Water Values in South Central Texas

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Introduction

South Central Texas[1] faces a significant projected water deficit, and regional water reallocations are occurring. Water in this region largely comes from four river basins (Guadalupe, San Antonio, Frio-Nueces, San Antonio-Nueces River Basins) and four Aquifers (Edwards, Carrizo, Gulf Coast and Edwards-Trinity Aquifers).

In this note, we will discuss the value of water in different sectors in the region.

Background on Water Ownership

Water ownership is a factor in determining water values. Water in the river basins and the Edwards Aquifer is allocated via water rights permits. In the rivers water permits were issued by the 'first in time first in right' rule, most of the water rights were issued to farmers (agriculture sector) due to their earlier historical use. When water is scarce the more senior rights holders get first access and more junior water rights holders can find that the water has all been used when their turn comes. Such permits and the degree of certainty of water associated with them causes different use values for surface water by user. There are not active water markets on these rivers.

Edwards Aquifer (EA) water was allocated according to historical use with the bulk going to agriculture. When water is short in the EA then uniform cutbacks are implemented across the user community. There is an active water market in the EA. Substantial water transfers have occurred through leasing and selling. In this market there are trade restrictions. Namely the market managing Edwards Aquifer Authority rules indicate: a) agriculture needs to retain 1 acre foot of the original permit allocation; b) trading from west to east of Cibilo Creek needs justification in terms of no harm to spring flows; c) for trades from Uvalde County to Comal, Hays, Guadalupe, or Caldwell County, a 5:1 transfer ratio - 5 acre feet of water must be purchased in Uvalde for each acre foot used, the other 4 held by the groundwater trust and d) for trades from Medina, Atascosa, or Bexar County to Comal, Hays, Guadalupe, or Caldwell County, a 3:1 transfer ratio - 3 acre feet of water must be purchased for each acre foot used and

[1] We define this region as the part of the state that includes the Guadalupe and Frio River basins plus everything in between. This includes the cities of Uvalde, New Braunfels, San Marcos, Victoria, San Antonio and Corpus Christi plus a number of others along with substantial water using agricultural areas, power plants, hydraulic fracturing, and industries use plus substantial recreation and endangered species habitat.

the other 2 go into the groundwater trust (Edwards Aquifer Authority 2017). Economically, these rules will cause water to have different values in different places and industries.

Water Use Values by Sector

Agricultural Sector use value

There are two ways to estimate the value of water for use in agricultural irrigation, one based on the land rent of irrigated land relative to that for dryland (McCarl 1997), the other based on the differences in net profits of irrigated crops and dryland crops. These two methods are implemented below to derive an irrigation use value.

- *Land rent method*

When irrigated land is rented, it typically involves access to property wells but does not come with irrigation equipment or any offset of water pumping cost. We thus can assume that the difference in land rental rates between irrigated land and dryland is the value of associated water access. Based on this assumption, the value of water could be calculated as

$$Water\ Value = \frac{land\ rent_{irrigated} - land\ rent_{dryland}}{Irrigation\ Water\ Use}$$

where the irrigation water use is on a per acre basis and is calculated based on a weighted average across the prevailing. We will do this on a county basis.

As an example, USDA reports annual land rental rates for irrigated land in Medina County were $100 per acre in 2016, while annual land rental rates for dryland in Medina County were $23.50 per acre (USDA National Agricultural Statistics Service 2017). Therefore, the difference in land rental rates $76.50 per acre which is reflective of the value of water access. The 2015 crop mix and estimates of water usage by crop are in Table 1. The water usage estimates therein came from the AgriLife Extension Budget for District 10 (Texas A&M Agrilife Extension 2018). The crop mix is based on the USDA QuickStats and Farm Service Agency reported county level 2015 crop planted acreage data (USDA 2018; USDA Farm Service Agency 2018). The resultant average irrigation water usage is 1.023 acre feet per acre. Therefore, the estimated annual water value in Medina County is $74.78 per acre foot. For a sale value if we assume an interest rate of 6%, the capitalized water value (or an estimate of a water rights sale value) is $1246 per acre foot.

Table 1: Crop Planted Acres and Water Usage per Acre in Medina County

Crop	Water Usage (Acft/Acre)	Acres	% share
Wheat	0.50	12,800	35.46
Corn	2.08	7,810	21.63
Cotton	1.25	5,909	16.37
Sorghum	0.71	4,620	12.80
Sesame	0.71	3,554	9.85
Cucumber	0.50	816	2.26
Peanut	0.96	268	0.74

Cabbage	1.08	244	0.68
Onion	2.00	78	0.22
Total		36,099	100

We used this approach to derive water value estimates in each of the regional counties. Since crop mixes vary, we evaluated this using mixes from the years 2000 to 2015 which gave us a range of water values. Table 2 presents the results.

The results show that the agricultural value of water is lowest in the Nueces Delta and highest in the Winter Garden Region, and with the values in the Guadalupe Delta and Edwards Aquifer Area generally falling in the middle. This is because dryland rental rates are higher in the Nueces coastal region where there higher precipitation raises dryland rental rates. Consequently, the rental rate difference is smaller and water for irrigation is not as valuable. We also note that the water values are highest in the drier west and lower in the wetter east again reflecting differences in dryland rental rates.

Table 2: Water value estimation based on land rent

Sub Region	County	Total Irrigated Land (Acres)	Annual Water Value (Leasing Value)			Long Term Water Value(Sale Price)		
			Median	Min	Max	Median	Min	Max
Winter Garden	Zavala	13,718	$76	$50	$115	$1,256	$828	$1,917
	Dimmit	1,676	$80	$51	$135	$1,338	$857	$2,250
	Frio	41,926	$98	$82	$121	$1,626	$1,366	$2,018
Edwards Aquifer Area	Bexar	12,759	$69	$48	$97	$1,149	$794	$1,611
	Medina	36,099	$52	$46	$75	$862	$767	$1,247
	Uvalde	36,606	$54	$48	$84	$904	$794	$1,406
Guadalupe San Antonio River Delta (Victoria Area)	Victoria	4,218	$42	$28	$83	$701	$471	$1,383
	Refugio	31,500	$38	$14	$39	$633	$230	$656
Nueces River Delta (Corpus Christi Area)	Nueces	819	$14	$13	$14	$229	$221	$229
	San Patricio	12,352	$6	$6	$6	$101	$100	$103

➢ *Crop net profit method*

The second approach for estimating agricultural water value is based on the difference in net profits between irrigated land and dryland crops. In that case we assume the extra profits from irrigated crops over dryland crops can be treated as the value of water. In this method, we do not count land rental rates to avoid double counting. The calculation steps are as following

1. Compute Net profit for relevant crops (*i*) by irrigation or dryland status *l*

$$NetProfit_{i,l} = Price_i * Yield_{i,l} - Cost_{i,l}$$

   Where the yield for irrigated and dryland crops along with the production cost estimates are from Texas A&M Extension (Texas A&M Agrilife Extension 2018). Here we used two set of prices to estimate the net profit, one is the projected crop prices from Texas A&M Extension (Texas A&M Agrilife Extension 2018). The other uses the field crops prices (corn, cotton, sorghum and wheat) for 2012 where prices were at record highs.

2. Compute weighted average profit across the relevant crop mix by irrigation status (*l*-dryland or irrigated land) using the crop mix from USDA,

$$WNetProfit_l = \frac{\sum_i Acres_{i,l} * NetProfit_{i,l}}{\sum_i Acres_{i,l}}$$

3. Compute weighted average water usage across the irrigated crop mix

$$IrrigationWater\ Use = \frac{\sum_i Acres_{i,irrigated} * WaterUsage_i}{\sum_i Acres_{i,irrigated}}$$

   where the estimates of irrigation water usage by crop are from Texas A&M AgriLife Extension and vary by district (Texas A&M Agrilife Extension 2018).

4. Value of Water estimated based on crop net profit

$$Water\ Value = \frac{WNetProfit_{irrigated} - WNetProfit_{dryland}}{IrrigationWater\ Use}$$

In step 3 we use the historical crop mix from 2000 to 2016 to get a range of crop acreage weighted average water usage estimates. We also used those weights and 2018 crop prices in step 2 to get weighted average net profits of dryland and irrigated land production. Then applying the equation in step 4 with the water use variations arising under the alternative crop mixes, we get a range of water values. The resultant water value using 2018 projected crop prices is presented in Table 3.

Compared to the water value estimated by the land rent approach, the estimation of net profit approach has higher variance with some negative values and higher maximum values. There are three factors that may be causing this fluctuation. These are the crop budgets, the historical crop mixes and the crop prices. First, the crop budgets we used from Texas A&M Agrilife Extension are setup for the district level, which may not reflect county conditions and thus may contribute to estimation error. For example, the net profit for dryland wheat is -$108.77 given the projected price of $3.83 per bushel. But the farmers still choose to plant wheat. This may because: a) the crop budget is not right; b) rotational needs cause the planting; or c) the farmers had higher price or yield expectations. Second, the historical crop mixes we used may not match with the crop budget data. In order to estimate net profits and water usage per acre irrigated land, we used the historical crop mix in forming a weighted average. The crop mix is the decision the farmers made based on expected profitability at the time they plant crops but yield and/or price expectations may have been too high and biased relative to earlier crop mixes. We used the 2017 crop budget in all cases. Third, farmers may have been expecting higher prices. To examine this we redid the calculation using 2012 crop prices for field crops (corn, cotton, sorghum and wheat) where prices were at record highs. The results with those prices are given in Table 4. Under those prices water value for irrigation is substantially higher but some negative water values remain.

Considering the factors stated above, the estimated water value by the net profit method has high variation and we feel the land rent method is the one to use so will not explore the net profit based estimates further.

Table 3: Value of water estimated based on crop net profit method (projected 2018 price)

Sub Region	County	Total Irrigated Land (Acres)	Water Value (Leasing Value)			Capitalized Water Value		
			Median	Min	Max	Median	Min	Max
Winter Garden	Zavala	13,718	$224	$48	$573	$3,741	$794	$9,542
	Dimmit	1,675	$72	$0	$4,497	$1,206	$0	$74,954
	Frio	41,926	$238	$129	$571	$3,974	$2,151	$9,511
Edwards Aquifer Area (San Antonio Area)	Bexar	12,759	$33	$0	$77	$546	$0	$1,282
	Medina	36,099	$63	$40	$139	$1,055	$670	$2,323
	Uvalde	36,606	$92	$44	$188	$1,531	$739	$3,126
Guadalupe San Antonio River Delta (Victoria Area)	Victoria	4,218	$226	$88	$336	$3,765	$1,468	$5,593
	Refugio	31,500	$0	$0	$377	$0	$0	$6,283
Nueces River Delta (Corpus Christi Area)	Nueces	819	$343	$0	$417	$5,718	$0	$6,948
	San Patricio	12,352	$95	$56	$195	$1,581	$925	$3,251

Table 4: Water Value based on crop net profit method using higher field crops prices (the 2012 price of corn, cotton, sorghum and wheat)

Sub Region	County	Total Irrigated land (Acres)	Water Value (Leasing Value)			Capitalized Water Value		
			Median	Min	Max	Median	Min	Max
Winter Garden	Zavala	13,718	$2,313	$434	$7,991	$38,555	$7,235	$133,191
	Dimmit	1,675	$343	$135	$4,497	$5,722	$2,249	$74,954
	Frio	41,926	$848	$324	$3,849	$14,126	$5,400	$64,156
Edwards Aquifer Area (San Antonio Area)	Bexar	12,759	$482	$232	$1,799	$8,038	$3,870	$29,980
	Medina	36,099	$1,454	$688	$2,939	$24,229	$11,471	$48,980
	Uvalde	36,606	$1,519	$692	$2,542	$25,311	$11,526	$42,368
Guadalupe San Antonio River Delta (Victoria Area)	Victoria	4,218	$892	$0	$9,045	$14,869	$0	$150,743
	Refugio	31,500	$0	$0	$7,327	$0	$0	$122,110
Nueces River Delta (Corpus Christi Area)	Nueces	819	$243	$0	$2,497	$4,044	$0	$41,620
	San Patricio	12,352	$3,392	$348	$5,975	$56,525	$5,807	$99,588

Municipal and Industrial Water Value

Another water using party and one whose demand is growing involves municipal and industrial parties. Also in a number of instances those parties are implementing projects for future water supplies. As a consequence water values for those parties can be examined by considering water rates paid, and the amount being paid for water under the new projects being developed.

- *Water rates*

Rates for water delivered to municipal and industrial customers in selected counties are reported in Table 5. These come from the Texas Water and Wastewater Survey by Texas Municipal League (Texas Municipal League 2018). The municipal water prices range from $1,100 to $2,200 per acre foot and the industrial water prices are higher ranging from $1,300 to $3,330. However, that data source only contains retail prices of delivered, treated water, which is not homogeneous with the water used in the agricultural sector as there is no treatment. Thus to compare we would have to subtract the pumping, treatment, distribution and billing costs to get a raw water value. However, since we do not have an accurate estimates on the pumping, treating and distribution cost of the M&I water, we listed the fully delivered, treated water value here.

Table 5: Retail Municipal and Industrial Water Prices in SCT Counties ($/Acft)

Sub Region	County	Municipal Sector	Industrial Sector
Winter Garden Region	Zavala	$ 1,690	$ 1,659
	Dimmit	$ 2,028	$ 3,330
	Frio	$ 1,735	$ 1,626
Edwards Aquifer Area (San Antonio Area)	Bexar	$ 1,788	$ 1,946
	Medina	$ 1,642	$ 1,337
	Uvalde	$ 1,740	$ 1,804
Guadalupe San Antonio River Delta (Victoria Area)	Victoria	$ 1,110	$ 1,118
	Calhoun	$ 2,134	$ 2,134
	Refugio	$ 1,678	$ 1,485
Nueces River Delta (Corpus Christi Area)	Nueces	$ 1,676	$ 1,531
	San Patricio	$ 2,197	$ 1,521

Data Source : Texas Water and Wastewater Survey (Texas Municipal League 2018)

Additionally since water rates are set by non-profit public utilities, pricing is typically based on average cost not marginal cost. This implies that the marginal cost of municipal and industrial supply is likely higher than the level given by the rates. Also, some public utilities, like SAWS, have external funding to cover costs. Therefore, the price charged consumers is even lower than the average cost, which implies the water value in M&I might be higher than the retail prices.

Water Projects

A way of estimating the marginal cost of added M&I water supplies is to examine the cost being paid for newly added by newly developed water development projects. In the region there is a set of proposed and in cases implemented projects that are contained within the Texas Water Development Board (TWDB) regional water plans (region L and N plans in Texas Water Development Board 2016). The broad types of water projects include: a) building new wells and/or converting the purpose of current wells; b) transferring groundwater from other places through pipelines; c) building new Off-Chanel Reservoirs (OCR); d) building new Aquifer Storage and Recovery (ASR) projects; e) desalinating brackish ground water; f) transferring surface and ground water from places outside of the SCT region to the region; and g) desalinating seawater and transferring it to points of usage. Among the projects, TWDB cost estimates indicate that building new wells and/or converting purpose of current wells provide the cheapest increases in domestic water supply, but are limited in water availability. Desalinating seawater and transferring to users are the most expensive possibilities, but have high to unlimited water available. Meanwhile, the OCR and ASR projects are built to store water when the water supply is sufficient and release the water when there is shortage. They do not increase total water supply but rather shift time availability.

Several of these regional water projects have been or are being constructed. These have been mostly developed by the San Antonio Water System (SAWS) for municipal and, in cases, industrial supply. They are the: a) Regional Carrizo project that pumps fresh ground water from the Carrizo Aquifer in Gonzales County and transfers water to San Antonio using a 50 mile long pipeline; b) Local Carrizo project that builds new wells in Bexar county pumping fresh ground water from the Carrizo Aquifer into the SAWS system; c) GBRA Western Canyon project that is an agreement with the Guadalupe-Blanco River Authority to lease water from Canyon Lake and transfer it to San Antonio; d) Trinity Oliver Ranch and Trinity WECo projects that transfer fresh ground water from the Trinity Aquifer to San Antonio; e) Desal Phase I project that desalinates brackish ground water from the lower Wilcox Aquifer to supply San Antonio water usage; f) Medina System project that leases and transfers water from Medina Lake to San Antonio although this agreement terminates in 2020 and has no extension option; and g) Twin Oaks ASR project that is an aquifer storage and recovery project, which stores extra Edwards Aquifer water in the Carrizo Aquifer during times of excess supply for recovery in drought years transferring it to San Antonio. The yield and costs of these existing water projects are listed in Table 6. The water provided by the water projects costs range from $173/Acft to $3,012/Acft.

Table 6: Water projects yields and unit cost of existing water projects

Water Project	Yield (AFY)	Total Capital Cost (Million $)	Annual O&M Cost (Million $)	Annualized Capital Cost Figured at 5% Interest Rate for 30 years (Million $)	Annual Total Cost (Million $)	Unit Cost ($/Acft)
Regional Carrizo	11,557	127.1	9.4	8.3	17.6	1,526
Local Carrizo	9,900	15.2	0.7	1.0	1.7	173
GBRA Western Canyon	8,980	15.7	8.6	1.0	9.6	1,071
Trinity Oliver Ranch	2,000	10.0	1.0	0.7	1.6	806
Trinity WECo	16,467	17.9	20.2	1.2	21.4	1,299
Desal Phase I	13,440	196.4	5.7	12.8	18.5	1,374
Medina System	2,000	19.7	4.7	1.3	6.0	3,012
Twin Oaks ASR (SAWS)[1]	50,000	238.2	2.6	15.5	18.1	362

Data Source: 2017 Water Management Plan (SAWS 2017)

[1] Cost of Twin Oaks ASR is from TWDB Report : An Assessment of Aquifer Storage and Recovery in Texas (Malcolm Pirnie, Inc, ASR Systems, LLC and Jackson, Sjoberg, McCarthy & Wilson, LLP 2011)

Cooling Water Retrofitting

Another large water user involves electrical generation facilities and their use of cooling water. Yang (2019) estimated the regional cost of converting the electrical generator cooling method from recirculating cooling to dry cooling and the associated savings in consumptive water use. Specifically, estimating the cost of reducing water use via retrofits of existing plants and in building new plants with dry as opposed to recirculating plants. Those water values average $4,041 per acre foot and range across 26 existing and 3 potential new plants from $934 to $8,215 per acre foot. If we develop new plants directly with dry cooling, the cost of water saved is about $2,268-$4,100 per acre foot.

Fracking Water

An emerging water use in the region is for hydraulic fracturing (fracking) in oil and gas production. A study by (Vargas 2019)based on data from Baker Hughes ((Sharr 2014; Albanese, et al. 2016) estimates that the total cost of delivered water in fracking sector ranges from $54,264 to $219,380 per acre foot. However, in this case, most of the costs are for transporting, storing and treating the fresh and produced water. The reported cost of freshwater sourcing is still high ranging from $2,326 to $6,202 per acre foot fresh water. Also recycling treated water recovered during pumping operations (so called "produced" water) costs about $31,000 to $139,000 dollars per acre foot for treatment, transportation and storage.

Water market prices

Another approach for estimating water value comes through the use of water market lease and sale prices. We examined water market prices for transactions in the Edwards Aquifer water market. In particular, transaction records were obtained from the Edwards Aquifer Authority for the period 2005 to 2015. Within that data set there were 6,810 recorded transactions, but of those only 698 records contained price information, with 120 of them being sale transactions and 578 being leases. The weighted average leasing and sale price by transferor and transferee permit use sector and aquifer pools are presented in Table 7 and Table 8.

Here we see the average lease price ranges from $52 per acre foot to $228 per acre foot. Most of the water rights are transferred from the agricultural sector to municipal sector or transferred within the agricultural sector. The prices show that when farmers lease water to the M&I sector, they get a higher price than they do when leasing water to other farmers. However, the EAA rules in part cause this as

- The amount farmers can transfer to M&I sectors is limited. Typically agriculture needs to keep at least one acre foot in agricultural use (Edwards Aquifer Authority 2017)..
- Trading from Uvalde pool to San Antonio Pool requires 5 acre feet of permits be purchased to obtain 1 acre foot for use in the San Antonio Pool (Edwards Aquifer Authority 2017).
- Trading from Medina county to the San Antonio pool requires 3 acre feet of permits be purchased to obtain 1 acre foot for use in the San Antonio Pool (Edwards Aquifer Authority 2017)
- Trades from west of Cibolo Creek to east of it requires one to show that spring flow will not be impacted.

This causes, water leases and sales in the San Antonio Pool to be more expensive than water in the Uvalde Pool and also the transactions to municipal and industrial users to be more expensive than those to agricultural users.

We also see that most water permit transactions go from the agricultural sector to the municipal sector in both pools. Sales prices average higher amounts when the water permit sells to M&I sector as opposed to other farmers likely due to the retention rules and trading ratios discussed above.

Table 7: Weighted average leasing price and contract amount in Edwards Aquifer water market

		Transferor Pool			
		San Antonio Pool		Uvalde Pool	
Transferor Permit Use	Transferee Permit Use	Average Transfer Price ($/Acft)	Total Transferred Quantity (Acft)	Weighted Transferred Price ($/Acft)	Transferred Quantity (Acft)
Agricultural	Agricultural	$ 65	9,665	$ 52	13,095
	Industrial	$ 140	2,436	$ 130	40
	Municipal	$ 121	23,062	$ 119	7,039
Industrial	Agricultural	-	-	-	-
	Industrial	$ 228	797	-	-
	Municipal	$ 172	116	-	-
Municipal	Agricultural	$ 120	263	-	-
	Industrial	$ 129	1,105	-	-
	Municipal	$ 173	3,944	-	-

Table 8: Weighted average sale price and contract amount in Edwards Aquifer water market

		Transferor Pool			
		San Antonio Pool		Uvalde Pool	
Transferor Permit Use	Transferee Permit Use	Weighted Transferred Price ($/Acft)	Transferred Quantity (Acft)	Weighted Transferred Price ($/Acft)	Transferred Quantity (Acft)
Agricultural	Agricultural	$ 363	543	$ 652	393
	Industrial	$ 1,467	133	$ 10	31
	Municipal	$ 4,915	4,376	$ 5,116	3,827
Industrial	Agricultural	-	-	$ 10	75
	Industrial	$ 3,000	1	-	-
	Municipal	$ 6,017	3260	-	-
Municipal	Agricultural	$ 13,000	17	-	-
	Industrial	-	-	-	-
	Municipal	$ 5,207	318	-	-

Two additional estimates have been done over the EAA market data. Griffin and Shafiezadeh (2017) analyzed the data we had plus supplemented it with data obtained by telephone from the San Antonio Water System, and the San Antonio River Authority. They found the mean lease price was $112 per acre foot in their augmented data set. This is slightly higher than the weighted average lease price across the observations we had ($103).

Another estimate was done by Thayer (2018) using econometric analysis over payroll data finding the leasing value of water in Edwards Water Market in terms of value added was $554 per acre foot. Thayer (2018) argues that Edwards Aquifer Water Market underestimates the water value in the region although that study does not consider the value added on the purchaser side.

Comparative Water Values

The results above show water has different values in different sectors. This comes about in part, because water transfers are limited by: a) costs and the availability of means of conveyance or natural water movement; b) water availability; c) existing water rights of surface water and Edwards Aquifer water; d) right of capture laws for much of the groundwater; e) transfer restrictions in the form of EAA rules; f) leasing versus sales possibilities; g) the lack of a clearing house where buyers can find sellers; and h) a lack of active markets operating for the rivers.

Figure 1 presents the cumulative water consumption amount and the water prices by sectors and the cumulative water project yields vs the water projects cost. Note, we removed the water projects in the ASR and OCR categories, because water projects in these two categories do not increase overall regional water supplies but rather just store the water and release it when needed to manage seasonality and drought cycles. Other categories of water projects, such as transferring water from outside regions increase regional water supply.

The value of water used for the agricultural sector is the one based on land rental rates, the 2015 crop mix and 2018 projected price. We then sorted the water values, calculated the cumulative amounts, and presented the values across all the sectors in Figure 1.

Generally water has lowest value in agricultural use. But the different nature of the water supplied in each sector merits comment. The water value in agriculture does not include any treatment and distribution cost, which makes it cheaper. The water value in municipal, industrial and mining sectors includes all treatment, distribution and billing costs, which we believe is around $600-$1000 per acre foot. While the cost estimates for the water projects include part of the treatment and distribution costs, which depends on the design of water projects, varying from $300 to $1000 per acre foot. Most water projects include the cost of treating water, building new pipelines and hooking it into the existing network, but do not include the cost of distributing the water to customers.

Thus for comparison only we subtract $600 per acre foot from the M&I, mining sector and water project water values in Figure 1 to make the water characteristics similar to raw water in agricultural sector.

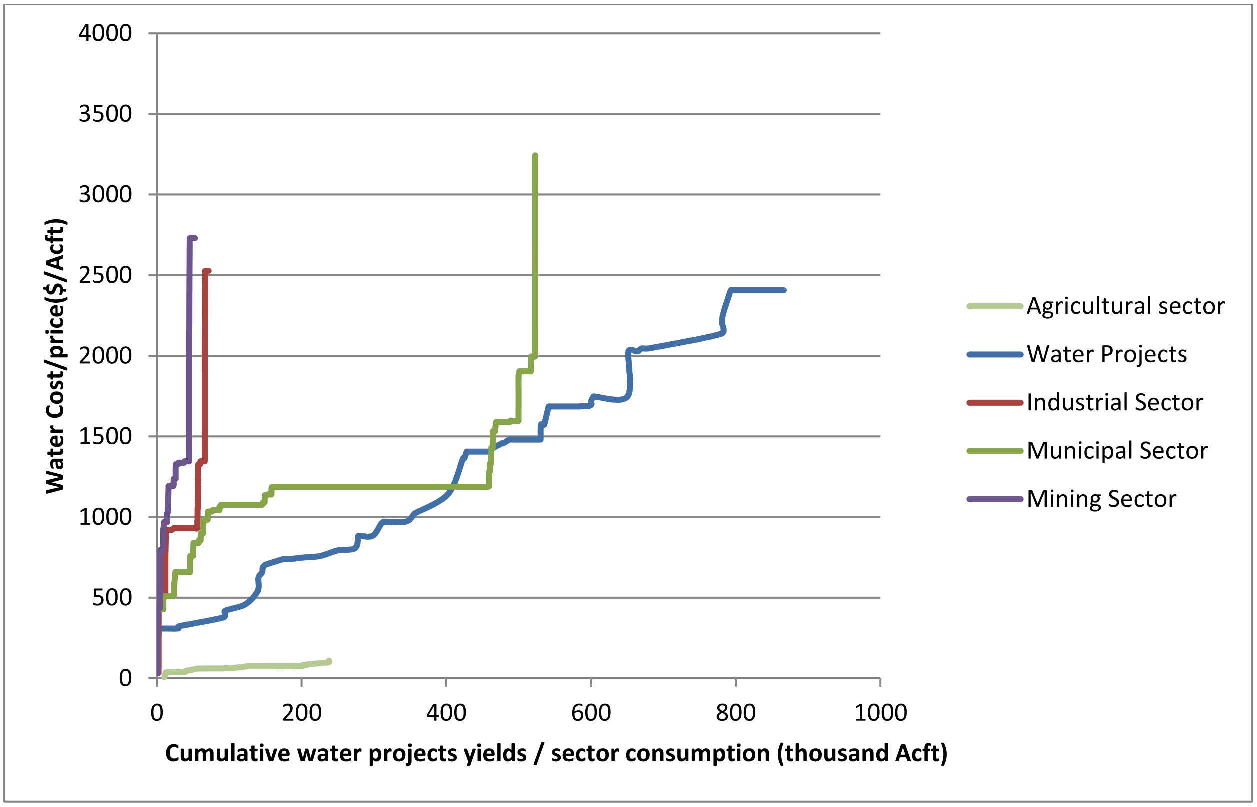

Figure 1: Cumulative water projects yields/ sector consumption (Acft) vs unit water prices ($/Acft)

We found that municipal sector consumed most of the water, and agricultural sector is the second largest water consumer (Figure 1). With the population increase in the future, more water will be needed to support the municipal water usage. As proposed by Texas Demographic Center (2018), the population in San Antonio will increase 40% from 2015 until 2050 under the assumption of half the migration rate of 2015, and the population doubles if the 2015 growth and migration rate persist. The municipal water demand will consequently increase. The water projects are designed to increase the future regional M&I water supply, and as expected the cost of water delivered via the projects will be higher than the current retail price.

Agriculture, the second largest water use group, holds most of the water rights. The water value in agriculture is still smaller than the water price in the M&I sectors and most of the water project costs even after removing the treatment and distribution costs as in Figure 1. Allowing broader water trading in a broader joint river and aquifer water market and relaxing the rules in the water market plus adding conveyance infrastructure might allow further water transactions lowering M&I water stress and lower the water price, while increasing agricultural income. But as shown in Thayer (2018) would greatly reduce rural area economic activity potentially requiring forms of compensation.

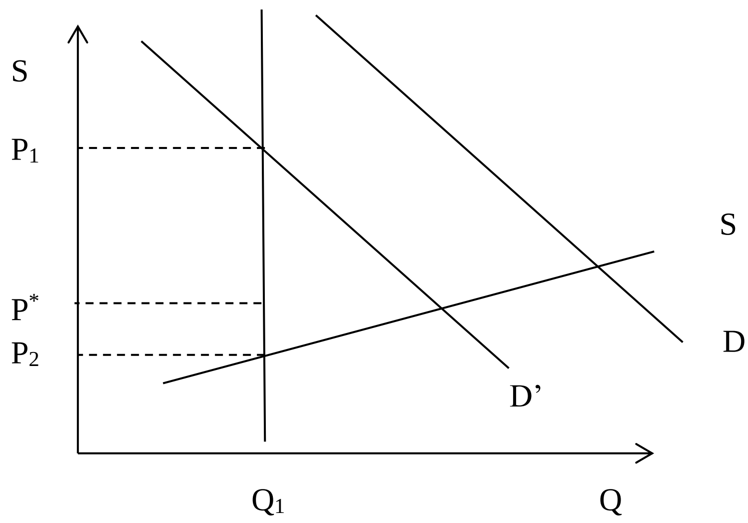

Figure 2: Water market

We should also explore why prices are different. Economic theory offers one explanation basically saying the prices differ based on the negotiating power of the parties to the sale. In particular, as shown in Figure 2 (where D is the demand curve of municipal and industrial water, S is the supply curve of all potential agricultural irrigation water, D' is the M&I water after removing the cost of treatment and distribution, and Q_1 is the maximum agricultural water rights permits that can transfer, P_1 is the cost of developing the next new M&I project and P_2 is the value of water in agriculture). Under these circumstances any price between P_1 and P_2 would be s win for the farmers and a win for the M&I water users. Suppose the deal price is P^*, the farmers can gain (P^*- P_2) more by leasing water to others than if they irrigate crops which seems to be the motivation for many of the water market transactions. Under such a price the M&I users pay (P_1- P^*) which is less that less than the maximum amount they were willing to pay (as manifest in the high water cost from the projects under development) and through that this lower price ends up reducing M&I water rates. Theory indicates the value of P^* will be determined by the relative bargaining power of the farmers and the M& agency buyers. As the EAA transactions prices show the average price is well below the project prices this means farmers to date have had less negotiation power than the M&I buyers.

Drought impacts

Municipal and industrial water users and planners are often worried about peak demands that in most cases occur at peak usage times of the year like mid-summer and during droughts. Often as a consequence water suppliers have access to more than needed during average conditions.

Drought is the other concern that influences water values. For example, SAWS holds permits and leases allowing use of 284,277 acre feet of water from the Edwards Aquifer, but this would be reduced to 159,195 acre feet in the worst drought years due to the elevation and spring flow driven drought management rules (SAWS 2017). Therefore, SAWS is looking to expand water access to get enough firm yield to meet the peak demand under severe droughts and it is doing this through project development to reduce reliance on the aquifer. This also increases the cost of water in the M&I sectors.

Additionally the peaking factor[2] for half of the water projects is just 1, with only around 20% of the water projects having a peaking factor greater than 1.5. This implies that the water projects if fully relied on do not have much extra capacity to meet peak demands.

Climate change effects on water values

Climate change is also a looming issue in the regional water situation. Projections show climate change is expected to increase demands and lower supplies which will increase values and this in turn would raise the need for additional project activity which would also increase water values.

References

Albanese, N., B. Garbaczewski, S. Goel, A. LaSalle, C. Liu, Q. Liu, W. Utami, and Y. Wang. 2016. "Water Usage in U.S. Unconventional Drilling." In *SIPA GRADUATE STUDENT CAPSTONE REPORT CLIENT: BARCLAYS*. Available at: https://sipa.columbia.edu/file/3339/download?token=saHSWsYY [Accessed December 3, 2019].

Edwards Aquifer Authority. 2017. "Edwards Aquifer Authority Rules." Available at: https://www.edwardsaquifer.org/eaa/legislation-and-rules/eaa-rules.

Griffin, J.M., and H. Shafiezadeh. 2017. "The Evolution of a Two Price Water Market in the Edwards Aquifer."

Malcolm Pirnie, Inc, ASR Systems, LLC, and Jackson, Sjoberg, McCarthy & Wilson, LLP. 2011. "An Assessment of Aquifer Storage and Recovery in Texas." Texas Water Development Board No. 0904830940, Texas Water Development Board. Available at: http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/0904830940_AquiferStorage.pdf.

SAWS. 2017. "2017 Water Management Plan." Available at: http://www.saws.org/wp-content/uploads/2019/02/20171107_SAWS-2017-Water-Management-Plan.pdf.

Sharr, A. 2014. "Water Management Trends & The Eagle Ford." Baker Hughes. Available at: http://www.tamuk.edu/eagleford/pdf/Baker_Hughes_April%20Sharr.pdf [Accessed August 15, 2019].

Texas A&M Agrilife Extension. 2018. "Budgets by Extension District | Extension Agricultural Economics." Available at: https://agecoext.tamu.edu/resources/crop-livestock-budgets/budgets-by-extension-district/ [Accessed October 1, 2018].

[2] Peaking factor is defined as the ratio of maximum daily supply over the average daily supply.

Texas Demographic Center. 2018. "2018 Texas Population Projections Data Tool." Available at: https://demographics.texas.gov/Data/TPEPP/Projections/Tool?fid=58BC64C5EDA34506AB0988A3CE24CF49.

Texas Municipal League. 2018. "Texas Water and Wastewater Survey." Texas Municipal League.

Texas Water Development Board. 2017. "Planning Region L | 2017 Texas State Water Plan." Available at: https://2017.texasstatewaterplan.org/region/L [Accessed October 2, 2018].

Texas Water Development Board. 2016. "State water plan for 2016 – regional plans." Available at: 2016.

Thayer, A. 2018. *Climate, Water, Water Markets, and Texas Agriculture: Three Essays*. PhD Thesis.

USDA. 2018. *Quick Stats 2.0*. Washington D.C., USA: National Agricultural Statistics Service, US Deparment of Agriculture. Available at: https://quickstats.nass.usda.gov/.

USDA Farm Service Agency. 2018. "ARC/PLC program data." Available at: https://www.fsa.usda.gov/programs-and-services/arcplc_program/arcplc-program-data/index.

USDA National Agricultural Statistics Service. 2017. "Texas Cash Rents County Estimates." Available at: https://www.nass.usda.gov/Statistics_by_State/Texas/Publications/Current_News_Release/2017_Rls/tx_ce_cash_rent_2017.pdf.

Vargas, A.M. 2019. *Efficient Management And Procurement Of Freshwater And Adaptations In Water Scarce Regions Via Agricultural Technology*. College Station, TX: Texas A & M University.

Yang, Y.Q. 2019. *Economics of energy sector in FEW Nexus water stressed region: a case study in South Central Texas*. Ph.D. Dissertation,. College Station, TX: Texas A&M University.