatives: (1) a water tax that varies monthly across regions and over time in response to drought conditions or (2) the creation of an active water market capable of moving trapped water and pricing that responds to drought conditions.

The tax option will fix the underpricing problem and the inflexible nature of water prices during droughts. As prices rise, a water tax will encourage conservation, especially in droughts when conservation is essential. The proposed tax will vary regionally, monthly, and differentiate between agricultural and municipal demands. The tax is based on the Palmer Drought Severity Index (PDSI). Applying a water tax will solve the pricing problem of artificially low and inflexible prices. It allows users to face the cost of the real scarcity of water in their region, which will result in water conservation. However, the tax fails to deal with the second problem of water being trapped, which prompts us to look to our next alternative.

Our second option focuses on the creation of a water market in Texas. Unlike the tax, this strategy will address both the pricing problem as well as the problem of water being trapped. We acknowledge that creating a viable water market is not a simple task. Consequently, we identify four essentials steps in creating a water market. The first step is increasing the amount of water available for trade. This can be accomplished by introducing price flexibility into river authority contracting, lifting regulations on return flows, and amending take or pay contracts to allow resale of unused water. The second step involves allowing water transfers between surface water and groundwater by relaxing usage restrictions imposed by groundwater conservation districts (GCDs) on groundwater and by the TCEQ on surface water diversions. The third step consists of increasing inter-basin transfers in the state by eliminating the junior rights provision that limits inter-basin transfers. The fourth, and perhaps most challenging step is removing the administrative impediments to intra-basin transfers. To address these administrative challenges, we offer three options: (1) speed up the TCEQ permit process, (2) implement more Watermaster systems and (3) implement an innovative Watermaster Lite system in more water abundant areas.

I. Introduction

A. Texas Water Supplies: Adequate Today but Inadequate in Future

From providing for basic human needs, to satisfying agricultural, industrial and municipal demands, water is essential. In the past, Texas has been blessed with significant groundwater and surface water resources. By 2020, it is estimated that total surface water supplies will provide 7.5 million acre feet (MAF), and groundwater will provide 7.2 MAF per year (TWDB 2017). However, predictions suggest that total water supply will decrease from 15.2 MAF per year to about 13.6 MAF by 2070, while the demand for water is expected to rise to 21.6 MAF per year, leaving the state with an 8.9 MAF annual shortfall (TWDB 2017). Due to the declining groundwater availability resources, it is important that this report focus on surface water.

B. A Diverse Geography and Regulatory Apparatuses

Because of its size and diverse geography, water management in Texas is unique. Western regions of Texas have an arid climate, while the eastern part of the state receives plentiful rainfall. While the average precipitation rate across the state is 70.9 cm per year, the mean annual precipitation increases uniformly from west to east across Texas from 20 to 140 cm (Wurbs 2014). For the purpose of surface water management, Texas is divided into 15 rivers basins and eight coastal basins. The TCEQ is the primary regulatory agency for surface water. In addition to managing the permit application system for surface water, the TCEQ maintains and updates detailed surface water flow models called WAM models for several purposes including determining available water rights, future water planning, and managing environmental flows (Wurbs 2015).

As for groundwater, Texas has 9 major aquifers and 21 minor aquifers. Eighty percent of Texas is underlain by these aquifers (Wurbs 2014). Regulation of pumping from these aquifers is essentially managed by 100+ Groundwater Conservation Districts (GCD) across the state. These insular GCDs have regulatory power over current and future pumping rates. As explained in the 2016 Bush School Groundwater Capstone, the projected diminished future availability of groundwater may be more of a regulation-induced shortage than a physical shortage (Brady et al 2016).

C. Differing Property Rights Govern Ground and Surface Water

While hydrologically connected through the water cycle, the ownership of surface water and groundwater is quite different, leading to separate legal structures. Compare Texas Water

Code Chapter 11 with *Id.* Chapter 36 (regulating privately owned groundwater). In Texas, groundwater is considered private property and owned by the landowner. Nevertheless, GCDs wield considerable power over who pumps and how much. In *Edwards Aquifer Authority vs. Day*, the Texas Supreme Court *reaffirmed* that landowners have a constitutionally protected real property interest in groundwater similar to landowner's property interest in oil and gas and can assert a regulatory takings claim against a GCD. The Texas Legislature has codified this ownership in Texas Water Code § 36.002.

Unlike groundwater, surface water is owned by the state and regulated by the TCEQ. The primary legal doctrine that governs surface water pumping is the prior appropriation doctrine, which introduces the idea of "first in right, first in time". This means that water rights issued at an earlier point in time have priority over water rights issued at a later date. In the event that a senior right holder's entire allocation is unavailable, a junior right holders allocation may be curtailed (Jarvis 2016).

D. The Texas Water Development Board Oversees New Surface Water Projects

Every five years, the Texas Water Development Board publishes a state water plan containing a comprehensive guide for water management[1]. The 2017 Texas Water Plan intends to deal with the projected 8.9 MAF water shortage by increasing the amount of surface water available. Increasing new surface water supplies account for about 45 percent of the total recommended water management supply strategies in the Plan (TWDB 2017). Such strategies are essential to implement in the future to ensure the reliability of water sources for the future. Water management strategies allow planners to reduce the risk of streamflow variances and measure water storage capacity and future source reliability. Among these strategies, are proposals for increased use of reservoirs.

There are issues with relying heavily on new reservoirs for increased water supplies. Reservoir evaporation rates are immense. Work by Wurbs and Ayala found the mean evaporation from the 3415 reservoirs in the Texas water rights permit system was 7.53 billion cubic meters per year. In 2010, that volume of evaporative losses was equal to 61% of total agricultural or 126% of total municipal water use (Wurbs 2013). As temperatures rise, so do evaporation rates. Furthermore, reservoirs are directly dependent on rainfall, whereas groundwater is not as directly dependent on current rainfall.

[1] Texas Water Code § 16.051

E. Absence of a Functioning Water Market Poses More Difficulties

There is no functioning water market in Texas capable of reacting to short term fluctuations in supply and demand, except for the Lower Rio Grande Watermaster System.[2] The severe drought of 2011 exposed this fact. Most Texas counties saw a 25% drop in their annual precipitation rates (Nielson-Gammon 2011). By October of 2011, 88% of Texas was classified to be in an exceptional drought according to the Palmer Drought Severity Index (Nielson-Gammon 2011). Even though precipitation rates and water supplies across the state were at an all-time low, water did not move from less drought prone areas to the driest regions. Additionally, the price of water did not rise.

The famous law suit by the Texas Farm Bureau against the TCEQ exposed the absence of a market.[3] Because of regulatory constraints farmers with senior diversion permits could not sell their surface water allocations to junior rights users such as municipalities and power plants. With no ability to trade water, the TCEQ responded by authorizing these lower priority municipalities and power plants to pre-empt the ability of the senior rights holders to divert surface water as an emergency action to maintain these vital uses. While ultimately the Courts ruled that the TCEQ pre-emption was not legal, this whole episode occurred because of the lack of a viable water market. If irrigators with senior rights could have leased their senior appropriations on a temporary basis to water-starved municipalities, they would have done so. A viable water market would have avoided both putting the TCEQ in the awkward position of ignoring the long recognized prior appropriations doctrine, and the lawsuit.

The absence of a viable water market in Texas is a serious concern. If there is no scarcity premium of water reflected in its price, few incentives exist to conserve and move water from low value uses to high value uses. The absence of a water market traps water both geographically and usage wise. Because water cannot flow to its most efficient use, there is little incentive to conserve one's supply. As we shall see, there are a number of reasons why we do not have a viable water market. There is no one single culprit.

F. Resumption of Rainfall should not result in Complacency

While talk of reforms and markets were sparked during this drought, they quickly dissipated shortly after precipitation rates increased in 2012 and returned to normal thereafter

[2] Some might argue that since river authorities and municipalities engage in long term contracts, this is evidence of a market. But an active market requires more than long term contracts, it must be able to respond to short term fluctuations in supply and demand.

[3] Tex. Comm'n on Envtl. Quality v. Tex. Farm Bureau, 460 S.W.3d 264 (Tex. App. – Corpus Christi, 2017, pet. denied).

(McDonald 2016). Now, we should not become complacent to address these issues of surface water management. Rather than waiting until the next major drought and rush into ill-conceived fixes, we have the luxury of approaching these issues in a thoughtful, deliberate manner. This report focuses on several areas in which surface water policy can be improved and provides possible solutions to the problems.

G. *Special Thanks*

In the process of completing this year long project, we would especially like to thank the many contributors whose advice and guidance were crucial to completion of our project. Through classroom presentations and phone interviews, these people shared with us their expertise on surface water issues. Our criteria in seeking outside help was to look for expertise both inside and outside the state government. Also, to get a flavor for the various stakeholder interests, we solicited input from a variety of groups. Needless to say, these individuals are not responsible for the content of this report, nor do they necessarily concur with its policy prescriptions. Special thanks are due the following: Toby Baker (Commissioner, TCEQ), Michael J. Booth (attorney, Booth, Ahrens & Werkenthin), Charlie Flatten (Hill Country Alliance), James Fletcher (Texas Water Future), Bob Harden (RW Harden & Associates), John Hoffman (LCRA), Ed McCarthy (attorney, McCarthy & McCarthy), Carlos Rubinstein (RSAH2O), Amy Settemeyer (TCEQ), Haskell Simon (rice farmer), Kathleen White (Texas Public Policy Foundation), Professor Kirk Winemiller (Texas A&M Wildlife and Fisheries Science), Professor Ralph Wurbs (Texas A&M Hydrology Department).

II. The Three Fundamental Problems of Surface Water Regulation in Texas

Too often by focusing on the problems, we fail to mention the successes of Texas surface water policy. So let us briefly recount the positives. First, property rights are well-defined under the prior appropriation doctrine. This means that while the State owns the water, individual permit holders enjoy a legal system that protects their rights. Second, Texas is a leader in the science of surface water modelling through its WAM modelling effort. Third, the TCEQ brings an impressive array of technical expertise to the difficult tasks of overseeing the granting of permits and monitoring environmental quality. Finally, the TWDB provides planning over a 50-year horizon and attempts to devise incentives to expand water infrastructure.

With appreciation for these achievements, let us briefly list three major problem areas whose solutions animate this report:

1. There are certain areas for improvement in the State Water Plan. Even though Texas is a leading state in its preparation of a detailed forward looking 50-year State Water Plan, there are issues that provide opportunity for improvement. Moreover, these problems are relatively solvable.

2. The second major problem area is water allocation. The state has abundant water resources—both surface and groundwater—in certain locations where they are being relatively underutilized. If low-cost mechanisms can be found to move water to the areas of greater need, Texas can avoid high cost alternatives like seawater desalination. It is useful to think of improving water allocation through three avenues: (1) conjunctive use of ground and surface water (2) reallocation of water resources within a river basin and (3) reallocation of surface water between river basins.

3. Surface water in Texas is underpriced and inflexible in the face of droughts. The current pricing system does not include a scarcity premium for raw water. Gold commands a scarcity premium far in excess of the basic cost to mine and refine the ore. Yet, Texas surface water, a far more essential resource, commands no such scarcity premium. Especially during a drought, it is critical for prices to rise encouraging conservation.

A. Problem Area One: The Planning Process and SWIFT Funding

The TWDB State Water Planning Process is praised by water planners nationwide, and since the adoption of a regionally-based, bottom-up approach in 1997 the gap between planning and implementation has shrunk (Bruun, 2017, 3). This bottom-up approach allows for the input of hundreds of stakeholders, planning group members, and consultants, which results in a comprehensive approach to water planning (Bruun, 2017, 4). The implementation and allocation of SWIFT Funding, which subsidizes water infrastructure improvements, now depends on their inclusion in the State Water Plan. Thus, the State Water Plan matters now more than ever. Despite these achievements, there are shortfalls in the current state water planning process that cannot be ignored and are easily addressed.

The TWDB State Plan identifies 2,500+ water management projects designed to satisfy the majority of the projected 8.9 MAF shortage. However, even when taking into the consideration the implementation of every one of these projects, the state still expects to fall short of its needed supply by 2070 (TWDB State Water Plan 2017, 11). While the TWDB believes that over 30% of the 8.9 MAF shortage can be addressed by using "demand management" strategies such as irrigation and municipal conservation, new forms of infrastructure must also be constructed. Of the 8.9 million AF of additional annual supply needed to meet future needs, new reservoirs will account for 14%, or approximately 1.15 million AF, with only 1.3% being attributed to future groundwater desalination projects and 1.8% to new aquifer storage and recovery (ASR) facilities (TWDB State Plan 2017, A-8). This highlights that the TWDB prioritizes the construction of reservoirs over other forms of technology such as ASR and desalination.

Problem 1.1: The Over Reliance on New Reservoir Construction without concern for Feasibility

The last major reservoir to be constructed in Texas was Jim Chapman Lake, now referred to as Cooper Lake. This reservoir provides water for the North Texas Municipal Water District, the Sulphur River Municipal Water District, and the city of Irving (U.S. Army Corps of Engineers [USACE]. The first feasibility study for the reservoir was requested in 1948, but construction was not completed until 1991, a full 43 years later (USACE). Despite the fact that a major reservoir has not been built in a quarter of a century, and the fact that Cooper Lake took over forty years to become a reality, the State Water Plan still calls for the construction of twenty-six new reservoirs by 2070 (TWDB State Water Plan, A-108). Since the 1990s, regulations pertaining to reservoirs (put into place by both federal and state governing agencies, such as the EPA, the Army Corps of Engineers, and the TCEQ) have only gotten more stringent. It appears unrealistic to believe that over twenty-five major reservoirs will be built in the next 50 years. Still, the ability to meet future water needs throughout the state is highly dependent on the construction of these reservoirs.

Problem 1.2: Lack of Consideration for Alternative Scenarios

This problem is twofold. Firstly, future water availability models are based on the drought of record and this system runs off of the assumption that the drought of record will repeat itself in the future (TWDB State Water Plan, A-3). However, weather is unpredictable, and may be becoming more unpredictable due to climate change. The state of Texas may very well experience a drought that lasts longer or is worse in severity than our drought of record. It is important to develop contingency plans for such a situation.

Secondly, this problem is compounded by the assumption that the 2,500+ water management projects outlined in the State Water Plan will be implemented (TWDB State Water

Plan 2017). Even with the implementation of all water management projects, it is projected that the state will still fall almost half a million acre feet short of water demands by 2070 (TWDB State Water Plan 2017). Meeting future water demand throughout the state will require adaptation and contingency planning, which while being done in some regions, is not a point of emphasis in the current State Water Plan.

Problem 1.3: Conflicting Criteria for Selection of SWIFT fund projects

While making water funds available through the SWIFT is beneficial the implementation of SWIFT funding raises concerns. The process by which SWIFT Fund applications are prioritized is highly complex; yet inconsistencies in the process seem clear. First, the regional planning groups utilize what is referred to as the "Uniform Standards[4]" to rank the projects included in their regional plan.[5] The TWDB then utilizes its own criteria and ranking system[6] when considering SWIFT Fund allocation, which is considerably different from the Uniform Standards utilized by the regional planning groups. It is unclear as to why the standards used by the TWDB and the regionally planning groups are not the same, and how conflicting evaluations are resolved. In addition, neither ranking system takes into account vital concerns related to water infrastructure projects. While the Uniform Standards attempt to judge the feasibility of a water infrastructure project, the environmental concerns that could serve to have a substantial impact on the feasibility of an option do not appear to be considered.

Curiously, the standards seem rather arbitrary and subject to manipulation in favor of certain politically favorable projects. The Uniform Standards allocate 40% of the weight to "Decade of Need," but there is no criteria included as to how that estimate is calculated. Meanwhile, the TWDB ranking system makes no mention of the Decade of Need in its calculation, despite the fact that the regional planning groups assign the most weight to that consideration. The project viability criteria takes into account whether or not the project is the "only economically feasible source of new supply," but yet again, provides no instructions for how this is calculated (HB 4 Stakeholder Committee, 14). Overall, the allocation and ranking process seems to be highly prone to inaccuracies. Furthermore, there exists a fundamental disconnect between the systems

---

[4] https://www.twdb.texas.gov/financial/programs/swift/doc/HB_4_SHC_Uniform_Standards.pdf

[5] The conflicting criteria emanated from HB-4, which created SWIFT. To provide consistent criteria would require legislative reconciliation of the two.

[6] 31 Texas Administrative Code §363.1304

utilized by the regional planning committees and the TWDB headquarters. A final criticism is that in comparing alternative sources of water, costs appear to play a minor role in the choice of projects to fund.

B. Problem Area 2: Texas has a Water Allocation Problem

A continuous argument within the water policy community and academic literature highlights that there is not a water shortage problem, *per se*, but rather a water allocation problem (Ashworth, 2011). The eastern regions of Texas have abundant surface water supplies, while the western regions are more arid and vulnerable to droughts. Likewise, in some areas there are prolific aquifers and limited surface water; yet there is little conjunctive use of the two. This section addresses impediments under the current system that contribute to the surface water allocation problem. We categorize them as inability to transfer (a) groundwater and surface water (b) surface water within a river basin, and (c) surface water between river basins.

Problem 2.1: Limited Transfers between Groundwater and Surface Water

Texas water policies fail to recognize the relationship between groundwater and surface water (Kaiser 2011)[7]. There are two main arguments to support merging surface water and groundwater policies. First, is the inherent hydrological interconnection between surface and groundwater. Second, from a user's perspective, groundwater and surface water are economic substitutes to one another. Current regulation fails to recognize these facts, treating the two as separate entities. It is important to emphasize that for most water uses, like municipal, industrial and agricultural uses, there is no major quality difference between surface water and groundwater, the choice of which one to utilize should fall almost exclusively on cost. Even though the State owns the surface water and landowners own the ground water, there is no inherent reason that regulatory constraints should prevent their substitution.

a. As a long-term supply alternative: Transfers from abundant Groundwater aquifers to Surface Water

Where surface water is limited, there is a need to increase long term water supplies to meet the increased demand from economic and population growth. Where groundwater is abundant, an increased use of groundwater is an efficient way to increase water supply in the long term at a

[7] Surface water is state owned and allocated under the prior appropriation doctrine. Groundwater is privately owned, historically allocated under the rule of capture, and regulated by local groundwater conservation districts (Kaiser 2011).

lower cost than other alternatives. For these aquifers, the current regulation of groundwater by GCDs restricts the supply of groundwater to an inefficient level. Brady et. al (2016) found that even at increased pumping rates, for five of the nine largest aquifers, many years of supply would be available before reaching 50% of an aquifer's storage capacity (Brady et al, 2016). Compared to the costs of new surface water reservoirs and desalination, groundwater in these aquifers is a low-cost alternative[8] to be utilized first before transitioning to high cost alternatives.

b. *As a short term drought expedient: Transfers of Groundwater*

Even in the case where groundwater is not an abundant long term supply source, there is a rationale for an emergency conjunctive use of groundwater with surface water supply sources to alleviate short term supply problems. During a drought, surface water is much more vulnerable to the lack of rainfall than groundwater. Surface water becomes increasingly scarce leaving a gap between the demand for surface water and its supply. Currently, there is no policy that incentivizes groundwater owners to react to droughts by increasing groundwater pumping. Usage-based GCD regulations effectively preclude an irrigator from selling his groundwater to a nearby municipality or power plant whose surface water is facing curtailment or depletion.

Problem 2.2: Inadequate Intra-basin Transfers

Transfers of water within a river basin face several regulatory impediments. Water transfers are defined as "a voluntary agreement that results in a temporary or permanent change in the type, time or place of use of water and/or a water right" (Water Transfers of the West, 2012). Interestingly, the infrastructure to support water transfers exists, particularly within a river basin, because the river and its tributaries provide a natural water highway. However, there are several impediments that prevent these highways from being utilized by water right holders and other entities.

The primary impediment to transfers within a river basin is the complicated regulatory process imposed by the TCEQ in its effort to comply with legislative and legal constraints. Currently, potential buyers are not as likely to buy a water right if they need to make permit modifications, such as a change in location of diversion, rate, or use of the water. The bureaucratic process in place is time consuming and expensive for potential buyers and sellers.

[8] It is important to consider that transportation costs may be a limiting factor for both surface and groundwater project development.

The amendment process requires the TCEQ to perform a technical review using the WAM dataset to see how the amendment will affect water right holders in the basin. Then the TCEQ will publish notice of the proposed water right amendment(s) to potentially affected parties within the basin. Water right holders and other affected persons and entities then have the authority to request a public hearing. If a 30-day period passes without receipt of an objection, then the TCEQ may complete the application without holding a public hearing (Caroom and Maxwell, 2013).

This amendment process is particularly troublesome during a drought when permit holders not using their full allocation would like to lease (temporarily sell) their water to another party at a different diversion point. As surface water becomes scarce and demand for water expands, the inability to easily transfer water rights (either by short term leases or outright sales of water rights) limits the market from allocating water to its highest value uses. In turn, the constraint on transfers limits conservation from taking place by encouraging users to "use it or lose it". Senior right holders that fail to use their diversion each year effectively lose it to downstream junior right holders.

Problem 2.3: Restrictions on Interbasin Transfers

According to former TCEQ Commissioner and TWDB Chairman, Carlos Rubinstein, Texas will not be able to fix its water problems until we can successfully move water from "where it is, to where it is not" (Personal Communication, January 16, 2017). One way to do this is through interbasin transfers, moving water from abundant areas in East Texas to Central and West Texas. A major issue that arises when discussing interbasin transfers is the junior rights provision. The Texas Water Code states, "If an amendment is made to the water right to effectuate an interbasin transfer of water for a term, the affected portion of the water right shall be junior to all existing water rights in the basin of origin only for the term of the amendment."[9] The provision disincentives a water market from appearing, because it devaluates the water right. When a transfer outside of the basin occurs, the value of the water is greatly diminished due to its resultant junior priority date. For example, a buyer would not want to invest in a costly pipeline that might only be used a fraction of the year, or only during very wet years, when junior right holders can divert. Since the Legislature enacted the so-called "junior rights provision" in 1997, the number of interbasin transfers has declined significantly (Neeley, 204, 2). For example, after the junior rights

[9] Texas Water Code § 11.085.

provision was implemented there was an approximate 500,000 AF decrease in the volume of water utilized for interbasin transfers (Votteler, Alexander and Moore 2006).

C. Problem Area 3: Water Prices are Artificially Cheap and Inflexible

A reoccurring theme within the literature and our surface water policy research revolves around the underpricing of water in Texas (Griffin, 2011). This section seeks to highlight how water is being underpriced and how that inhibits water conservation and innovation. Within this problem, we identify five contributing factors giving rise to the underpricing of surface water.

Problem 3.1: No scarcity premium for raw water

A serious problem in surface water is that prices do not register a scarcity premium like we observe for other resources. Thus, raw surface water is priced artificially low. To illustrate the magnitude of underpricing in surface water, groundwater pumping rights in the Edwards Aquifer are routinely traded and the party leasing the water may pay between $100 to $250 per AF per year under a lease depending on the buyers and sellers (Edwards Aquifer Authority, Water Transfer Data, 2016). This pricing reflects the true scarcity premium of the raw water before the buyer adds the costs of transporting, treating, and distributing the water.

The reason that surface water prices do not include any scarcity premium is largely the result of limited opportunities to trade surface water rights. River authorities typically control the bulk of diversion permits within a river basin. As quasi-governmental entities, river authorities are constrained to charge rates that only recover their costs. Those costs do not include any scarcity premium for the water that they acquired many years ago. Another contributing factor is that TCEQ approval process for changes in points of diversions are costly and time consuming. Thus, there is limited opportunity for development of a market like there is in the Edwards Aquifer to automatically register the scarcity premiums associated with water.

Problem 3.2: Current wholesale and retail water prices based on historic costs

Whether for raw water sold by river authorities or potable water provided by municipalities, the prices are based on the historical costs of building the infrastructure. Unfortunately, because these historical costs are far below the current costs of replicating either the resource or the necessary infrastructure, they do not incorporate the scarcity premium of raw water.

Water prices shown by the wholesale water rates illustrate this problem. A good example of a river authority provider is the Lower Colorado River Authority (LCRA). The LCRA provides firm long-term water contracts, ten-year term contracts, and interruptible water contracts for raw water (LCRA, 2017). In 2011, LCRA's rate for raw water was $151 per acre-foot and this price remained constant throughout the year, despite the drought of record. Clearly, there is a need to develop price flexibility to deal with such situations, as to encourage conservation during a drought periods.

Moving down the supply chain are water wholesalers who purchase raw water at some diversion point, treat it, and deliver it to local municipalities. They are likewise subject to regulated rates-- using traditional rate of return regulation.[10]

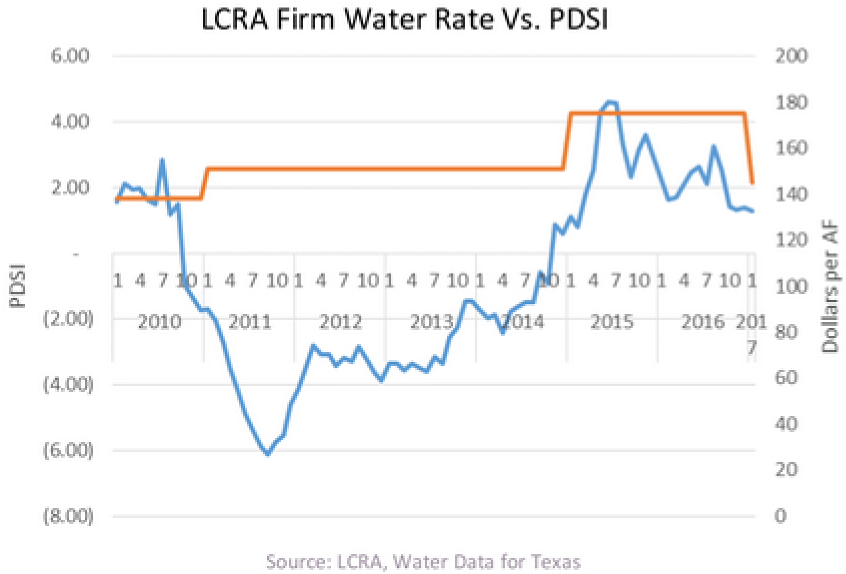
The presence of regulated rates for the transportation, treatment, and local delivery of water is a good thing by protecting consumers from the exercise of monopoly power by wholesale providers. Nevertheless, a by-product of this regulatory scheme is that prices are inflexible and based on historical costs which tend to not reflect current costs. Even within a regulated price system it is possible to introduce price flexibility. For example, in regulated electricity markets peak-load pricing is applied to curtail usage during extreme conditions, similar approaches could be applied for surface water during drought conditions.

Problem 3.3: Inflexible prices that don't respond to droughts

The inability of the price of wholesale water to fluctuate in response to drought conditions is an impediment to efficient water usage throughout Texas. The price of wholesale water contracts in Texas set by Texas river authority providing the water typically includes a flat fee, which is invariant of consumption, and a volumetric fee, which is dependent on how much water is used (Griffin, 2011). For example, Figure 1 shows the regulated rate charged by LCRA to its municipal customers over the period 2010 to 2016. Figure 1 also shows the PDSI drought index showing the most severe drought in history in 2011. Note that LCRA's prices, which were based solely on its own historical costs, showed no response to the drought. Therefore, the contract price does not change in accordance with changes in drought conditions. In a well-functioning water market (even if operation, maintenance, and capital costs remained the same), if water became more scarce, the price would increase, causing consumers to conserve.

[10] Texas Water Code, § 13.016

Figure 1



Problem 3.4: Take-or-Pay Contracts actually encourage overuse during droughts

Long-term "take or pay" contracts give no incentive to municipalities and other users, even during droughts, to conserve water. Whether they consume all of their allocated water or not, users are charged for the specific amount of water by wholesale water suppliers. Suppliers concern is their guaranteed stable revenue over water conservation. Paradoxically, cities purchasing water with "take or pay" provisions do not want their customers to conserve as this would lead to less city revenues from water sales and the inability to cover the cost of their "take or pay" contract. For example, NTMWD requires cities to purchase a maximum amount of water annually, regardless of whether the city uses the entire amount of water. Four cities, Garland, Mesquite, Plano, and Richardson, arranged a petition seeking a review of their water rates because together they paid $178 million for water they didn't use (Plano n.d.). Take or pay contracts provide few incentives to conserve. Municipalities find themselves better off taking their whole allocated amount of water under the contract even if they do not absolutely need it. This allocation inefficiency creates a vicious cycle by increasing demand for water during droughts, which prevents it from being used by its highest valued users.

Problem 3.5: Pricing return flows at zero further reduces supplies during droughts

Another significant problem area regarding surface water management in Texas is return flows. The TCEQ defines return flows as the portion of state water diverted from a water supply and beneficially used which is not consumed as a consequence of that use and returned to a body of water (TCEQ, 2016). While this concept may initially sound straightforward, indirect reuse (i.e. return flows released to a river) has been "the subject of regulatory confusion for many years" (Bradsby 2016). While some state policies encourage users to reuse their water, return flows are often not included in the right permits (Wurbs, 2015). This means that when the permit holder returns the water to the river, the returned water becomes state property subject to re-appropriation. The owner receives no compensation for the return flow and thus has little incentive to return the water for use downstream.

As previously mentioned, the 2017 State Water plan calls for 14 percent of total water supplies to come from reuse management strategies, and 7.6 percent will come specifically from indirect reuse.[11]To achieve this goal of increasing water supplies for reuse, several aspects of return flows policy must be reformed. When water users discharge and abandon any effluent into a river or stream, it becomes state water, available for appropriation. Texas Water Code contains provisions to allow groundwater users to maintain ownership of their groundwater-based return flows through TCEQ authorization. [12] By requiring TCEQ approval of the use of the watercourse to maintain ownership of return flow it devalues the private property right intrinsic to groundwater.

Another issue surrounds return flows from surface water. If a permittee does not have provisions for reuse included in their water right, they may seek amendments to the water right. Because a permit amendment can change the priority date for a reuse permit based on the characteristics of the permit, right holders may become junior rights as to the volume of reuse water, and thus discouraged from seeking access to their return flows in light of the time and cost associated with securing the amendment. If a permit amendment significantly changes the permit priority date for the reuse, then some dischargers may avoid this process altogether as a more junior priority date is subject to greater restrictions during times of drought and for environmental flows may limit the utility of the amendment. These administrative requirements discourage users from

[11] 2017 Texas State Water Plan p. 9; Indirect reuse is defined as water returned to state waterways and then extracted for a beneficial use, while direct reuse is defined as effluent water piped directly to a wastewater treatment center to a beneficial use

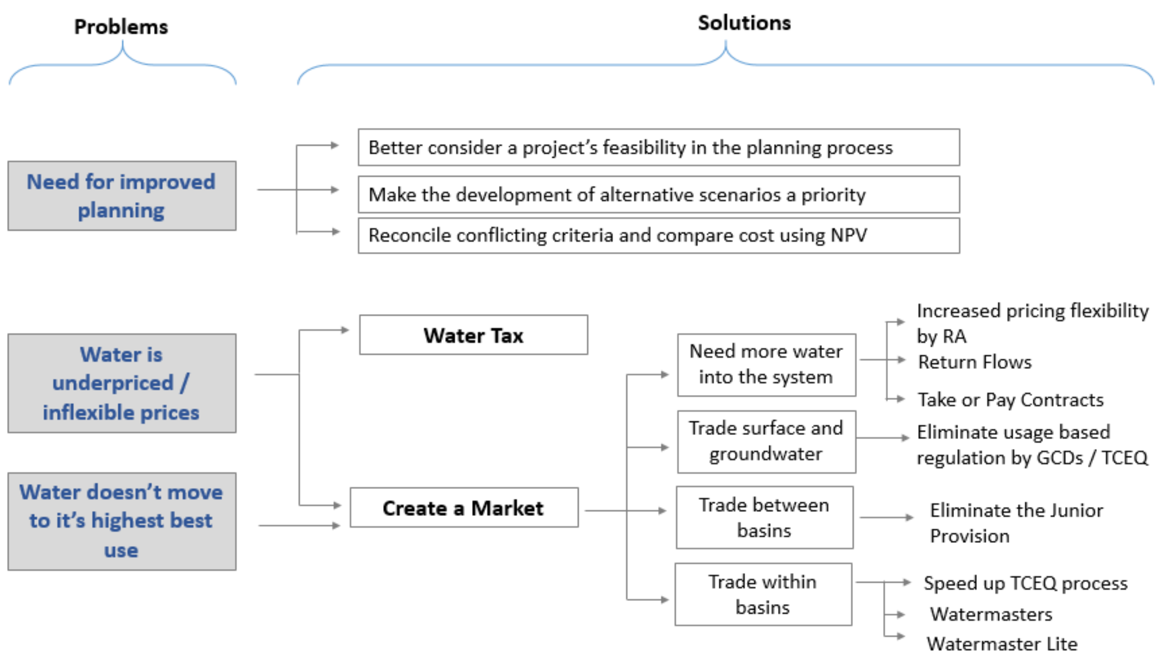
[12] Texas Water Code §11.042b

marketing their discharged water. If return flows have no value, there is little incentive to encourage their use.

III. Solutions

In this section of the report, we will present solutions to the three identified problem areas. The first solution is to improve the planning process. We argue this must be done before looking to solve other problems. This is a necessary step to ensure efficient water management for future generations. Even if all of these solutions to the planning process are implemented, we are left with the problems of how to best utilize the existing supplies of surface water. We propose two separate solutions. The first describes how a water tax could work and what problems it could solve. The second considers creating a water market and its complexities. Figure 2 serves as a roadmap to our proposed solutions.

Figure 2: Solutions Outline



A. Improving the Planning Process

Despite having a well-respected and comprehensive water plan, the water planning process and SWIFT funding allocation have areas for improvement. In response to the problems enumerated above, we propose three basic suggestions.

1. Ensure that unrealistic projects showing little to no progress towards implementation are not continually relied upon in planning.

Water management projects from previous plans that have not yet been implemented can continue to be recommended in future Plans. The 2017 State Water Plan surveyed project sponsor implementation and found that only 7% of project sponsors reported implementation[13] (TWDB State Water Plan 105).[14] While these surveys are useful, they should become a larger priority, and implementation information of strategies introduced in earlier state water plans should also be included, not just those in the prior plan. The Texas Water Code should be amended to include a provision stating that a water management strategy that has not shown progress towards implementation after a certain number of years should be removed from consideration and viable alternatives must be developed.

This provision would allow the Water Management Strategies project to be more realistic, especially when it comes to reservoir construction. There are currently over 5,000 water management strategies. Now that so many have been put forward we should begin to shift focus towards their implementation.

In addition, the uniform standards utilized by the regionally planning groups should be amended to address this issue. Currently, the feasibility rating of a project only concerns the availability of water rights and the scientific/hydrological practicality. Missing is a consideration for regulatory barriers that effect a project's implementation. For example, a measure of environmental impact could be included in the uniform standards as a way of assessing potential implementation struggles.

[13] 66% of those contacted provided no information on progress, 20% showed no implementation at all, 7% showed progress towards implementation, and only 7% were implemented

[14] According to the TWDB "Progress toward implementation" includes "start of project construction or pre-implementation activity such as negotiating contracts, applying for and securing financing or state and federal permits, or conducting preliminary engineering studies" or "achieve of a portion of the total anticipated conservation savings" – Page 105.

2. Make alternative scenario and contingency planning a priority in all regions to address risk and uncertainties in future supplies

While the State Water Plan acknowledges that the feasibility of the implementation of projects depends on "political and financial process." However, according to the 2017 plan, only *some* of the planning groups have recommended strategies beyond drought of record conditions to address risks and uncertainties such as more rapid population growth, system failure, and failure to implemented recommended strategies into in the planning process (TWDB 2017 Plan, 10-11). This type of alternative scenario planning must be a priority in all regions, especially due to the fact that implementation of strategies is lacking and that scientists and records indicate that areas of the state could exceed the drought of record in the future (TWDB 2017 Plan, 39).

In response to the 2011 drought, each region includes a section on drought response plans (TWDB 2017 Plan, 31-39).[15,16] This has made the TWDB planning process more responsive and aware of planning for droughts, but this same type of risk and uncertainty planning could and should be expanded to include other scenarios, such as more rapid population growth and the failure to implement water management projects in the estimated time frame.

3. Further improvements to the SWIFT funding criteria should include efforts to increase consistency and net present value calculations of costs per acre foot.

Projects eligible for SWIFT funding are ranked twice: once by the regional planning group and then again by the TWDB's central office. As described in the previous section, the style and criteria of the ranking systems are quite different. Uniformity of criteria would allow for more accurate comparisons between the two, which would serve to help ensure that each entity is being honest and impartial with their rankings.

The State Water Plan should calculate the net-present value of water supply for the alternative projects being considered. Comparing the net present value of cost-per-AF would allow for the comparison of projects which may provide differing amounts of water, and have different time tables for construction. Discounting allows us to consider the time value of money, and is used to find the net present value of an infrastructure project that will have both costs and benefits

[15] This section includes information such as current and planned responses to drought, triggers for drought contingency plans, and identifying alternative sources for municipalities relying on a single source of supply.
[16] For example, water suppliers were faced with a hypothetical situation in which they only had 180 days of water supply left in a time of drought, and had to find alternative sources of supply.

(in this case, water supply), years into the future. The higher the discount rate, the more emphasis that is placed on the present as opposed to the future (Shaw, 2005, 60-61).

For example, Table 3.1 shows a simple comparison of two projects: Project A and Project B. Once constructed, Project A will provide 600 thousand AF per year, but would not be completed for 20 years. Project B will provide only 300 thousand AF per year, but will be constructed by year 8. The cost of each project also varies: early on Project A will cost less than Project B per year since Project B will be constructed earlier, but between years 12 and 20 Project A is substantially more expensive than Project B. Utilizing net present value analysis can help us compare the cost of each project. With a discount rate of zero, Project A is the clear winner, as the cost per acre-foot is much lower than Project B. However, at a .05 discount rate, Project B is the better option. At a .03 discount rate,

Project A is only slightly more cost effective.. This method allows us to compare the present value of two projects with considerably different costs and capacities. Discounting allows for a consideration of how much we value the present relative to the future.

Table 1: Cost Benefit Analysis Comparison

Project A			Project B		
Year	Cost (In thousands)	Acre Feet (In Thousands)	Year	Cost (in thousands)	Acre Feet (In thousands)
1	50	0	1	50	0
2	50	0	2	100	0
3	50	0	3	100	0
4	50	0	4	100	0
5	50	0	5	500	0
6	50	0	6	500	0
7	50	0	7	500	0
8	50	0	8	30	300
9	50	0	9	30	300
10	100	0	10	30	300
11	100	0	11	30	300
12	125	0	12	30	300
13	150	0	13	30	300
14	175	0	14	30	300
15	500	0	15	30	300
16	500	0	16	30	300
17	500	0	17	30	300
18	500	0	18	30	300
19	500	0	19	30	300
20	500	0	20	30	300
21	10	600	21	30	300
22	10	600	22	30	300
23	10	600	23	30	300
...			...		
68	10	600	68	30	300
69	10	600	69	30	300
70	10	600	70	30	300

Project A				Project B			
Discount Rate	NPV of Costs (in thousands)	NPV of Acre Feet (in thousands)	Discounted Cost per acre foot	Discount Rate	NPV of Costs (in thousands)	NPV of Acre Feet (in thousands)	Discounted Cost per acre foot
0	4600	30000	**153**	**0**	3740	18900	198
0.03	2775	8548	**325**	**0.03**	2267	6868	330
0.05	2063	4128	500	**0.05**	1834	4067	**451**

Source: Capstone Estimations

B. Policy Solutions for Water Under-Pricing and Misallocation

As previously stated, we have both a water pricing problem as well as a water allocation problem. To address the problem that water prices are artificially cheap and inflexible during droughts, we first propose a water tax that would vary across regions and vary monthly depending on rainfall. We then propose the option of creating a water market, which would be designed to deal both with the pricing problem of water and the allocation problems.

C. Regional Water Taxes: that varies with water availability by region.

A water tax is designed to address the problem that water prices are artificially cheap and inflexible during droughts. First, the water tax can solve the lack of a scarcity premium because it would vary with water availability by region, and can be altered by the State accordingly to address long-term water needs. Second, as the value of the tax will automatically vary with monthly water availability, it will increase water prices during droughts. Thus, a water tax will act as a water scarcity signal and create incentives to conserve. In fact, Olmstead et al (2009) suggest that using price mechanisms to allocate scarce water supply is more cost effective than implementing other programs for water conservation. It is important to emphasize that the water tax will not solve the water allocation problem because it will not directly incentivize water transactions, nor will it remedy existing administrative problems.

In addition to signaling scarcity and promoting conservation, a tax will generate revenues that can be used for financing future water projects. The following section addresses the main characteristics of the tax and potential scenarios of tax values with their corresponding estimated revenues and conservation.

a) How the tax would work

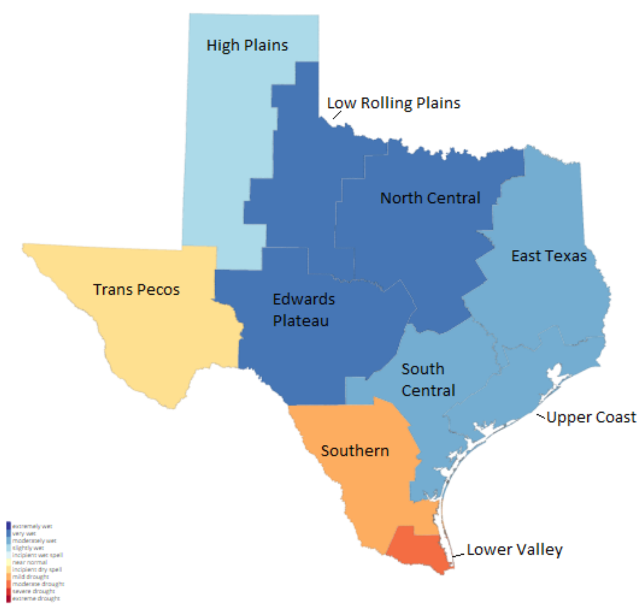
1. The tax should vary with water availability

The most important characteristic of the tax is that it must vary with water availability, reflecting the true value of water in the short and long term. This means that the tax should increase when there is less water available like in the case of a drought.

Another feature is that the tax should vary regionally to reflect water availability. A regional drought indicator, the Palmer Drought Severity Index (PDSI) can be used as a measure of water availability to determine the value of the tax. According to Water Data for Texas (2017) the PDSI index is "a meteorological drought index based on recent precipitation and temperature and is used to assess the severity of dry or wet spells of weather." The PDSI generally varies between -6 and +6, where negative values denote dry spells. In recent years, the lowest value that the PDSI has reached in Texas was in September 2011 in the Low Rolling Plains (-6.99).

The tax would vary monthly and regionally with the PDSI, which is reported monthly for the ten different regions in Texas (see figure 3). This feature will allow the tax to recognize the different hydrological conditions of each region and their water availability. An important advantage of having a regional tax instead of a statewide tax is that a regional tax will provide greater incentives to conserve in the most drought-prone regions.

Figure 3: Texas Regions for PDSI



Source: Water Data for Texas – PDSI October 2016

2. Exceptions and Discounts

The proposed tax contemplates three major exemptions. The first exception excludes applying the tax to the area managed by the Rio Grande Watermaster region, which has a functioning water market. The second exemption excludes 1AF of water per month to all permit holders. This exemption reduces the impact and administration burden on small users. In addition, the proposed tax offers an 80% discount for agricultural users. Charging a lower tax for agricultural users is justified by the theory of optimal commodity taxation of Ramsey (1927). This theory suggests that in order to minimize the "deadweight loss" of a tax, the tax rates should be lower for more elastic commodities and higher for those more inelastic uses (Gruber, 2013). Since agricultural users tend to be more price responsive[17] than municipal users, they should face a lower tax.

3. Payment options and enforcement mechanisms

In order to facilitate payments and revenue collection, all water users will have access to an online account where they will report their monthly water consumption to the TCEQ, who will act as the tax collector[18]. This account will show the tax rate for that month and the total amount owed by the user. Consumers will be able to pay their accrued bill once a year in order to minimize transaction and administrative costs.

Additionally, to allow users to plan ahead, all users will be able to access a prediction of the value of the tax for their region for the current month.

The main enforcement mechanism for the tax consists of applying extremely high penalties for those that are caught diverting water without reporting it. If the penalty is high enough, this should incentivize water users to report accurately.

b) Tax formula and estimation of scenarios

The main objective of the tax is to reflect the true scarcity of water, and thereby encourage the optimal level of conservation. The proposed tax can be calculated using Equation 1. This equation shows that the value of the tax depends on three factors: i) the numerator (Y), ii) a fixed parameter (Z) in the denominator, and iii) the PDSI. After simulating with different parameter numbers, we use a value of 7.1 for Z which in absolute values is slightly larger than the lowest PDSI (during

---

[17] According to a review of studies by Diaz et al. (2000), the range of elasticities estimated for agricultural users can be over 1, suggesting that agricultural can be elastic to water prices. On the contrary, elasticities estimations for other users suggest that they are mostly inelastic to water prices.

[18] The funds could be used for general revenue purposes or earmarked for special purposes

the drought of 2011). We have calculated three base scenarios with values of Y of 50, 100, and 200.

$$Tax = \frac{Y}{Z+PDSI_{rt}} \qquad \text{Equation 1}$$

Where Tax, represents the water tax per AF for a region r in a month t. The tax for agricultural users will follow the same equation but be only 20% of the calculated value generated by Equation 1.

We estimate the corresponding tax values, water conservation and revenue that would have been generated in the period 2010 – 2016 for the nine[19] regions in Texas.

1. ***Tax values***

The estimation of the tax that each region would have faced since 2010 show two important points. The first is that the tax structure allows the value to vary considerably with water availability and that the starting value of the tax has an important effect in the average values and level of variability of the tax. Based on the period January 2010- January 2017, the statewide average tax with Y= 100 would have been about $26/AF and varied from a low of $7/AF to a high of $909/AF in one month. If the value of Y were set at 50, the above numbers would be halved and if Y = 200, the above numbers would be doubled.

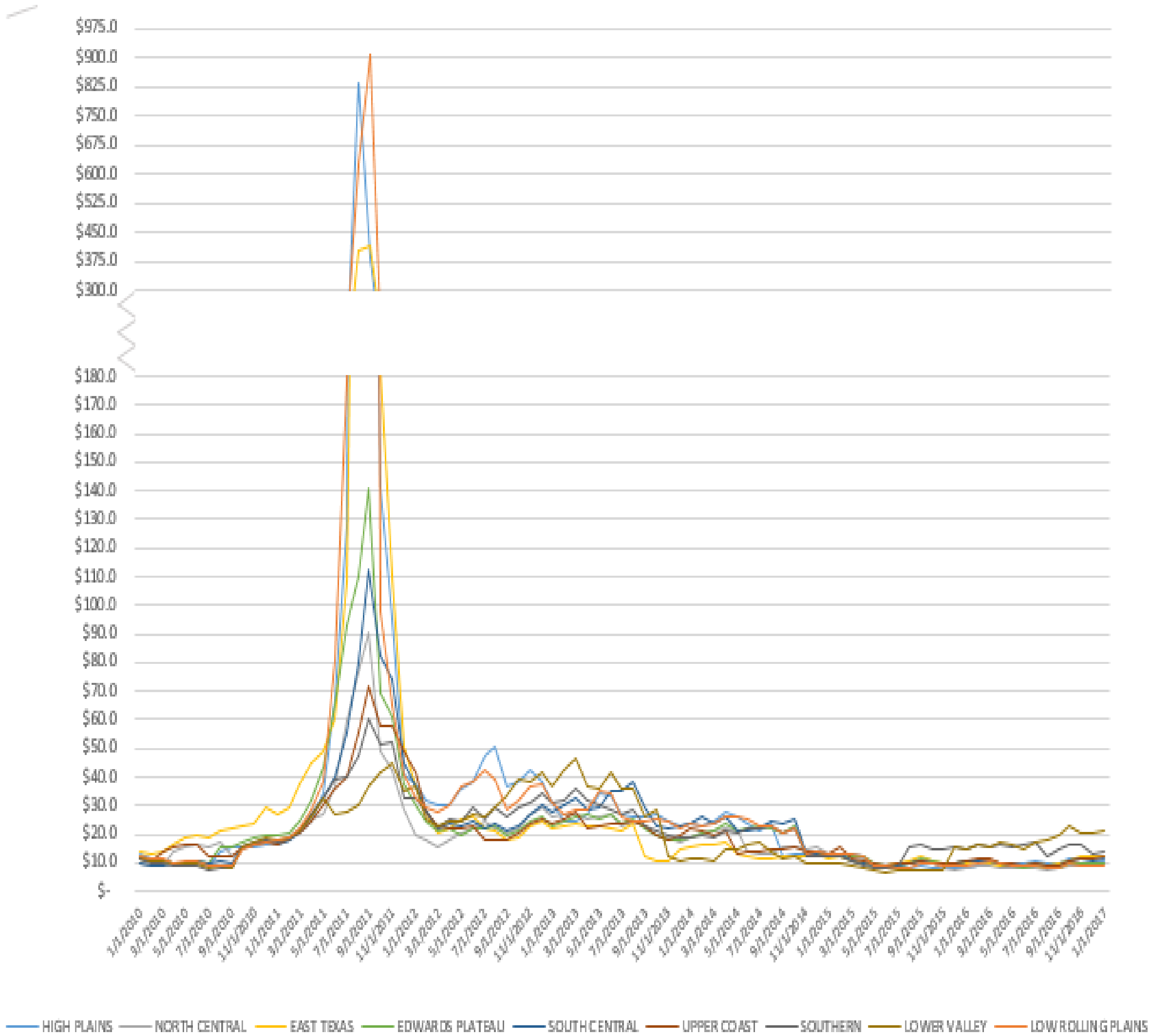
The variability of the tax with water availability is also showed graphically as the tax values dramatically increase in 2011(the year of the drought) for all staring values and the values decrease in wet years like 2016 (See Figure 4).

The second important conclusion from these estimations is that most of the time, when water is abundant, the tax is relatively low. Whereas, during drought conditions the value of the tax can reach very large values, which is a desireable feature of the tax. If water is scarce, it should cost more to encourage consumers to conserve. Although the tax can reach high values, these peaks rarely occur, and the majority of the regions would face low tax values each month since 2010. For a Y=100, 83.3% of tax values would have been less or equal to $30 per AF[20]. Conversely, the tax exceeded $100/AF in only 2.2% of the cases.

[19] As the Rio Grande is exempted from the fee, the estimations exclude the Trans Pecos regions, which means that estimations are done only for 9 of the 10 regions.

[20] For a starting value of $50, 91% of the tax values would have been below $20 per AF and for a starting value of $200, 73.7% of the tax values would have below $50 per AF.

Figure 4: Tax Values by Region (2010 – Jan 2017) Y=100



Source: Capstone Team Estimations

The value of the water tax will not have a significant burden on Texas families. For example, a family of four[21], would have to pay an additional $11.80 per year for an average tax of $26.37 (Y=100). This means that for a family that is paying $3 per 1,000 gallons it represents an increase in their annual bill of 2.7%[22]. During drought periods when the tax exceeds $100/AF, their average monthly bill would increase by $10.50 per month (which represents a 29% increase of their

[21] According to the EPA (2017) an average family of four uses 400 gallons of water per day.
[22] In addition, the tax will not become a large burden for agricultural users. For example, a tax with a Y=100 results in average tax for agricultural users of $2.67 per AF which represents a price increase of 5% relative to the LCRA prices for interruptible contracts.

monthly bill) providing a strong incentive to conserve. While this is a substantial increase over the 2010-2017, it occurred in only 2.2% of the cases.

2. *Water Conservation*

Applying a water tax will allow users to face the real scarcity cost of water in their region, which will result in water conservation. This means that the tax will achieve one of its objectives, which is to reduce water consumption, especially in drought conditions like 2011. Based on the values of the tax previously calculated, we can estimate the percentage of reduction in water consumption for each month. Equation 2, shows that water conservation depends on the price elasticity of demand for water, the value of the tax and the original water price.

$$Conservation\ (\%) = elasticity\ x\ \left(\frac{Tax}{Water\ Price}\right) x\ 100\% \qquad \text{Equation 3}$$

For this estimation, the short run water price elasticity[23] used is 0.38. This means that increasing water prices by 10% would reduce water usage by 3.8%. For water prices in Equation 2, we used LCRA current water rates. ($145[24] for firm water used and $49.88[25] for agricultural (interruptible) water). The conservation estimates differentiate between agricultural users and nonagricultural users to account for different original prices and difference in the values of the tax. Figure 5 shows what the conservation (in percentage points) trends would have been since 2010 if the tax was applied. As expected, the amount of water saved each year depends on the value of the tax which in turn depends on drought conditions. Water conservation is higher during droughts due to the tax increase.

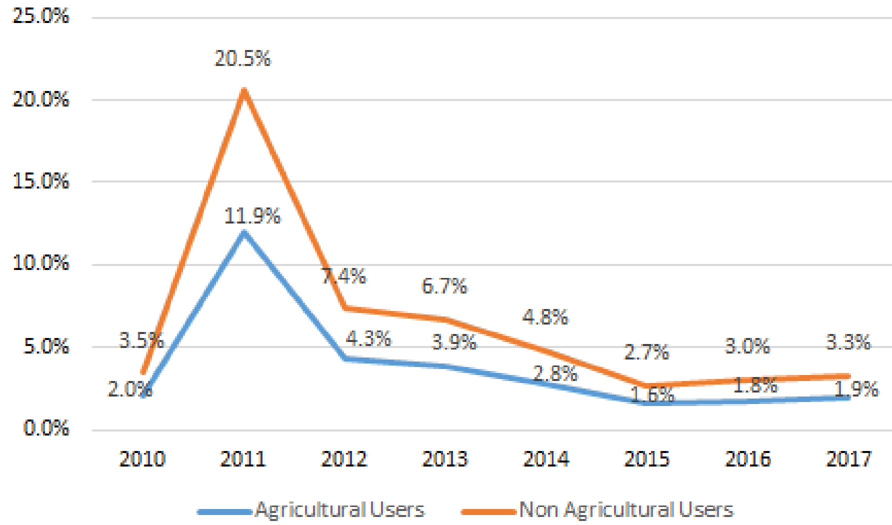
Water conservation resulting from the tax can be equivalent to increasing water supply by a certain percentage as it decreases the water deficit. For instance, in 2011 a tax with a $Y = 100$ would have been equivalent to an increase in supply of surface water by 20% for nonagricultural uses and 12% for agricultural users.

[23] See M. Espey, J. Espey, and W. D. Shaw (1997) and Bell & Griffin (2005).

[24] LCRA, Water Supply Contracts, http://www.lcra.org/water/water-supply/water-supply-contracts/Pages/default.aspx

[25] LCRA, Feb. 17, 2016, LCRA Board adopts new rules for interruptible water customers, http://www.lcra.org/about/newsroom/news-releases/Pages/LCRA-Board-adopts-new-rules-for-interruptible-water-customers.aspx

Figure 5: Percentage of water conservation across all regions (2010 – Jan 2017) (Y=100)



Source: Capstone Team Estimations

Conservation arising from the water tax can have an important long run impact. The TWDB estimates that due to an increase in demand and slight decrease in surface water supply, the deficit of water in 2070 would be 8.9 million AF per year. Based on the tax conservation estimations and the prediction of surface water availability in 2070, we can estimate how much water could have been saved relative to the 2070 deficit. The average water savings for non-agricultural users based on the estimations of the period 2010 to 2017 is 7% and for agricultural users is 4%. Assuming that the percentage of conservation of 2070 equals these averages, we estimate that the total conservation would represent 7.4% of the water deficit of that year[26] (8.9 million AF). While the conservation effects during hypothesized "normal conditions" is not as large as during a drought, one should focus on the conservation potential during drought conditions, which as shown in Figure 5 would have been quite large in 2011.

3. *Estimated Tax Revenue*

The revenue estimation intends to provide a general idea of how much revenue would be generated for Y=100. The estimated revenues are calculated using the average tax of the year, multiplied by the amount of diversion from surface water.[27]

---

[26] This percentage is calculated assuming an elasticity of -0.38, but literature suggest that elasticities increase in the long run. Consequently there could be a larger conservation in the future that the current estimation.

[27] The amount of water diverted is calculated as the sum of monthly diversions (accounting for the 1AF exemption) and not accounting for the water diverted from the Rio Grande. Since no data was available for 2015 and 2016, we assumed that the diversion in this two years were equal to

In a wet year, like 2015, a tax with Y=100 would result in a revenue of $224 million which would have represented 27.1% of the operating budgets of the TCEQ and TWDB combined in 2015[28]. In a dry year, like 2011, a tax based on Y=100 would result in a revenue of $1.5 billion--twice the operating budgets of the TCEQ and TWDB combined in 2011.

D. Create a Water Market

A water market is a comprehensive solution that will solve both the water pricing problem (underpriced and inflexible), and the water allocation problem. First, a water market would solve the underpricing problem arising from the lack of a scarcity premium. With a market, water prices will respond to water scarcity, but their usefulness will be particularly significant in times of drought. Higher prices signal the scarcity of water to economic agents, creating incentives for water conservation. Secondly, a market will solve the allocation problem, encouraging water to move to its highest valued use. If owners of groundwater and surface water permits can sell their water, they will voluntarily respond by selling it for higher valued uses. As noted in the previous section, there is currently no active water market to allow water to move to its highest valued uses, despite the existence of river basins that could serve as major water highways.

Creating a viable water market in Texas will not be easy. At least four impediments have blocked its development. In order to facilitate a water market in Texas, four necessary steps must be taken. The first step consists of increasing the amount of water in the system available for trade by changing restrictions on river authority's pricing, return flows, and take or pay contracts. The second step consists of allowing water transfers between surface and groundwater, enabling groundwater to substitute for scarce surface water especially during droughts. The third step is to facilitate interbasin transfers, which have not been occurring despite abundant supplies in East Texas. The fourth and final step is to promote intra-basin transfers to make better use of our river basins as water highways transferring water to its highest valued use. Conceptually, this is the toughest of the four steps to solve so we consider three alternative administrative solutions. They include (1) speeding up the TCEQ permit process, (2) implementing more Watermasters and (3) experimenting with a new Watermaster Lite system. The details of the solutions are described below.

that of 2014. The data was obtained from the Water Use Data 2000 – 2014 from TCEQ Website: https://www.tceq.texas.gov/permitting/water_rights/wr-permitting/wrwud.

[28] For the values of TCEQ and TWDB expenditures see Comptroller Office (2017).

Step 1: Increasing the Amount of Water Available for Trade:

a) Encourage More Flexible Pricing by River Authorities

As mentioned in the problems section, inflexible water pricing results in a lack of conservation. While this issue would be addressed by the previously mentioned water tax, river authorities play a key role in setting long term fixed prices. More innovative price setting mechanisms need to be developed. We suggest two main strategies to allow river authorities to set flexible water prices that will fluctuate with

Where uncommitted supplies exist, encourage river authorities to maintain an emergency pool to be auctioned off during droughts.

If river authorities are allowed to auction uncommitted supplies during a drought, an auction would assure that these emergency supplies went to their most efficient use. The idea of emergency supplies is similar to electric utilities maintaining peak load capacity. Peak load pricing has a long history of being applied to regulated public electric power producers and could be utilized for water as well.

Even in long term contracts, encourage river authorities to introduce automatic r price escalators that would be triggered as reservoir storage falls below certain threshold levels.

It is quite common for river authorities to enter into long term, fixed price contracts that guarantee a buyer water for 30 or more years. Because of this long span of time, major droughts will surely occur during the duration of the contract. During such periods, it is critical that prices rise so as to encourage conservation. The idea is simple. Set some threshold of reservoir capacity (e.g. 50%). As storage falls below this threshold, the prices would automatically escalate by a predetermined formula. If municipalities were aware of this provision, they could inform their customers, encourage conservation, and help mitigate the effects of the drought.

b) More Efficient Use of Return Flows

The 2017 Texas State Water plan predicts that reuse water management strategies will produce 723,000 AF per year per by 2070, accounting for 14 percent of total water supplies (TWDB 2017). However, the amount of water generated from reuse in 2020 will only amount to four percent of the total water supplies. Clearly, a large deficit exists between the current figures on reuse and the predicted amount of water to be supplied by reuse in the future. Indirect reuse and increased utilization of return flows are critical for meeting these 2070 goals and increasing the future total water supplies.

Currently, the uncertainty surrounding ownership of groundwater return flows and the TCEQ permitting process prevent indirect reuse from becoming a viable strategy to augment future water supplies.

Solution for groundwater return flows: Ownership of groundwater return flows should be automatically maintained

Many groundwater owners have not actively sought to maintain ownership of their return flows. This makes effluent groundwater worthless to the discharger and prevents the marketing of this resource. Because the discharger must seek TCEQ approval, transaction costs associated with filing and receiving authorization may outweigh the benefits of owning the return flows. Instead, if ownership of return flows from groundwater was automatically maintained with no necessity for permitting, dischargers would have a greater incentive to return effluent to waterways so they can potentially market these return flows downstream. Amending the Texas Water Code allowing for automatic authorization of groundwater return flows would have positive implications for water markets as well as for increased environmental flows. The amended water code should require the discharger provide notice of the points of discharge and diversion, and the rate and volume of the discharge and subsequent diversion.

Solution for surface water return flows: Ownership should reside with buyer and original priority date of the water right should apply

Another issue is the permitting process of surface water return flows. If a water right permit holder wants to utilize or sell surface water-based effluent returned to a river or stream, they must have a reuse permit or obtain a bed and banks permit. Currently, prior appropriation further complicates this process. If a right holder seeks a permit for return flows after their initial water right, or amends certain permit characteristics of an existing reuse permit, their permit may be issued a new priority date instead of reflecting the original priority date of the water right.

Allowing the priority date for a reuse permit to remain the same on permit amendments will incentivize right holders to utilize access to their return flows. If an amendment significantly changes priority date, some dischargers may avoid this process due to greater restrictions placed on a more junior priority date during times of drought and for environmental flows. Regardless of when the return flow permit is issued, permits should retain the original priority date.

c) Current Take-or-pay contracts encourage waste

As stated in the problem section, take or pay contracts prevent conservation. Since buyers pay for water regardless of whether to use it or not, they are inclined to use the full amount of water, as allocated on their contract. Thus, they have no incentive to conserve.

Solution: Allow all take-or-pay contract buyers the ability to resell their unused contracted water

If contracted water buyers could resell their unused contract water, they would have an incentive to conserve water. This policy option encourages municipalities to conserve water and participate in the market, where water will reach its highest valued user.

Step 2: Conjunctive Use of Surface Water and Ground Water

Another fundamental issue in Texas is that groundwater and surface water resources are not managed conjunctively. In some Texas regions, groundwater may be abundant whereas surface water is scarce. In other areas, surface water maybe plentiful with fewer groundwater resources. Texas water policy fails to recognize the interchangeable nature of groundwater and surface water, preventing an integrated market from developing.

Current case law provides precedent and continues to support strong property rights for ground water[29,30]. Yet, regulatory barriers prevent groundwater and surface water from moving to its highest valued beneficial use.

Solution: Eliminate usage based regulations by the GCDs and TCEQ.

Groundwater owners should be able to utilize the water they own, as long as it is used for a beneficial use set forth by the Chapter 11 of the Texas Water Code[31] . If groundwater is going towards a beneficial use as specified by the Texas Water Code, there should be no further regulation on when and where a water right holder can use their water. One set of commentators explained that rule of capture has been greatly modified and skewed through the years, but the balance between GCD’s and private ownership of the water as a property right, while delicate, still demonstrates property ownership as a priority (37 Tex. Tech L. Rev. 1 2004-2005).

This should extend to surface water as well. If a permit holder is simply changing the use of surface water from one beneficial use to another, at least when the use is not more consumptive,

---

[29] *Houston & Texas Central Railroad Co. v. East*, 81 S.W. 279 (Tex. 1904).

[30] *City of Corpus Christi v. City of Pleasanton*, 276 S.W.2d 798 (Tex. 1955).

[31] Texas Water Code Chapter 11 defines “beneficial use” to include: domestic and municipal, agricultural and industrial, mining, hydroelectric, navigation, recreation and pleasure, public parks and game preserves.

the TCEQ approval process should not be required. Allowing changes in water usage will facilitate a water market and allow water to move from lower valued uses to higher valued uses.

Step 3: Eliminate Junior Rights Provision restricting Interbasin Transfers

As previously mentioned, water resources in Texas are not evenly distributed across the state. Water transfers from areas with substantial water supplies to areas where water is very scarce, are necessary for efficient water allocation. Senate Bill 1's so-called "junior rights" provision is a major impediment to interbasin transfers. This provision mandates that a senior water right holder who participates in an interbasin transfer will lose their original priority date, becoming junior to all other water right holders in the basin. Because Texas follows the prior appropriation system, meaning "first in time, first in right", senior rights are particularly valuable as they are the least likely to be cut off during times of drought (WGA 2012). Because water rights are devalued when they are made "more junior", the junior provision disincentives both right holders from selling their water and buyers from purchasing a right they know will be more vulnerable to drought in the future. This section offers two solutions to promote interbasin transfers.

Solution: The junior provision must be eliminated to encourage interbasin transfers.

If interbasin transfers do occur, another issue arises concerning compensation for the area of origin (i.e. the water basin that will transfer water to a different location). In all western states, the most important criteria for approval or rejection of a request for water right transfer is the "no injury" rule (WGA 2012). This means changing existing water rights should not produce negative externalities for other vested water rights. Even if Senate Bill 1 requirements are eliminated, the negative impacts on the area of origin must be solved.

Solution: Texas should utilize mitigation funds and arbitration to compensate the area of origin for interbasin transfers

River basins and communities in Texas should utilize an arbitrator to create their own context-specific mitigation funds. There are several examples of successful mitigation funds in other states. For example, in the Metropoliintan Water District (MWD) and Palo Verdo Valley Irrigation District's (PVID) interbasin water contract, the MWD provides a Community Involvement Fund (CIF). The CIF compensates the area of origin in the form of training programs for community members, support for small business, and cash per AF of water diverted (WGA, 2012). In Nevada, areas of origin simply impose a $10 fee per AF on all water that is transferred out of the county (WSWC, 2012). These solutions can be applied in Texas.

Step 4: Intrabasin transfers

Even within a river basin, it is difficult to change points of diversion to move water to its highest valued uses. This is especially true for intra-basin transfers, as the water right amendment process is time-consuming and expensive. From 2013 to 2016, there was a 55% increase in the days it took to process a water permit application. This is problematic in that without intra-basin transfers, water will not be able to reach its highest valued use and will continue to have an undervalued price. This section addresses three potential solutions that aim to (i) speed up the TCEQ permitting process to facilitate more transfers (ii) encouraging more Watermasters and (iii) experimenting with Watermaster Lite systems.

Solution: Option 1. Speed up the TCEQ water permitting process by automatically processing a permit application if there is only a change in the purpose of use or an additional new use added onto the permit, as long as it falls within one of the seven beneficial surface water uses[32]; allow the TCEQ to automatically process environmental flow applications; and use Web. 2.0 forum platforms to allow water right holders to submit their concerns, comments, and questions.

Texas law states a water right amendment must be authorized for change in the place of use, purpose of use, point of diversion, rate of diversion, acreage to be irrigated, and any other use of the water[33]. Our solution eliminates technical reviews and public notice for permit amendments that are solely changing their purpose of use or adding a secondary purpose of use. Such requests would only require an administrative check for all the components of the application.

For example, if Permit A has an agricultural and industrial permit, but wants to add a domestic and municipal use, then Permit A would submit all of the information needed on the permit application. The TCEQ would check to ensure that the permit was complete and then automatically authorize this transaction, without running a technical review or issuing a public notice.

[32] Texas Water Code §11.024 defines beneficial uses as domestic and municipal, agricultural and industrial, mining, hydroelectric power, navigation, recreation, and "other beneficial uses".
[33] *Idi.* § 11.122(a)

The mechanism to allow for the purchase of environmental flows should also be streamlined. Under this solution, a permit holder would be able to lease or sell his/her water for environmental flows without undergoing the TCEQ technical review or public notice. As this water would stay in the river, there is no permit holder negatively affected by this transaction and has immense benefits for the ecosystem of the river.

Lastly, Web 2.0 platforms allow viewers to interact with the webhost to receive information, ask questions, and receive answers. In the public notice process, all affected water right holders have the right to state their concerns and ask the TCEQ questions about a pending amendment or permit. This process could be streamlined by utilizing Web 2.0 technologies. This is better elaborated with an example.

Currently, if Permit A has a question regarding how the pending water amendment will affect the flow of the river, he/she must call, email, attend a public forum, or mail his/her question. The TCEQ then answers his/her question. Suppose permit B holder has the exact same question and goes through the same process and then the TCEQ also answers his/her question individually. However, if there were a forum for water right holders to post their questions, then Permit A would utilize the forum to ask his/her question and the TCEQ would answer them within the forum. Thereafter, rather than Permit B calling the TCEQ individually, he/she would have the answer because it is already answered in the forum.

However, it should be noted that even with these three changes implemented, the TCEQ permit amendment process might not be quick enough to facilitate market transactions especially during droughts. For example, during the 2011 drought, DOW Chemical made a senior call in the Brazos River to curtail junior water right holders from withdrawing water. The TCEQ curtailed water withdraws for every junior right holder in the basin, but made exceptions for municipalities and electric companies. Since there is so much bureaucratic red tape within the water transfer and leasing process, municipalities and electric companies had limited methods to obtain water for their citizen’s water and electric needs. Thus, the TCEQ usurped property rights to deal with the emergency. Under the framework of a market, junior water right holders, such as municipalities and electric companies, could have bought water from senior water right holders *if temporary changes in diversion points could be quickly approved by the TCEQ.* Skepticism whether the system could be made sufficiently flexible, brings us to propose two other alternatives.

Solution: Option 2. Implement a Watermaster in basins where there is more water scarcity

The key benefit to a Watermaster System is that it protects private property rights by regulating water diversions. Under the Watermaster System, water right holders are required to report their water diversions. Daily monitors patrol the basin to ensure that the accurate amount of water is reported, and that no illegal diversions are taking place. The Watermaster System also provides information on daily water levels, which allows consumers to have full information about how much water is in the river and who can divert.

As water in a particular basin becomes more scarce, it is essential to have a Watermaster to perform regular inspections to ensure protection of water rights. If there is lack of compliance under the Watermaster System, the Watermaster can prevent the water right holder from diverting and storing water. Watermasters effectively make use of the scarce water resource prudently. They provide an unbiased avenue for all permit holders in the basin to make use of the water in an efficient way.

The Watermaster actively collects information about river flow rates, who is diverting, and how much, thus they have full information about how much water is in the river on a given day. This allows all permit holders to have full information about how much of their right they own on a daily basis.

Watermasters allow for a more efficient system. Since every water right holder has to purchase a flow gauge and regularly report their water diversions, it allows the Watermaster to maintain a detailed analysis of river stream flows and keep up-to-date information. They can also allow for changes in diversions in an expeditious manner, allowing water to move from lower valued uses to higher valued uses.

More importantly, Watermasters have been very successful in Texas. The Rio Grande Watermaster is an example of a broadly proclaimed Watermaster System. However, the fact that it does not operate under the prior appropriation doctrine makes it easier to administer. Outside of the Rio Grande, Texas has three other operational Watermaster Systems: The South Texas Watermaster, the Concho River Watermaster, and most recently the Brazos Watermaster, which demonstrates that watermasters can work efficiently even under the Prior Appropriation Doctrine. Despite their effectiveness in managing water rights, there has been pushback from constituents because (i) they are costly to administer and (ii) for some water right holders the benefits do not outweigh the costs. However, as water becomes more scarce the necessity of enforcing property rights becomes more pertinent. The popularity of Watermaster Systems seems likely to grow.

Solution: Option 3. Consider a Watermaster Lite System for basins where water resources are more abundant

The goal of the Watermaster Lite System is to ensure that water can be transferred quickly by bypassing some of the regulatory burdens set forth by the TCEQ permitting process, but do so at a much lower cost than a full-blown Watermaster System. The Watermaster Lite System should be tried on an experimental basis to ensure it is effective before being implemented elsewhere. This system is intended to dramatically shorten the TCEQ processing time, increase market transactions, reduce transaction costs, and require less financial resources to administer than the traditional Watermaster System.

a) How to implement the Watermaster Lite?

The river will be divided into segments and each segment will have flow detectors installed to measure stream flow. The basin's water right holders will then be divided and assigned a color based upon seniority and their permitted acre-feet. This will require the TCEQ to calculate all of the total water permits in the basin based off of their acre-feet withdrawal limits. For example, in the Brazos River basin there is a total of 7,932,481 AF allocated to divert. Thereafter, water right holders would be divided into five groups. The most senior quintile of the 1,983,120 AF would be categorized into the color "black"; the second most senior quintile of the 1,983,120 AF would be categorized in the color "red"; the third set of junior diverters will be categorized into "orange"; the next quintile would be "yellow"; and the most junior 1,983,120 AF would be categorized into "green". Under this system, the whole river basin will be grouped by the acre footage and seniority of its diverters. Additionally, each river segment will be assigned a minimum flow rate would be set for black, red, orange, yellow, and green permit holders.

This system aims to create a spot market based off of short-term (less than a year) changes in diversions that will be automatically granted provided three conditions are met. (i) The first condition is the flow rate in their river segment and permit type is satisfied within a 10% margin of error. (The flow rate will incorporate environmental flows for water rights issued post Senate Bill 3.) A second condition is (ii) The permit change in diversion will incorporate stream flow losses (including evaporation effects). For example, if the original permit called for a diversion rate of 10 AF daily and there was a 10% evaporation and transportation loss, the recipient would only be entitled to divert 9 AF daily. (iii) The permit would be subject to curtailment in the event of a senior right call.

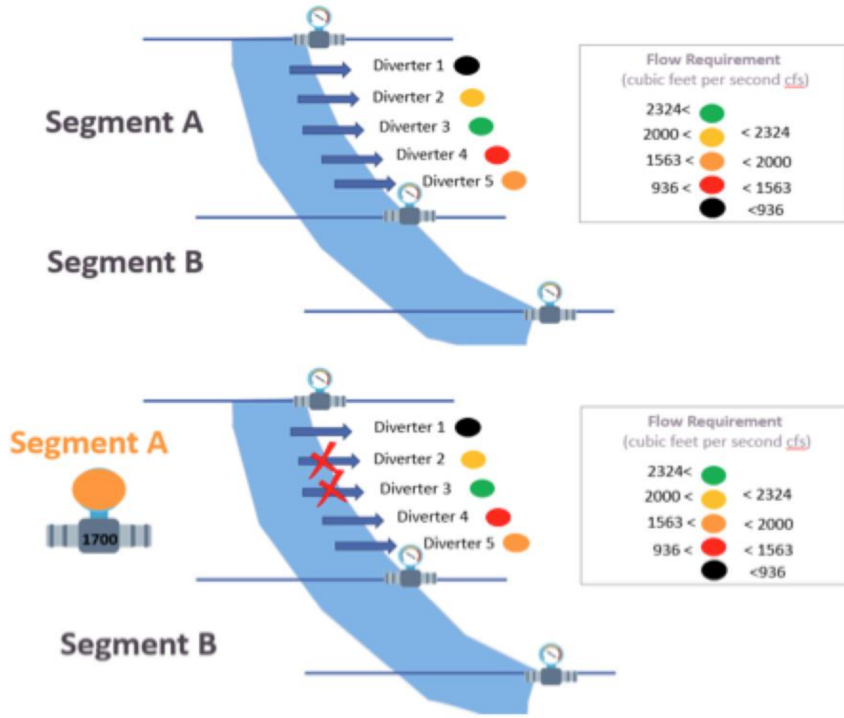
Once the river is properly divided, there will be monthly flow requirements that must be maintained for the run of the river and environmental flows. Thereafter, the flow requirements will be updated using the data collected from detectors. This will determine who can divert water based on the monthly stream flow. A monthly color will then be allocated to show the water right holder in the basin who can withdraw and trade water. This will enable buyers and sellers to effectively trade water, which will allow for a market to function, which is especially crucial during periods of drought

Table 2

Flow requirement (Cubic feet per second)	Percentage of Diverters (%)	Seniority	Color
More than 2362	100%	2001 to 2016	Green
Between 2000 and 2362	80%	1976 to 2000	
Between 936 and 1563	60%	1951 to 1975	Orange
Between 936 and 1563	40%	1925 to 1950	Red
Less than 936	20%	1883 to 1924	Black

This system is better stated with an example. Diverter A, from Figure 6, is the most senior water right holder in the basin and is allowed to divert 100 AF annually. Thereby, Diverter A is assigned the color “Black”, which means he/she can divert water even when the flows are less than 936,000 cfs. However, Diverter B, is a more junior water right holder and assigned the color “Yellow”, which indicates that when the flow rates are below 2000 cfs, he/she cannot divert water. In this scenario, Diverter B is no longer allowed to divert water, however Diverter B needs an additional 75 AF for his/her crops. While, Diverter A, only needs 25 AF. Since Diverter A has a senior water right and is not using all of his/her allocated share of water, under this system Diverter A could lease the remaining 75 AF to Diverter B. Such transactions would be allowed to take place on a monthly basis. For example, for a 30 day transfers, annual rate would be prorated to the daily equivalent of the permit’s allocated amount.

Figure 6



The Watermaster Lite system is proposed as an experimental option. Its application would no doubt require additional adjustments, and should first be refined for a particular river basin with abundant water. The system would also need adjustments for periods of drought. To succeed during a drought, the Watermaster Lite System must be cheap to administer and have the flexibility to allow temporary changes in diversion points.

The attraction of the Watermaster Lite System is that it retains many of the features of a Watermaster System, but would be potentially cheaper to operate and would have desirable self-policing attributes. Permit holders are likely to view it as less intrusive.

Work Cited:

Bell, D and Griffin, R. 2005. "Determinants of Demand for Water Used in Texas Communities." *Annual Meeting of the Western Agricultural Economics Association.* San Francisco.

Brady, Ross, Wayne Beckermann, Amber Capps, Braden Kennedy, Peyton McGee, Kayla Northcut, Mason Parish, Abdullilah Qadeer, Shuting Shan, and James Griffin. 2016. *Reorganizing Groundwater Regulation in Texas.* Capstone Project, Bush School of Government- Report to State Comptroller, Glenn Hegar.

Bradsby, Collette Barron. 2016. *What Now? Indirect Reuse After the TCEQ Decision in the Brazos River Authority System Operation Permit Contested Case: .* Austin: Texas Water Law Institute.

Bruun, B. 2017. "Commentary: The Regional Water Planning Process: A Texas Success Story." *Texas Water Journal* 8 (1).

Caroom, Douglas G., Susan M. Maxwell. 2013. *Texas Water Law Overview.* Austin: Texas Water Law Institute .

Comptroller Texas. 2017. *Transparency.* Accessed March 21, 2017. https://comptroller.texas.gov/transparency/spending/tools.php .

Comptroller Texas Transparency. 2017. *Comptroller Texas Transparency: Spending by Agency.* Accessed March 21, 2017. https://comptroller.texas.gov/transparency/spending/tools.php.

EPA. 2017. *Water Sense.* Accessed April 1, 2017. https://www3.epa.gov/watersense/about_us/facts.html.

Espey, M, J Espey, and W Shawn. 1997. "Price elasticity of residential demand for water: A meta-analysis." *Water Resources Research* 1369–1374.

Galbraith, Kate. "In Era of Drought, Texas Cities Boost Water Rates." The Texas Tribune. June 08, 2012.

Getches, D. H. (2005). Interbasin Water Transfers in Western United States: Issues and Lessons. *Water Conservation, Reuse, and Recycling: Proceedings of American Workshop*. https://www.nap.edu/read/11241/chapter/1.

Griffin, R. C. (2011). Water Policy in Texas: Responding to the Rise of Scarcity. Routledge.

Gruber, Jonathan. 2013. "Public finance and public policy." New York: Worth Publishers.

Gustavo E Diaz, Thomas C. Brown, and Oli Sveinsson. 2000. "Chp 2: Efficient Water Allocation." In *Aquarius: A Modeling System for River Basin Water Alloction*, by Thomas C. Brown, and Oli Sveinsson Gustavo E Diaz. General Technical Report RM-GTR-299-revised, Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.

Howe, Charles. 2005. "The Functions, Impacts and Effectiveness of Water Pricing: Evidence from the United States and Canada." *Water Resources Development* 43-53.

Jarvis, Glenn. 2016 . "Water Planning and Drought Management Under the Prior Appropriation Doctrine." *2016 Texas Water Law Institute.* Austin : The University of Texas. 88-107.

Kaiser, Ronald. 2011. "Texas Water Law and Organizations." In *Water Policy in Texas: Responding to the Rise of Scarcity*, by Ronald Griffin, 26-43. RFF Press.

LCRA. 2017. *Water Supply Contracts.* Accessed April 1, 2017. http://www.lcra.org/water/water-supply/water-supply-contracts/Pages/default.aspx.

Lower Colorado River Authority. 2016. *LCRA Board adopts new rules for interruptible water customers.* Feb 17. http://www.lcra.org/about/newsroom/news-releases/Pages/LCRA-Board-adopts-new-rules-for-interruptible-water-customers.aspx.

LCRA. 2015. *LCRA Water Rate.* November 16. Accessed January 2017. http://www.lcra.org/water/water-supply/water-supply-contracts/Documents/2015-11-6-LCRA-Water-Rates.pdf.

Neeley, J. (2, May 2014). *Texas Shoulnd't Block Interbasin Transfers.* Retrieved from Houston Chronicle : http://www.chron.com/neighborhood/bellaire/opinion/article/Texas-shouldn-t-block-interbasin-transfers-9659616.php.

Nielson-Gammon, John W. 2011. *The 2011 Texas Drought: A Briefing Packet for the Texas Legislature October 31, 2011* . legislature briefing , College Station : The State Climatologist .

NTMWD. 2016. *FY17 Budget and Rates.* October 20. Accessed January 2017. https://www.ntmwd.com/wp-content/uploads/2016/10/NTMWD-FY17-Budget-Rates-summary_102016.pdf.

M. Espey, J. Espey, and W. D. Shaw. 1997 . "Price elasticity of residential demand for water: A meta-analysis." *WATER RESOURCES RESEARCH*, VOL. 33, NO. 6, PAGES 1369-1374.

Dylan Drummond, McCarthy, Edward, Lynn Ray Sherman. 2004. "The Rule of Capture in Texas So Misunderstood After All These Years." *Texas Tech Law Review.*

McDonald, Ellen. 2016 294-324. "Direct Potable Reuse in Texas ." *2016 Texas Water Law Institute.* Austin : The Unviserity of Texas . 294-324.

Minard, Anne. 2015. "Interbasin Water Transfers. Water Matters!" http://uttoncenter.unm.edu/pdfs/water-matters-2015/19_Interbasin_Water_Transfers.pdf.

Olmstead, SM. 2009. "Comparing price and nonprice approaches to urban water conservation." *Water Resources Research 45.*

Satija, Neena. 2013. "TCEQ Approves Permit for Big North Texas Reservoir." *Texas Tribune.* http://www.texastribune.org/2013/09/24/big-decision-north-texas-water-supplies-lake-ralph/., September 24.

Smith, Rod, and Todd Doherty. 2012. *Water Transfers in the West.* Western Govenors Association.

Shaw, Douglass W. 2005. *Water Resource Economics and Policy: An Introduction.* Northhampton, MA: Edward Elgar.

Texas Commission on Enviromental Quality. 2017. *Water Rights and Water Use Data.* Accessed April 1, 2017. https://www.tceq.texas.gov/permitting/water_rights/wr-permitting/wrwud.

Texas Water Code 11.085(s)

TWDB. (2017). History of Reservoir Contruction in Texas. *Texas Water Development Board*.

http://www.twdb.gov/surfacewater/rivers/reserovirs/.

Texas Water Development Board. 2017. *State Water Plan.* Accessed March 13, 2017. https://www.twdb.texas.gov/waterplanning/swp/2017/index.asp .

TWDB. n.d. *State Water Implementation Fund for Texas (SWIFT).* Texas Water Development Board. Accessed January 27, 2017. https://www.twdb.texas.gov/financial/programs/swift/index.asp

TWDB. 2017. *Jim Chapman Lake (Sulphur River Basin).* Texas.Gov. Accessed March 2017. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwiWh_K30q7TAhUM5WMKHQF6BpsQFggkMAA&url=http%3A%2F%2Fwww.twdb.texas.gov%2Fsurfacewater%2Frivers%2Freservoirs%2Fjim_chapman%2F&usg=AFQjCNEp_hSWW219LvY1QxiV7u1x9yz18A&sig2=YCbWGpoWxTnxtLqAgtgx_A.

USACE. 2017. *History of Jim Chapman Lake/Cooper Dam.* U.S. Army. Accessed March 2017. from http://www.swf-wc.usace.army.mil/cooper/Information/History.asp.

Water Data for Texas. 2016. *Palmer Drought Severity Index (Monthly).* October. Accessed March 22, 2017. https://waterdatafortexas.org/drought/pdsi/monthly?time=2016-10.

Wurbs, Ralph. 2014. "Sustainable Statewide Water Resources Management in Texas." *Journal of Water Resources and Planning Management* 1-9.

Wurbs, Ralph, and Ayala, Ronaldo . 2013. "Reservoir evaporation in Texas, USA." *Journal of Hydrology* 1-9 .

—. 2017. "State Water Implementation Fund for Texas (SWIFT)." *TWDB.Texas.Gov.* Texas.Gov. Accessed March 2017. https://www.twdb.texas.gov/financial/programs/swift/index.asp.

—. 2013. "Submittal to the Texas Water Development Board from the House Bill 4 (83rd Texas Legislature Stakeholder Committee: Uniform Standards to be Used by Regional Water Planning Groups to Priortize Projects." *TWDB.Texas.Gov.* Texas.Gov. November. Accessed March 2017. http://www.twdb.texas.gov/financial/programs/swift/doc/HB_4_SHC_Uniform_Standards.pdf.