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Economic valuation of groundwater in Texas

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Abstract: Groundwater is a strategic economic asset, and recent Texas Supreme Court decisions have strengthened private ownership rights in groundwater. Despite the economic and political stakes, debate on how to actually value groundwater has been sparse. In response, this article sets forth seven methods of economically valuing groundwater in Texas and uses case studies and hypotheticals informed by real data to assess the valuation techniques' strengths and weaknesses under a range of conditions. In addition, the analysis shows how in practice, multiple valuation methods can be combined to render the most credible valuation range for a particular groundwater asset. Readers will also see how to marshal a wide range of publicly available data resources—including actual water sale and lease contracts—and analytically mesh them to arrive at a defensible valuation range for water assets under various conditions. These methods can help value water more accurately, create opportunities for unlocking additional economic value, and help manage groundwater resources more effectively for the benefit of future generations.

Keywords: groundwater, valuation, resource stewardship, capitalization

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Terms used in paper

Short name or acronym	Descriptive name
ASFMRA	American Society of Farm Managers and Rural Appraisers
DCF	discounted cash flow
EBITDA	earnings before interest, taxes, depreciation, and amortization
NPV	net present value
SAWS	San Antonio Water System
TDS	total dissolved solids
TWDB	Texas Water Development Board

INTRODUCTION

Groundwater in place has real, substantial, and quantifiable economic value in Texas. One of this article's core goals is to describe and analyze the existing set of methodologies that can be used to quantify a reasonable and defensible value range for groundwater assets across the state. This analysis draws directly upon the author's recent experience serving as a valuation expert in a Montgomery County groundwater proceeding.[1] It also builds upon the analytical foundations laid by Charles Kreitler and Bruce Darling in a 1997 paper titled *Value of Groundwater*, two subsequent analyses by Darling in 2007 and 2009, and most recently, a paper written by Ed McCarthy and Charles Porter for a Continuing Legal Education course in late 2016.[2]

The groundwater valuation methodologies addressed in this analysis are globally relevant and have been employed in other jurisdictions around the world, including Australia, Namibia, and Spain. Groundwater valuation is location-specific and fact-intensive. A diverse set of tools helps evaluators choose methods most appropriate for the conditions and factual realities inherent in the asset or set of water assets they are assessing.

Multiple valuation tools also help address the reality that, in some instances, water is the final good sold, though in other cases, such as farming or industrial uses, water is an essential intermediate input. Weather, water demand, hydrogeology, and other factors vary widely across Texas. As such, parties valuing water assets must make many judgment calls and assumptions. But this should not discourage the valuable contribution of developing and promulgating a common set of frameworks for pricing water.

Being able to value water in place is the gateway to facilitating a range of commercial and financial transactions that can unlock additional economic value from Texas groundwater resources. Indeed, if sufficiently protected by tract size, correlative rights withdrawal restrictions, or lease pooling, groundwater in place that underpins a cash flow-generating project can potentially also become collateral for reserve-backed lending.

Furthermore, better groundwater valuation will facilitate fairer resolution of disputes. For instance, groundwater valuation in place is important for assessing the value at stake in cases where groundwater owners are litigating against groundwater

[1]Mr. Collins served as a groundwater valuation expert in the proceeding of *Petition of the Cities of Conroe and Magnolia, Texas Appealing Desired Future Conditions of GMA 14 Adopted by Lone Star Groundwater Conservation District*, SOAH DOCKET NO. 958-17-3121, which was settled in November 2017.

[2]Charles W. Kreitler and Bruce K. Darling, "Value of Ground Water," presented at the Seventh Annual Conference on Texas Water Law, 13-14 November 1997, Austin, TX; Bruce K. Darling, "Groundwater in Texas: Marketability and Market Value," The Water Report, 15 July 2007; Bruce K. Darling, "The Rule of Capture, Changing Perspectives on Water Management in Texas, the Tragedy of the Commons, and Developments in the Valuation of Groundwater," Conference Paper, April 2009, DOI: 10.13140/RG.2.1.1516.3047; Edmond R. McCarthy Jr. and Charles R. Porter Jr., "Valuation of Water Rights," 2016 Texas Water Law Institute, https://utcle.org/practice-areas/index/practice_area_id/26.

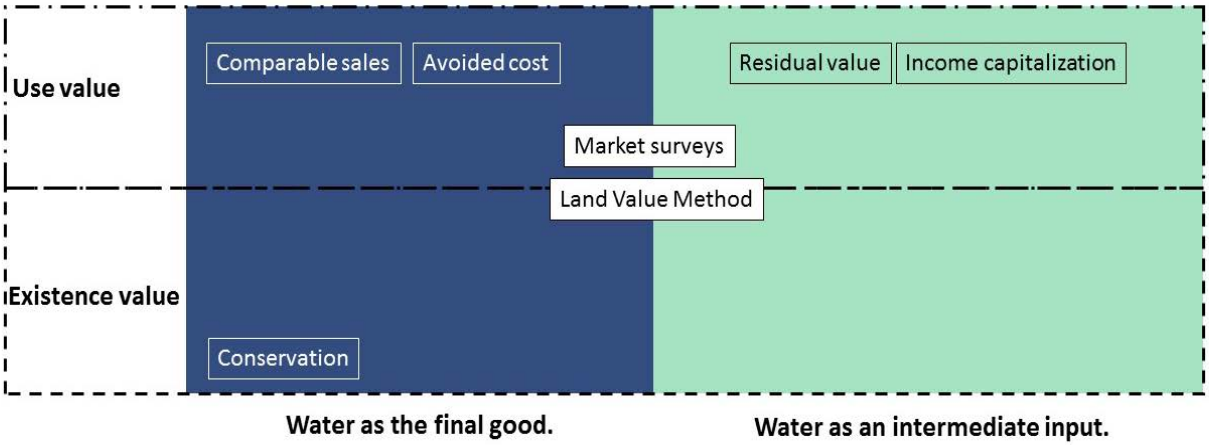

Figure 1. Overview of key groundwater valuation methods.

conservation districts, whose regulatory actions have impaired water owners' access to, and use of, their natural capital assets.[3] Texas courts are also seeing an increase in cases where one party believes that physical actions taken by another have somehow impaired its ability to access groundwater it owns.[4]

This article aims to lay down foundational methods and parameters and does so fully acknowledging that iterative improvements to the techniques discussed are inevitable as commercial transactions occur, more scholars engage the subject, and more groundwater cases wind their way through the courts.

INTRODUCTION TO PRINCIPAL VALUATION METHODS

There are seven core methods for evaluating the economic value of groundwater in Texas: (1) comparable sales (including market surveys), (2) avoided cost, (3) land value method, (4) residual value, (5) income capitalization, (6) net present value valuation, and (7) conservation value. Ultimately, useful valuations of groundwater incorporate a number of elements, each of which contributes to the asset's worth. These include, but are not limited to, (1) the capital and recurring operational costs of extracting water; (2) the costs of transporting the water to market; (3) treatment costs (when applicable); and (4) economic benefits that may be conferred simply by having a certain volume of water in place in an aquifer.

Figure 1 outlines the core methodologies and highlights their key characteristics, while the accompanying discussion very briefly outlines the fundamental parameters of each concept. Subsequently, this article will analyze each method in greater detail, offer case examples where the methods have been—or could be—applied, and evaluate the strengths and weaknesses of each.

Groundwater valuation methods summary

1. **Comparable sales.** This method entails examining transactions where groundwater was bought or sold to see what values are feasible for a water sale in the area of interest. For example, if groundwater from the Carrizo-Wilcox Aquifer in Burleson County is purchased by the San Antonio Water System (SAWS) at a royalty rate of $460 per acre-foot to supply San Antonio, water from an equally productive part of the aquifer nearby would likely be worth at least approximately as much to Austin, College Station, or another municipal consumer.
2. **Avoided cost.** This method values groundwater by seeing how much money a consumer could save by obtaining water from an alternative, cheaper source. Consider the following simplified hypothetical: if a city currently purchases water from one source for $1,000 per acre-foot but could obtain water from an alternative groundwater source for $700 per acre-foot, the avoided cost value of water from the second source would be up to $300 per acre-foot. Any avoided cost relative to the baseline supply source would be a net economic benefit to the consumer, all else held equal.

[3]See, for instance: *Edwards Aquifer Auth. v. Bragg*, 421 S.W.3d 118 (Tex. App.—San Antonio 2013, pet. denied); *Forestar [USA] Real Estate Group, Inc. v. Lost Pines Groundwater Conservation District, et al.,* No. 15,369, Texas Dist., Lee Co.; *Petition of the Cities of Conroe and Magnolia, Texas Appealing Desired Future Conditions of GMA 14 Adopted by Lone Star Groundwater Conservation District*, SOAH DOCKET NO. 958-17-3121.

[4]See, for instance: *Edwards Aquifer Auth. v. Day*, 369 S.W.3d 814 (Tex. 2012) (landowners own groundwater beneath their tract as real private property and have an interest in groundwater that is compensable under the takings clause of the Texas Constitution); *Coyote Lake Ranch, LLC v. City of Lubbock*, 498 S.W.3d 53 (Tex. 2016), reh'g denied (Sept. 23, 2016) (accommodation doctrine applied to the relationship between as owner of severed groundwater estate and surface estate).

3. **Land value method.** The land value method is an inductive approach that derives water values by comparing transactions of irrigated and non-irrigated farmland. For example, if dry cropland in an area sells for $1,000 per acre and irrigated cropland in the same zone sells for $2,000 per acre, this would suggest that the water associated with the land is worth $1,000 per surface acre. This technique often crosses over with the comparable sales method and can be combined with data on the thickness of water-bearing layers to actually develop a price per saturated foot for water in place.
4. **Residual value.** This method helps assess how much a consumer can pay for water. It looks at how much income someone makes from a water-dependent activity such as growing hay, subtracts the costs, and divides the remaining net income by the amount of water needed. If a farmer's income for growing corn is $100 after costs and she needs 1 acre-foot of water to grow that corn, then the residual value of water to her is $100 per acre-foot because in theory that's the most she could pay for the water from another supplier (or the highest extraction cost she could afford for self-produced water) and still break even.
5. **Income capitalization.** This method also examines capacity to pay for water. It converts the income generated by an asset into an estimate of its overall value. A farm whose annual net operating income is $100 with a capitalization rate of 10% would have an annual capitalized crop value of $1,000 [$100÷10%]. For water-intensive assets such as farms, it can also yield a value for the water input by taking the capitalized income value and dividing it by the volume of water needed to produce it. If the farm's crop needs 10 acre-feet of water, the water would be worth $100 per acre-foot to the farmer [$1,000 in capitalized income per year ÷ 10 acre-feet per year to generate that income].
6. **Net present value.** This method focuses on assessing an asset's current value based on its likely future cash flows. Net present value (NPV) analyses are fundamentally predicated on the time value of money—in other words, the concept that a dollar today is typically worth more than a dollar tomorrow. In practice, buyers and sellers of oilfield water supply facilities, farms, and other cash-generating water investments often use an NPV-based approach to value their assets.
7. **Conservation value.** The prior four core methods center upon the use value of water. Conservation value, in contrast, more fundamentally rests upon the "existence" value of water. Determining conservation value can require a multi-faceted analysis that considers factors such as ecosystem services value and the costs that aquifer depletion might impose. In addition, because groundwater is private property in Texas, groundwater conservation programs should compensate water owners for idling their natural capital assets.

IN-DEPTH ANALYSIS OF PRINCIPAL VALUATION METHODS

This section explores each of the seven principal groundwater valuation methods in depth, with a detailed examination of their respective strengths and weaknesses. It also demonstrates how valuation methods often "cross pollinate" in practice and how a proper valuation is frequently a multi-method, if not multi-disciplinary, endeavor. The author also shares some methods he has used to obtain transaction data and a set of adjustment factors that can help analysts compensate for differences in local conditions when assessing groundwater assets. Finally, the author also includes data from sample transactions showing how groundwater has been priced in recent years across Texas in land purchases, groundwater estate sales, and water leases.

Method 1: Comparable sales

Comparable sales valuation means examining transactions where groundwater was bought or sold and seeing what the prices were for those transactions. If available, recent sales or leases of comparably situated water rights or water resources in place typically offer the most dependable metric for determining the value of water resources in that location.

Comparable transaction valuations are predicated on the principle that the "fair market value of property" denotes "the amount that a willing buyer, who desires but is not obligated to buy, would pay a willing seller, who desires but is not obligated to sell."[5] This fundamental idea of fair market value is also enshrined in the Texas Water Code, which states in relevant part that:

> *"[w]henever the law requires the payment of fair market value for a water right, <u>fair market value shall be determined by the amount of money that a willing buyer would pay a willing seller, neither of which is under any compulsion to buy or sell, for the water in an arms-length transaction and shall not be limited to the amount of money that the owner of the water right has paid or is paying for the water</u>."[6] [emphasis added]*

In other words, the water right's or asset's value should be based on *actual market conditions as dictated by supply and demand and other factors* and not be determined simply on the

[5] Op. Tex. Attn'y Gen. No. LO-98-082 (1998).

[6] Tex. Water Code Ann. § 11.0275 (West).

basis of compensating a water owner based on what they themselves originally paid for the property. To yield a true "fair market value," the transaction should occur between parties that are operating under normal commercial conditions and are not facing any type of financial, regulatory, or other duress that could skew the terms of the deal.

Water valuators using comparable sales methodology are in good company. For a cross-industry comparison, consider that National Football League and National Basketball Association player contracts involve very large amounts of money, the market for talent is relatively illiquid, and precise transaction terms are often kept confidential.[7] Notwithstanding these challenges, many player agents and teams use the terms and economic parameters reflected in prior agreements as a baseline to inform new contractual negotiations for player signings each year during the free agency period where total transaction value turnover approaches $2 billion per league.[8]

On an even larger scale, reporting of comparable transaction prices—including bids and offers where a transaction was not necessarily consummated—provides the basis for indices used to price commodity contracts in markets for natural gas, petrochemicals, and crude oil.[9] Combined trade turnover in markets priced off indices from Platts, Argus, and other price providers can exceed $300 billion per year.[10] As such, using comparable sales transaction data to value and price groundwater in Texas is highly defensible and will become more so as additional data from sales and leases become publicly available.

Obtaining comparable transaction data

Water marketing in Texas is generally opaque, and deal terms are often kept private. Actual signed water supply and purchase agreements and judicial rulings and settlements, which collectively generally offer the highest fidelity source of information, can be obtained through a number of channels, including (a) open records requests to municipalities, their water suppliers (such as SAWS or Alliance Water), and other public entities that own or regulate groundwater resources; (b) discussions with private water sellers, purchasers, and parties such as county extension agents and others who may have access to deal flow information; (c) judicial decisions; and (d) for the San Antonio area, periodic water rights purchase solicitations by SAWS.[11]

In addition, surveys can be a relevant technique for helping to assess value along several portions of the groundwater value chain, including sales prices, production costs, and transport costs. The most reliable information is likely to come from parties who are already either participating in the market, such as oilfield water sellers, or farmers, who are actively preparing to do so. In a nutshell, these parties either (1) have already made the necessary capital investments in requisite physical infrastructure and permits and/or (2) are geographically situated near water demand and can credibly enter the market on short notice.

Simply asking landowners "what would you sell or buy water for?" risks placing them in a situation where their response may lack the anchoring context of knowing the value of water-dependent outputs, water extraction costs, and other important information that helps inform the ultimate value of water in a given area for a particular application.

Municipal water sourcing data tends to be more sparse than that from the oilfield but still useful. Municipalities typically do not enter into water sales and purchase transactions as frequently as oilfield parties do, but when they enter the market, the volumes of water and dollar amount of capital at stake are often enormous. Many of these agreements have terms of at least 30 years, which forces the parties to thoroughly contemplate future supply/demand conditions, hydrological risks, capital market conditions, and other factors. As such, if the water appraiser is weighing the value information transmitted from short-term oilfield supply deals in a given area versus longer-term, higher volumes, and more capital-intensive municipal deals, the municipal deals arguably hold a greater validity over a longer period for baseline valuation assessments.

Judicial rulings

While not "sales" in the traditional sense, court rulings offer a number of unique factors that can make them useful barometers of groundwater value. First, judicial opinions are matters of public record, which makes them broad and transparent benchmarks that are far more accessible than most water sales and purchase contracts. Second, each party to litigation often faces enormous financial stakes and has commensurately high incentives to provide as powerful of evidence as possible to sup-

[7] https://www.cbssports.com/nfl/news/agents-take-the-top-10-nfl-contracts-from-players-side-of-the-negotiating-table/.

[8] See, for instance: "2015 NFL salary Cap and Adjusted Team Positions," NFLPA, 24 March 2015, https://www.nflpa.com/news/all-news/2015-nfl-salary-cap-and-adjusted-team-positions#update; as well as Anthony Chiang, "NBA free agent spending spree up to $1.8 billion in total contract value," PalmBeachPost.com, 2 July 2016, http://heatzone.blog.palmbeachpost.com/2016/07/02/nba-free-agent-spending-spree-up-to-1-8-billion-in-total-contract-value/.

[9] See, for instance: "METHODOLOGY AND SPECIFICATIONS GUIDE: AMERICAS PETROCHEMICALS," S&P Global Platts, Updated April 2017, https://www.platts.com/IM.Platts.Content/MethodologyReferences/MethodologySpecs/americas-petrochemicals-methodology.pdf.

[10] Terry Macalister, "Price reporting agencies cut out of the loop," The Guardian, 8 May 2013, https://www.theguardian.com/business/2013/may/08/price-reporting-agency-boycott.

[11] McCarthy and Porter, "Valuation of Water Rights," 2016 Texas Water Law Institute, https://utcle.org/practice-areas/index/practice_area_id/26.

port their position. Third, while a judicially driven transaction is compelled, the analysis underlying it draws upon a robust debate and information discovery process that is more likely than not to render its value reasonably reflective of actual prevailing market conditions.

The body of judicial and jury decisions, along with settlements on groundwater value disputes in Texas, remains relatively small but already includes at least two prominent case examples. The first, *Bragg v. Edwards Aquifer Authority*, centered on a damage claim arising from the Edwards Aquifer Authority's decision to deny groundwater pumpage rights to a pecan farming couple in Medina County. After approximately a decade of litigation, a Medina County jury awarded the Braggs $2.5 million in damages, finding that one orchard was worth $1.67 million with full access to Edwards Aquifer groundwater but only $300,000 if water access was limited to 120 acre-feet per year, as the Edwards Aquifer Authority desired.[12] The jury also found that a second pecan orchard was worth $1.18 million with full access to the necessary water volumes but had no value as a commercial pecan farm without water rights. The *Bragg* valuation relies heavily upon the cash-generation potential of agricultural land with and without access to water.

The second case, *State of Texas v. 7KX Investments*, involved the condemnation of approximately 28 acres of property for the construction of a rest stop alongside Interstate 35 in Bell County, near Temple. The State offered to pay approximately $500,000 for the land it sought to acquire. However, this offer proved unacceptable to the owner, 7KX Investments, which had drilled six large volume groundwater supply wells on the tract and would not be able to access the water once the State built the rest stop because the aquifer could not be reached using directional drilling.[13] The jury awarded 7KX $5.8 million for the condemned land, based largely on the long-term likely sales value of the groundwater resources that lay beneath it.

The case ultimately settled for $5.5 million just prior to the commencement of oral arguments before the Third Court of Appeals, meaning the land was effectively valued at more than $196,000 per acre.[14] The settlement in *7KX Investments* was very likely predicated on the future income generation potential of the proven commercial-scale water resource under the tract taken by the State of Texas. Supporting this idea, the final settlement amount fell nearly in the middle of the 50-year total groundwater value estimate of $4.5 million and $6.2 million offered by the Plaintiff's expert witness.[15]

Adjusting comparable transaction data for specific assets

Groundwater valuations are best framed in terms of what Charles Porter and Ed McCarthy call "the most probable price."[16] Most importantly, this means that groundwater prices result from dynamic interaction between many variables and so a valuation dollar figure at any given point is a "snapshot" in time and could rise or decline meaningfully months or even weeks later.

Businesses often use a "fair value" approach intended to reflect market activity, timing, and a range of other factors to reach value estimates for water assets. For instance, Martin Marrieta—a large, publicly traded corporation with major land holdings in Texas—employs "a market approach to determine the fair value of water rights that may be associated with its properties."[17] The company specifies that it values other intangible assets using an "excess earnings" method or a replacement cost approach, but classifies water rights entirely differently, which strongly suggests that "market approach" in this context means "comparable sales."

Forestar Group, another large, publicly traded corporation whose business focuses on relatively illiquid assets such as real estate and groundwater, offers a useful three-level framework for assessing the "fair value" of property interests in water:

1. Level 1: "Quoted prices in active markets for identical assets or liabilities."[18]
2. Level 2: "Inputs other than Level 1 that are observable, either directly or indirectly, such as quoted prices for similar assets or liabilities; quoted prices in markets that are not active; or other inputs that are observable or can

[12]Jess Krochtengel, "Texas Jury Awards Pecan Farmers $2.5M In Water Takings Suit," Law 360, 23 February 2016, https://www.law360.com/articles/762833/texas-jury-awards-pecan-farmers-2-5m-in-water-takings-suit.

[13]Paul A. Romer, "Rest stop dispute finally comes to end," tdtnews.com, 1 July 2009, http://www.tdtnews.com/archive/article_ffa15658-9cc1-566f-99dc-0f0343ba804b.html.

[14]Johns Marrs Ellis & Hodge, LLP, "Trials & Appeals," State of Texas v. 7KX Investments, No. 03-10-0069, In the Third District Court of Appeals, Austin, Texas (2011), http://jmehlaw.com/trials-appeals/types-of-cases/condemnationeminent-domain/.

[15]Paul Romer, "Setting a precedent: Bell case possible landmark for eminent domain involving underground water rights," tdtnews.com, 23 August 2009, http://www.tdtnews.com/archive/article_33fbf22f-c781-53fd-811e-9a7657c55fbe.html.

[16]Charles Porter and Ed McCarthy, "Valuation of Water Rights," 2016 Texas Water Law Institute, https://utcle.org/practice-areas/index/practice_area_id/26.

[17]"Martin Marrieta Materials 2016 Annual Report," http://files.shareholder.com/downloads/MLM/5519439460x0x932416/88AB9794-3EC6-462A-AAAA-0ED16EE13FC0/Annual_Report_2016.pdf.

[18]Forestar Group, Form 10-K, 2016. Pg. 70. Available from http://investor.forestargroup.com/phoenix.zhtml?c=216546&p=irol-sec&control_symbol=&control_symbol.

Figure 2. Vista Ridge delivered water cost visualization. Source: SAWS

be corroborated by observable market data for substantially the full term of the assets or liabilities," and[19]

3. Level 3: "Unobservable inputs that are supported by little or no market activity and that are significant to the fair value of the assets or liabilities."[20]

Aside from high-activity oilfield areas, the main high-activity "market" for groundwater in Texas to date is in the Edwards Aquifer, which provides an online portal for parties wishing to sell or lease groundwater, but does not comprehensively report transaction and price data.[21] For other groundwater transactions throughout Texas, data availability is even sparser, which makes finding "apples-to-apples" transaction data upon which to price the water difficult. Accordingly, buyers and sellers must generally apply multiple adjustment factors to determine a defensible fair value range for a transaction at a given place and time.

Key variables to consider when adjusting comparable transaction valuations include the 11 criteria enumerated below. These factors are not rank-ordered because under various circumstances their relative importance may differ. For instance, a rapidly growing city in a drier part of Texas may be most concerned about a resource's drought resistance and water quality, while an oilfield or factory user may be most concerned with how quickly water can be brought online and the availability of rights of way and infrastructure to get it to market.

Factors 1-3: Water location, the existence of production and delivery infrastructure, and the cost of such infrastructure. These factors tend to be closely related to one another, hence the decision to group them in a bloc here. Take for instance the Vista Ridge project supplying water from Burleson County to San Antonio. As of February 2017, the project's expected water cost per acre-foot was $460 per acre-foot to purchase the water from Bluewater Systems, $1,146 per acre-foot to finance infrastructure costs, $191 per acre-foot in electricity costs, and $196 per acre-foot in operations and maintenance costs, for a final delivered water price of $1,993 per acre-foot.[22] In simple terms, infrastructure and debt service costs alone account for nearly 60% of the final delivered water price for the Vista Ridge project (Figure 2).

4: Market competition. Multiple parties competing for a water asset will likely drive up the price, while a lack of competition empowers a potential buyer to seek a lower price.[23]

5: Water quality. The price of water may be varied based on its quality. For instance, in agreements to supply municipal drinking water, water volumes with lower total dissolved solids (TDS) content (a proxy for salinity) can entitle producers to higher royalty payments while water volumes with higher TDS levels yield lower royalty payments.[24] Conversely, oilfield water supply agreements in Texas have been designed to incentivize the use of high-TDS non-potable water for fracturing fluid by prohibiting the production of water below a specific TDS level and requiring a lessee to effectively forfeit the gross revenues earned from any sales of water below a certain defined TDS level.[25]

6: A closely related concept is **the cost of physically extracting and treating the water**. A water seller will likely have to discount the price of water they are selling if that water has a quality impairment that requires a customer to spend on treatment. Quality-related premiums and discounts abound in the oil and gas world and provide ample precedent for parties valuing water and structuring sales and purchase agreements.

7: The intended use of the water. Agricultural users are the largest users of water per unit of economic output produced but also generally have the lowest capacity to pay, municipal users have a medium capacity to pay and contract the largest steady volumes of water for the longest periods, and specialty users such as oilfield frac'ers have much smaller volume

[19]Ibid.

[20]Ibid.

[21]"Sellers Lessors Listing," Edwards Aquifer Authority, http://data.edwardsaquifer.org/sellerslessors.

[22]Data obtained from "Project Introduction: San Antonio's Vista Ridge Regional Water Project," Nancy Belinsky, VP & General Counsel, Delivered at 59th Annual V.G. Young School for County Commissioners Courts, Austin, TX, 8 February 2017.

[23]Bruce K. Darling, "Groundwater in Texas: Marketability and Market Value," The Water Report, 15 July 2007.

[24]See, for instance: Groundwater Rights Sales Contract between the Roark interests, Winkler Land, LLC, and the Midland County Fresh Water Supply District No.1 (2015).

[25]See, for instance: the Groundwater Lease signed on 1 November 2017 between the Texas General Land Office and Layne Water Midstream, LLC.

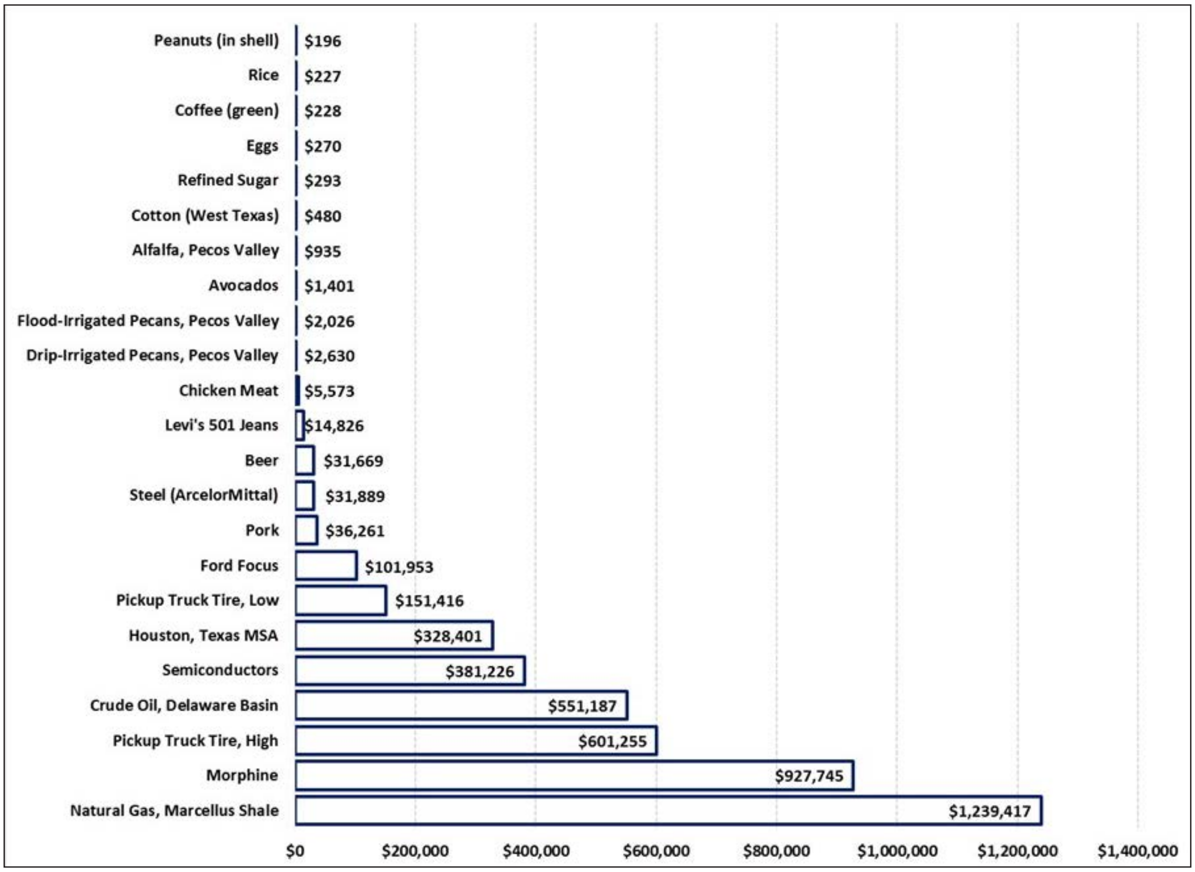

Figure 3. Economic value generated per acre-foot of water used, 2016 dollars. Source: Ag Extension Data, Company Reports, FracFocus, Mekonnen and Hoekstra, U.S. Census Bureau, USDA, Author's Estimates

requirements but can pay an order of magnitude higher than what a municipality or factory could (Figure 3).

8: Protection from drainage by neighboring pumpers. Texas currently governs groundwater under "rule of capture" principles that in practice mean water owners do not have access to a given volume of water nor do they have practical recourse to prevent themselves from being pumped out by neighboring users.[26] The practical implication is that water sourced from very large contiguous tracts or pooled leases is the most "protected" and, all else held equal, will likely command the highest valuations for groundwater in place in that particular area.

9: Political, legal, and regulatory barriers that could impede development of the resource. Developing water resources for off-tract use generally requires some—or at times all—of the following: groundwater conservation district export permits (which ideally need to cover a period of 15 years or longer to support the financing of infrastructure necessary to get the water to end users), payment of groundwater conservation district export fees, public support, the consent of third parties whose property must be crossed, and the consent of other parties who may hold a property interest in the groundwater resource in question. These "above-ground factors" often present the greatest challenge to developing a water asset and exert great influence on what a given groundwater asset is actually worth because potential investors will generally seek the highest practicable degree of regulatory certainty.

10: Time sensitivity of the end use. In practice, time sensitivity is often inversely correlated with the length of the period in which the consumer will need the water. For instance, sourcing water for hydraulic fracturing completions of oil and gas wells is the epitome of a "time-is-of-the-essence" transaction, but such purchases often occur on an irregular schedule and energy companies are generally unwilling to enter into longer-term or take-or-pay water procurement agreements. In contrast, cities that need water for the next 30 to 50 years will not pay as much as a frac'er and will not move as quickly to seal up a deal, but when a purchase agreement is executed, it typically spans multiple decades. The most rapidly implemented municipal water development and acquisition transactions typically occur when a city already owns an anchor water property—such as Midland's T-Bar Ranch—and then patches satel-

[26]Gabe Collins, Blue Gold: Commoditize Groundwater and Use Correlative Management to Balance City, Farm, and Frac Water Use in Texas, 55 Nat. Resources J. 441, 463 (2015).

lite properties such as the Roark and Clearwater Ranches into the supply corridor.

11: Resource dependability (i.e. drought resistance and available volumes). The value of a groundwater resource will be affected by how much water is available at a given time as well as by whether or not the aquifer is "mined" or recharges (such as the Edwards Aquifer in Central Texas).[27] Groundwater resources are generally much more insulated from drought than surface water sources. As such, access to groundwater can help cities and other water users hedge against a drought by offering them an alternative water source that replaces supplies lost from surface water sources and helps buy time for demand-side reforms aimed at optimizing water conservation.

Oilfield water assets, an important subset of the market in the Permian Basin and parts of South Texas, generally require analysts to apply a number of additional criteria to properly evaluate their potential economic value. First, how close is the asset to a state-owned highway that offers a potential right of way for pipelines or layflat hoses to be laid in the bar ditch? Second, how many drilling permits have been approved for the next six-12 months forward within a 20-mile radius of the asset? Third, how intense is the competition from other water suppliers in the area? Is there a larger supplier whose "zone of influence" curtails the potential market opportunities that the asset under evaluation might otherwise enjoy?[28]

Comparable transaction pricing has, to date, been the preferred method of valuing groundwater sold in Texas. But income-based value approaches are likely to become more prominent if institutional investors become more interested in Texas water assets, whether they are businesses directly selling water or those using water as a critical intermediate input (like farms). In Australia, the executive director of BDO, a prominent firm representing institutional buyers of agricultural assets, noted in a 2014 interview that "The comparable sales methodology is not the valuation methodology expected to be used by sophisticated investors…Instead, they are more likely to adopt an income approach when valuing agricultural businesses for acquisition, divestment and general reporting."[29]

Nevertheless, the comparable transactions method is likely to continue serving as a core groundwater valuation tool in Texas for at least two reasons. First, the final sale price of a given groundwater asset is likely to incorporate the influence of income-based valuation methods, particularly in cases where the water renders the land its value and drives its income generation potential. Second, basic human psychology makes it such that buyers and sellers of an asset will want to see what "similar" assets fetched on the market. And in turn, this information in many cases will "anchor" their own subsequent value perceptions and expectations.

How has groundwater actually been priced in Texas to date?

Data from actual sales shows three fundamental pathways in which buyers acquire access to groundwater in Texas (Figure 4). One method is to purchase the groundwater in place outright. The second method involves purchasing surface acreage to acquire the accompanying groundwater. The third method is to lease groundwater rights. The following section will offer case examples of each method and discuss how they price groundwater resources relative to one another.

Leasing and Sale of the Groundwater Estate in Texas

Texas law recognizes a separate groundwater estate that can be severed from the surface land and bought and sold as an independent asset. In its landmark *Coyote Lake Ranch* decision in May 2016, the Texas Supreme Court affirmed that the groundwater estate is not only a stand-alone real property interest, but that it is also dominant relative to the surface estate. Without specific contractual provisions to the contrary, a surface owner now generally cannot prevent a groundwater estate owner from making reasonable use of the surface in order to develop her asset.[30]

Coyote Lake Ranch reinforces the property rights underlying an approximately 50-year history of groundwater estate transactions in Texas. For example, in 1969 University Lands leased for up to 50 years all groundwater rights down to 1,200 feet depth on an 11,500-acre tract in Ward County to an entity called Duval Corporation, which subsequently transferred its interest to the Colorado River Municipal Water District.[31] Furthermore, in a 1986 transaction, University Lands leased all groundwater that was potable or capable of being rendered potable under a 1,319-acre tract in Upton County to the

[27]Bruce K. Darling, "The Rule of Capture, Changing Perspectives on Water Management in Texas, the Tragedy of the Commons, and Developments in the Valuation of Groundwater," Conference Paper, April 2009, DOI: 10.13140/RG.2.1.1516.3047.

[28]For these points, I am indebted to the insights shared with me in October 2017 by a large Delaware Basin frac water supplier.

[29]Matthew Cranston, "Earnings call for farm value," FarmOnline National, 17 March 2014, http://www.farmonline.com.au/story/3578573/earnings-call-for-farm-value/.

[30]*Coyote Lake Ranch, LLC v. City of Lubbock*, 498 S.W.3d 53, 65 (Tex. 2016), reh'g denied (Sept. 23, 2016). (The principle, absent an agreement to the contrary, that a severed mineral estate's implied right to use the surface must be exercised with due regard for the surface estate's rights, and the rules common to mineral and groundwater estates, compel the conclusion that the accommodation doctrine extends to groundwater estates.)

[31]Agreement available upon request.

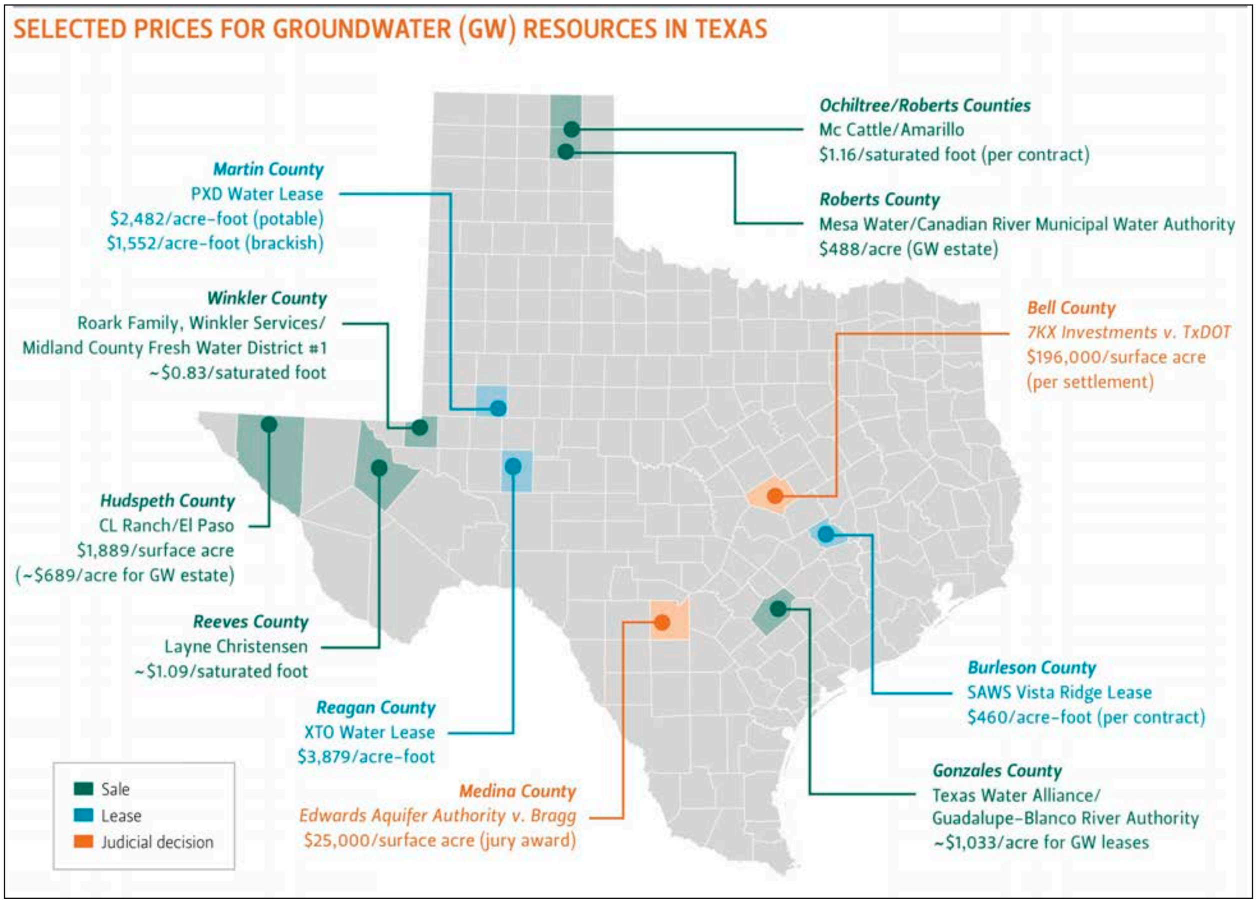

Figure 4. Selected valuations for groundwater resources in Texas, \$/acre-foot (flow values), \$/saturated foot (groundwater estate values), \$/surface acre (judicial values). Note: In sales tranactions listed, seller is listed first followed by the buyer (i.e., seller/buyer) where applicable. Source: Baker Institute for Public Policy, CRMWA, Water Supply Agreements, Company Reports, Local Newspapers, Author's Model (Layne Christensen asset).

Upton County Water District.[32] Like the Ward County agreement discussed above, the Upton County contract also used a total potential lease life of 50 years.

Moving to recent transactions, the Vista Ridge project is perhaps the signature groundwater lease project in Texas at present. Vista Ridge aims to begin supplying water to San Antonio in 2020 through a 142-mile pipeline from Burleson County. SAWS will purchase groundwater from a trust controlled by Blue Water VR at a price of \$460 per acre-foot.[33] This groundwater is sourced from a pool of 1,312 individual groundwater leases covering a total of 50,000 surface acres.[34]

Metropolitan Water Company, L.P. amassed these leases over a period of approximately 15 years as part of its Porter's Branch Groundwater Project, which the company claims "was the first large-scale Groundwater Lease Project in the State of Texas."[35] Met Water then transferred a portion of the total lease pool to Blue Water, which in turn marketed them to the Vista Ridge project. Landowners who leased their water receive a royalty equal to 10% of the water purchase price, or \$46 for each acre-foot produced.[36]

The author has also located two examples of agreements to sell groundwater in place.[37] One contract specified a price based on the thickness of water-saturated strata underneath the

[32]Agreement available upon request.

[33]Conformed Version of SAWS Vista Ridge Water Transmission and Purchase Agreement, as revised by the Third Amendment dated April 5, 2017, http://www.saws.org/your_water/waterresources/projects/vistaridge/download.cfm. Pg. 601.

[34]"Groundwater Leases of Metropolitan Water Company, L.P." http://www.metwater.com/landleases/index.html.

[35]Ibid.

[36]http://www.hillcountryalliance.org/wp-content/uploads/2015/12/Vista-Ridge-Project-Financial-Questions-Answered-Nov-18-2015-3.pdf.

[37]There are almost certainly many more such agreements, but most are confidential and kept inaccessible to the public. The agreements cited by the author involved a municipal entity and were thus accessible via a request under the Texas Open Records Act.

tract of interest, while the second agreement entailed the payment of a fixed price for the groundwater estate under a tract.

In the first instance, the City of Amarillo agreed in 2015 to purchase the groundwater estate from the base of the Ogallala Aquifer upwards under the lands of the Mc Cattle Company in Roberts and Ochiltree counties northwest of Amarillo. The City priced the water resource based on the feet of saturated water available under each acre in the surface tract and attached a value premium to those acres underlain by the thickest saturated layer. It paid $250 per surface acre for acreage underlain by a saturated layer with an average thickness less than 200 feet, $300 per acre for acreage with an average saturated thickness between 200 and 257 feet, and $1.16 per average saturated foot for each acre with saturated aquifer strata with an average thickness of 258 feet or more.[38]

In the second instance, the Midland County Fresh Water Supply District No. 1 paid $3.2 million to Winkler Services and members of the Roark family to purchase the groundwater rights underneath approximately 4,500 acres of the Roark Ranch.[39] Data from the Texas Water Development Board (TWDB) show that the average thickness of the Pecos Valley Aquifer under the tract is approximately 850 feet.[40] This suggests a groundwater estate purchase value of approximately $0.83 per water-bearing foot per acre.

Parties seeking water may also purchase an entire tract of land in order to access the water underneath. This is more likely to occur with sales of farmland, where property owners may be reluctant to sever the groundwater estate, since doing so impairs the land's farming value.[41] Accordingly, "unbundling" the value of the surface alone can shed light on the likely value of the groundwater beneath. This is important to parties considering agricultural investments where the water "renders the land its value," as well as to parties such as municipalities, water export project developers, or oilfield water suppliers that only seek access to the groundwater estate but may have to purchase the surface tract to obtain the water underneath.[42] Unbundling opens the door for a direct "apples-to-apples" comparison of the implied price paid for groundwater in a land purchase transaction and the price paid for an explicit agreement to acquire only the groundwater estate beneath a tract.

The value-unbundling process proceeds as follows:

1. Take the entire capital investment amount. In addition to the land and groundwater, this can also include the value of fixtures or improvements to the land, if relevant.
2. Subtract the cost of infrastructure, labor, and other non-land expenditures (which may have to be estimated) from the total capital investment amount.
3. Take the remaining dollar figure, which reflects the implied value paid for the land and divide by the number of acres in the tract to find the implied total cost per acre for the land and the water beneath.
4. Find data that reflect the value of the land per acre in its "most recent prior use" (farming, for instance).
5. Subtract the most recent prior-use value from the total value paid per acre of land. This reveals the implied "premium" paid for the groundwater.
6. Divide the premium by the average saturated thickness of the groundwater underlying the land to derive the implied value paid per saturated foot per acre.[43]

The author's recent work offers an example of how to develop in-place groundwater valuations by combining total purchase price or capital investment data and baseline land value data for a specific region of Texas, as outlined below.[44]

Finding the value

First, the author developed an input cost model based on technical and other data, then refined the model based on conversations with knowledgeable industry sources. Next, the estimated input cost figure ($15.2 million) was subtracted from the total reported project capital investment of $18 million, leaving an implied land cost just over $2.7 million. Dividing

[38]See Contract of Sale, Groundwater Rights between Mc Cattle Company and M&D McLain Family (sellers) and City of Amarillo (purchaser).

[39]Winkler Services also retained a royalty interest in water sold, with a scaled system that premium priced water from the ranch based on its quality as measured by total dissolved solids content.

[40]This figure was calculated by taking a shapefile of the Pecos Valley Aquifer from the Texas Water Development Board containing approximately 6800 data points, including thickness of the water-saturated strata, finding the 14 cells that completely or partially underlay the relevant sections of the Roark Ranch in Winkler County, and then averaging the thickness of those cells and using that number as the denominator to calculate the price paid for the groundwater estate.

[41]That said, in wetter areas near the Texas Triangle where high-value, large-volume water sales to municipalities are a real possibility, some landowners now wish to retain groundwater ownership interests in case water leasing occurs in the future. A groundwater conservation district official in Central Texas that the author spoke with in September 2017 noted that in that area, landowners increasingly seek to retain all or part of the groundwater estate associated with the tract they are selling.

[42]There can be exceptions. Consider, for instance, the hypothetical of a developer who purchases the entirety of the surface estate of a 1,000-acre tract for $1,000 per acre, then re-sells the surface rights for the same $1,000 per acre, but severs and retains the groundwater estate. Such situations are less likely now that more parties in Texas recognize the value of groundwater—especially for large tracts where farming, water sales to cities and the oilfield, and other such activities are feasible and may actually be a core reason for purchasing that particular piece of land.

[43]Derived from Gabriel Collins, "Valuation of Groundwater In Place at a Texas Frac Water Supplier," Baker Institute Issue Brief, 7 December 2017, https://www.bakerinstitute.org/media/files/research-document/c96199a5/bi-brief-120717-ces-groundwatervalue.pdf.

[44]Ibid.

Table 1. Estimating the likely value for the groundwater estate at Layne's Hermosa Oilfield Water Supply Asset. Source: Company reports, author's interviews of relevant providers of goods and services.

Item	Units	Number	Unit cost	Subtotal
Wells (new drill)	-	2	$127,250	$254,500
Wells (refurbish)		4	$65,000	$260,000
Storage ponds (built and lined)	bbl	750,000	$1.25	$937,500
Pumps (200 HP)	-	4	$25,000	$100,000
Booster pumps on pipeline		3	$10,000	$30,000
22-in high-density polyethylene pipeline	feet	107,000	$90.20	$9,651,400
Pipe fusion	joint welds	2,112	$150.00	$316,800
Trencher operation (Vermeer T1155)	feet	107,000	$7.50	$802,500
Right-of-Way	miles	20	$71,680	$1,433,600
Riser stations for water offtake		13	$15,000	$195,000
Labor	days	90	$8,400	$756,000
Branch lines linking wells to central pits	feet	21,000	$12	$252,000
Electronics on wells		6	$10,000	$60,000
Electrification		1	$50,000	$50,000
Concrete	tonnes	500	$167	$83,250
Rebar	tonnes	16	$600	$9,494
Roads	miles	1.50	$50,000	$75,000
Total, ex-land				$15,267,044
Total estimated CAPEX				$18,000,000
Implied land cost				$2,732,956
Acreage				1,000
Implied land value per acre				$2,733
Est. value of "farming only" farmland in trans-Pecos region ($/acre)				$750
Implied value premium for water, $/acre				$1,983
Average available aquifer thickness under tract				1,825
Implied price paid for groundwater estate ($/available foot)				$1.09

that number by 1,000 acres delivers a land cost of $2,733 per acre. Land sales value data from the Texas Chapter of the American Society of Farm Managers and Rural Appraisers (ASFMRA) indicate that irrigated cropland in the Trans-Pecos region of Texas sold for an average price of between $500 and $750 per acre in 2016.[45]

To be conservative, the high end of the ASFMRA value range ($750 per acre) was subtracted from the implied land valuation of $2,733 per acre, leaving an implied value premium

[45]"Texas Rural Land Value Trends for 2016" (report presented at the 27th Annual Outlook for Texas Land Markets, April 20, 2017), 23.

Cost of water City is forced to purchase from High Cost Water Authority	$1,000 per acre-foot
	-
New cost of self-sourced water if City deepens wells and taps Farmer Joe's deep aquifer.	$600 per acre-foot
	=
Implied maximum price City would be willing to pay for Farmer Joe's water	**$400 per acre-foot**

Figure 5. Avoided cost valuation in action—valuing Farmer Joe's deep aquifer rights.

of $1,983 per acre for groundwater. The Pecos Valley Aquifer shapefile from the TWDB was then laid over the approximate location of the Layne tract using QGIS software. The cells where the two layers overlapped were selected, and the thickness of each cell was used to calculate the average thickness of the water-bearing strata under the tract area (1,825 feet). Finally, the $1,983 implied water premium per acre was divided by 1,825 feet of potentially water-bearing thickness shown in the TWDB model data, yielding an implied groundwater estate valuation of $1.09 per saturated foot per acre (Table 1).

The price paid for water in place can become a basis for analyzing other groundwater transactions across the state, subject to adjustment factors.

Method 2: Avoided cost

Groundwater can also be valued relative to the savings realized by procuring water from a lower-cost supplier, since avoiding a cost effectively yields an economic benefit.[46] Other authors have called this concept "replacement cost," but the concepts are essentially alike, as both measure the cost of self-sourcing water to either compensate for a supply disruption or avoid procuring water from more expensive sources.[47] It is an especially relevant methodology in cases where an entity such as a city or farm owns the water wells and supporting infrastructure necessary to produce and deliver water but is subjected to a politically motivated requirement that it procure water from an alternative higher cost source (Figure 5).

[46]"Assessing the Value of Groundwater," UK Environment Agency, Science Report—SC040016/SR1, http://www2.aueb.gr/users/koundouri/resees/uploads/Econ%20Val%20GW.pdf.

[47]Charles Porter and Ed McCarthy, "Valuation of Water Rights," 2016 Texas Water Law Institute, https://utcle.org/practice-areas/index/practice_area_id/26.

Consider the following simplified hypothetical example:

Burdened City supplies its residents from a well whose water costs $100 per acre-foot to pump to the surface, $200 per acre-foot to treat, and $300 per acre-foot to distribute. Despite Burdened City having access to a relatively shallow aquifer, Acme Water Conservation District amends its ruleset to require all large-scale groundwater pumpers to reduce withdrawals by 50% and instead purchase water from an alternative supply source (the High Cost Water Authority) costing $1,000 per acre-foot.

Taking High Cost Water's price of $1,000 per acre-foot and subtracting the likely cost of self-sourced groundwater of $600 per acre-foot [$100 per acre-foot lifting cost + $200 per acre-foot treatment cost + $300 per acre-foot distribution cost] leaves a difference of $400 per acre-foot.

Under serious budgetary pressure from the cost of paying over 60% more for its water, Burdened City searches for alternative options. It decides to tap a deeper aquifer layer exempted from the groundwater pumping restrictions, whose rights are owned by Farmer Joe. The Farmer hasn't used the deeper water to date because it costs too much to pump for agricultural use. But the City has run its numbers and realizes that it can deepen its wells and use its existing infrastructure to produce, treat, and distribute Farmer Joe's water to municipal customers at the final cost of $600 per acre-foot described above.

So how much would the City potentially be willing to pay Farmer Joe for his water? The likely solution is up to $400 per acre-foot. Any amount between that figure and zero would represent a net economic gain for the City, as it would allow it to avoid the existing cost it must bear for supplies from High Cost Water Authority.

Avoided cost valuation will likely prove especially important to medium-sized and smaller cities as well as farmers and industrial water users. Such parties generally cannot take on

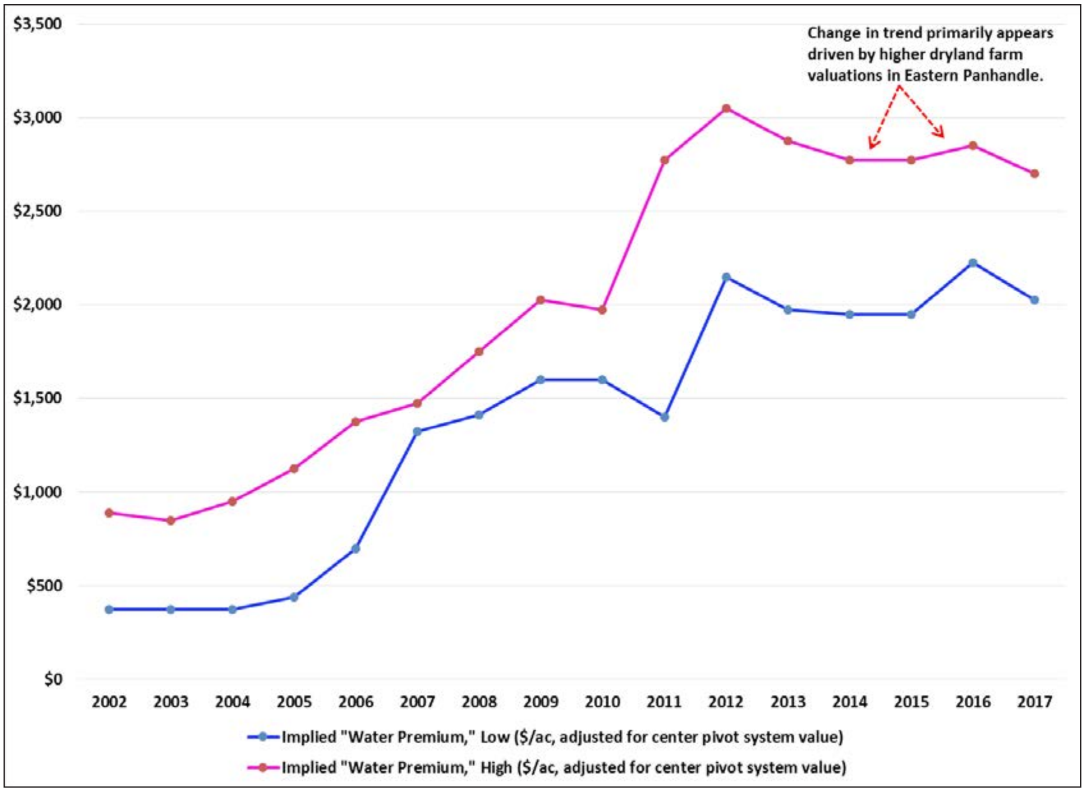

Figure 6. Implied water value in North Texas Panhandle based on land value method, $/acre. Source: ASFMRA, author's analysis.

the hefty financial risk of multibillion-dollar water supply projects like the Vista Ridge pipeline. Accordingly, they will likely seek to augment their water resources by acquiring groundwater-bearing tracts near their existing wellfields and pipelines, using a strategy of incremental expansion. This in turn is likely to drive ongoing market activity in the form of such cities/governmental entities and certain large private consumers leasing or purchasing entire land tracts or, at the very least, the groundwater estate beneath them.

Method 3: The land value method

The land value method is an inductive approach, which derives water values by comparing transactions of irrigated and non-irrigated farmland. For instance, if dry cropland in an area sells for $1,000 per acre and irrigated cropland in the same zone sells for $2,000 per acre, this would suggest that the water associated with the land is worth $1,000 per surface acre. The method is simple and provides a "starting-point" value for a broader assessment. Yet with proper adjustments for the capital costs of accessing and using the water (center pivot sprinklers, for instance), useful basic valuations can be rapidly obtained and used as reference points.

Data from the annual Texas Rural Land Value Trends report offer insights into the implied value of water per acre of farmland sold. The instant analysis focuses on the Northern Texas Panhandle. This region, consisting of Carson, Dallam, Gray, Hansford, Hartley, Hemphill, Hutchinson, Lipscomb, Moore, Ochiltree, Oldham, Potter, Roberts, and Sherman counties, is one of the most intensively farmed in Texas *and* relies almost exclusively on groundwater for irrigation. As such, the difference in value per acre between dryland and irrigated farm tracts offers a relatively "pure" indicator of how much value the water renders to the land. The land value method's utility in a farming-centric area such as Northwest Texas is reinforced by the fact that buyers and sellers of land in the area are typically sophisticated parties who understand the land's potential to yield income through agricultural production and how water is an integral component of that process.

To calculate the value of water on Northern Panhandle farmland, this author employs a three-step process. First, take the reported value range of "irrigated cropland good water," which in 2016 was $3,000–$4,000 per acre, based on reported transactions that year. Second, subtract the value of dry cropland in the eastern portion of the northern Panhandle ($750–$1,200 per acre) from the value of the irrigated land. This yields a difference of $2,250 per acre [$3,000–$750] on the low end and $2,800 per acre [$4,000–$1,200 per acre] on the high end. Third, these numbers should then be adjusted for the value per acre of center pivot sprinkler systems, which are the primary mode of irrigation in the northern Texas Panhandle.

Data from Texas A&M University suggest a cost range of $325–$375 per acre for a quarter-mile center pivot capable of watering 120 acres and $200–$250 per acre for a half-mile center pivot system capable of watering a 500-acre area, not including the costs of drilling water wells and installing pump equipment.[48] Since farm tracts vary in size but tend to be larger than 500 acres in the area of interest, this analysis assumes a cost of $225 per acre for center pivot systems, which we apply as an "adjustment factor." That step yields final implied water values in 2017 of $2,025 per acre on the low end [$2,250–$225] and $2,700 per acre on the high end [$2,925–$225] (Figure 6).

To "cross-check" the theoretical valuation outlined above, the author compares it to the price Amarillo paid for the Mc Cattle Company's groundwater estate in southern Roberts and northern Ochiltree counties, which, like the farmland discussed above, is located in the Northern Panhandle.

Under eight sample tracts of farmland listed for sale in the Northern Texas Panhandle as of late October 2017, the average thickness of the High Plains Aquifer averaged between 450 to 710 feet, depending on the tract. Amarillo paid $1.16 per saturated foot in 2015 for the thickest portions of the Mc Cattle groundwater estate. If we assume that there are 500 feet of saturated layer under a farm whose adjusted water value is $2,500 per acre using the land value method, this would suggest a value for water in-place of $5.00 per saturated foot.

The improvements made to land for farming can increase the surface tract's value and implicitly reduce the "groundwater premium" but even those adjustments would still likely leave groundwater estate values more than twice as high as those paid by Amarillo in its 2015 purchase. One possible explanation for the disparity is that a farm typically pumps and consumes water close to the wellhead, while supplying water from a distant asset—Mc Cattle's tracts are located roughly 90 miles from Amarillo—requires expensive infrastructure whose cost must also be borne by the end users of that water. The fact that a final delivered water price includes all costs necessary to pay back capital investments and cover operating expenses—from pumping, to treatment, to delivery—potentially limits the actual price that can be paid for the groundwater itself, lest the final delivered water become unaffordable for customers.

Method 4: Income capitalization

The income capitalization method is most appropriate for valuing groundwater in contexts where money is invested in a water-focused asset to generate cash flow. This happens when direct sales of water are occurring or where the water is a critical input to a broader industrial or agricultural process that generates cash flow *and* water's contribution to the final value of the product can be clearly attributed. As a general proposition, income capitalization should be employed as a valuation technique "only when actual income from the property can be established in a continuing on-going business." [49]

The income capitalization method fundamentally hinges on the perceived risk of an investment, as this is a key determinant of the discount rate applied to an income stream.[50] Water sales transactions often involve significant risks that can arise from timing, climate factors, and, perhaps most of all, legal, political, and regulatory barriers that prevent an owner from monetizing groundwater resources. Returns-focused investors generally want to pay back the original capital as quickly as possible and then begin garnering returns on the original capital employed. This reality has two immediate implications for prospective Texas water investments and the valuation of the underlying water.

First, as McCarthy and Porter point out, municipal and industrial water sourcing agreements generally specify prices, minimum offtake volumes, and a multi-year (often decades long) timetable over which the deal plays out. Each of these factors, generally speaking, "de-risks" a transaction and suggests capitalization rates should be lower than those that an appraiser would apply to more speculative water transactions. Second, oilfield water supply deals, which bear a high degree of risk from commodity price volatility and which are generally spot market or short-term deal structures without take-or-pay conditions, will usually entail much higher capitalization rates.

A capitalization rate of between 20% and 30% represents the level of returns that would likely be needed to entice capital into an oilfield water supply deal without long-term minimum volume commitments, as well as to offset the opportunity costs of putting capital to work in competing investments in real estate, oil and gas, and other sectors. Valuation estimates for municipal supply projects could likely be defensibly capitalized at lower rates.

Consider the Table 2 example, which compares the capitalized value of water used in the Trans-Pecos region of Texas as an intermediate input for growing alfalfa and as hydraulic fractur-

[48]"Center Pivot Irrigation," Texas Agricultural Extension Service," B-6096 4-00, http://aglifesciences.tamu.edu/baen/wp-content/uploads/sites/24/2017/01/B-6096-Center-Pivot-Irrigation.pdf.

[49]Foster v. United States, 2 Cl. Ct. 426, 448 (1983); The Texas Property Code further notes that when a governmental entity condemns land that includes groundwater rights and the rights may be developed or used for a public purpose, the resulting condemnation proceeding should use methodologies prescribed in Chapter 23 of the Texas Tax Code, which includes income capitalization Tex. Prop. Code Ann. § 21.0421 (West)(b); Tex. Tax Code Ann. § 23.012 (West).

[50]A broadly accepted "risk-free rate" is the annual interest rate paid on 10-year United States Treasury notes (commonly known as "T-Bills"). Investors generally seek to put their capital to work in exchange for returns that would be a multiple of the risk-free rate.

Table 2. Sample valuations of water using the income capitalization method.

	Alfalfa farm	Alfalfa farm, high	Municipal water sales	Intermittent frac water sales	Contract frac water sales
Acreage	640	640	N/A	N/A	N/A
Commodity Units Sold	6.8	6.8	15,000	1,500,000	9,000,000
	Tonnes	*Tonnes*	*Acre-Feet*	*Barrels*	*Barrels*
Unit Price	$196	$245	$500	$0.50	$0.50
	Per Tonne	*Per Tonne*	*Per Acre-Foot*	*Per Barrel*	*Per Barrel*
Gross Income	$854,400	$1,068,000	$7,500,000	$750,000	$4,500,000
Total Costs	$644,480	$644,480	$1,500,000	$60,000	$360,000
Net Income	$209,920	$423,520	$6,000,000	$690,000	$4,140,000
Capitalization Rate	16%	16%	10%	30%	15%
Implied Payback Time of Investment, Years	6.3	6.3	10.0	3.3	6.7
Capitalized Income	$1,312,000	$2,647,000	$60,000,000	$2,300,000	$27,600,000
Water Used Annually, acre-foot	1,626	2,033	15,000	193	1,160
Indicated value of groundwater used / sold, ($ / acre-foot)	**$807**	**$1,302**	**$4,000**	**$11,896**	**$23,791**
High leverage to commodity price changes	**A price increase of only 25% boosts the indicated value of the groundwater used by 160%.**			Significant, but lesser leverage to changes in Capitalization Rate	**A 50% reduction in the capitalization rate doubles the indicated value of groundwater sold.**

Source: Harry F. Blaney and Eldon G. Hanson, "Consumptive Use and Water Requirements in New Mexico," Technical Report 32, New Mexico State Engineer, Pg.19; "Period of Record Monthly Climate Summary: Pecos, TX," Western Regional Climate Center, http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?tx6892; Yonts et.al, "Water Loss from Above-Canopy and In-Canopy Sprinklers," University of Nebraska Extension, http://extensionpublications.unl.edu/assets/html/g1328/build/g1328.htm; Laurialt et.al, "The 2015 New Mexico Alfalfa Variety Test Report," New Mexico State University, http://aces.nmsu.edu/pubs/variety_trials/AVT15.pdf; Texas District 6 Alfalfa Crop Budget, 2017, TAMU Extension, https://agecoext.tamu.edu/resources/crop-livestock-budgets/budgets-by-extension-district/district-6-far-west/2017-district-6-texas-crop-and-livestock-budgets/, Texas District 6 Center Pivot Cotton Crop Budget, 2017, TAMU Extension, https://agecoext.tamu.edu/files/2017/02/2017D6TPCottonPivot.pdf; Author's Interview of Permian Basin-focused oilfield water investors, October 2017.

ing fluid. Two things quickly become apparent. First, changing the underlying commodity price massively shifts indicated water value when using the income capitalization method. Alfalfa that costs $196 per ton under normal conditions implies a water value of $807 per acre-foot. If we assume that alfalfa prices and water use each rise 25% due to drought, the indicated value of the groundwater used rises by 160%, leverage of more than six-fold. Second, changing the capitalization rate (i.e. the risk profile of an asset) also exerts substantial, although much less dramatic impacts on underlying water values.

To further test the data in Table 2, we analyzed a sales listing from an irrigated corn farm in Sunray, Texas, located approximately 50 miles north/northeast of Amarillo. The 480-acre center pivot-irrigated farm was listed as of early November 2017 on Lands of Texas for $1,488,000.[51] U.S. Department of Agriculture National Agricultural Statistics Service census data from 2013 indicate that statewide, Texas corn producers using pressure irrigation enjoyed a yield of 202 bushels per acre (~5 metric tons per acre). Crop budget data for the North Panhandle from Texas A&M suggest that growers in that area—where the Sunray farm is located—could potentially reap closer to 225 bushels per acre.[52] At a realized price of $3.80 per bushel, the farm could thus produce $855 per acre in revenue. Using data from the same crop budget, corn grown on land owned by the farmer would incur costs of approximately $748.56 per acre, yielding a net income of $106.44 per acre and $51,091.20 for the entire farm [$106.44 per acre X 480 acres]. At a capitalization rate of 16%, the capitalized net income would be $319,320.

So how does this translate into a value for water? Data from the TWDB show that between 1999 and 2007, farmers in the North Plains region applied an average of 14.44 inches of irrigation water to their crops per year—roughly 1.2 feet.[53] A farm like Sunray would thus likely require about 576 acre-feet of water per year to maintain its corn production, suggesting the water has an indicated value of approximately $554 per acre-foot [$319,320 of capitalized income ÷ 576 acre-feet of water]. Using a corn price of $5 per bushel would drive the implied water value up to nearly $1,961 per acre-foot; a 2.5-fold increase in implied water value driven by an increase of only 32% in the value of the underlying commodity being produced with the water.

It is interesting to consider how water valuations reached via the income capitalization method compare to alternative business valuations using multiples of cash flow or earnings. For instance, the hypothetical intermittent fracturing sales business shown in Table 2 has a capitalized income value of $2.3 million when valued with a 30% capitalization rate (indicating a volatile, high-risk business). Oilfield water investors the author has spoken with generally examine cash flow when evaluating such an asset. In doing so, they would typically use a rule of thumb that a water sales business is worth two to three times earnings before interest, taxes, depreciation, and amortization (EBITDA).[54] With annual net income of $690,000 in the example below, plus fixtures (wells, catchment pit, etc.) that are likely worth at least $500,000, this would suggest a business valuation of $1.9 million [$690,000 EBITDA X 2 + $500,000 in fixtures] on the lower end and $2.6 million on the upper end [$690,00 EBITDA X 3 + $500,000 in fixtures]. The capitalized income value suggested by the simple model above falls almost squarely in the middle of that range, which indicates it can be valid as a "quick-and-dirty" method for assessing possible values of a water-centric business.

Method 5: Residual Value

The concept of calculating a residual value (or "shadow price") for water is rooted in the idea that a profit-maximizing enterprise will only use water to the point at which the net revenue generated by using that additional unit of water is equal to the marginal cost of obtaining it.[55] Residual value analysis is appropriate for valuing water for agricultural or industrial use if comparable transaction data cannot be found or if water is an input that is not explicitly priced. Many of these circumstances would involve parties with their own water supply infrastructure, in which case "cost of substitute" valuation methods could also be used.

Crop budget residual valuation has been utilized to assess the value of water in multiple locations globally, including the High Plains region of the United States along with Spain, and Namibia.[56] At its core, this technique takes the total value of output from growing a specific crop or conducting a specif-

[51] https://www.landsoftexas.com/property/480-acres-in-Sherman-County-Texas/3440331.

[52] District 1 Crop Budget for Bt corn, sprinkler irrigated, Texas A&M AgriLife Extension, 2018, https://agecoext.tamu.edu/resources/crop-livestock-budgets/budgets-by-extension-district/district-1-panhandle/2018-district-1-texas-crop-and-livestock-budgets/.

[53] http://www.twdb.texas.gov/publications/reports/numbered_reports/doc/R378_IrrigationMetering.pdf.

[54] Broadly similar businesses such as manufacturing or construction firms might be evaluated using a multiple of 3-4 times "seller's discretionary earnings," a measure analogous to cash flow, as commonly defined. Barbara Taylor, "Determining Your Company's Value: Multiples and Rules of Thumb," The New York Times, 15 July 2010, https://boss.blogs.nytimes.com/2010/07/15/determining-your-companys-value-multiples-and-rules-of-thumb/.

[55] Mesa-Jurado, M.A. et. al., Irrigation Water Value Scenarios for 2015: Application to Guadalquivir River," Paper prepared for presentation at the 107th EAAE Seminar "Modelling of Agricultural and Rural Development Policies". Seville, Spain, January 29th -February 1st, 2008, https://ageconsearch.umn.edu/bitstream/6450/2/pp08me20.pdf.

[56] Concept drawn from Jadwiga R. Ziolkowska, "Shadow price of water for irrigation—A case of the High Plains", In Agricultural Water Management, Volume 153, 2015, Pages 20-31, ISSN 0378-3774, https://doi.org/10.1016/j.agwat.2015.01.024. See also: J. Berbel, M.A. Mesa-Jurado, J.M. Piston, "Value of irrigation water in Guadalquivir Basin (Spain) by residual value method," Water Resour. Manage., 25 (6) (2011), pp. 1565-1579 and "Case studies of water valuation in Namibia's commercial farming areas, G.M. Lange, R. Hassam (Eds.), The Economics of Water Management in Southern Africa: An Environmental Accounting Approach, Edward Elgar Publishing, Chelthenham (2006), pp. 237-255, and finally, James Macgregor, et.al., "Estimating the Economic Value of Water in Namibia," paper prepared for 1st WARFSA/Waternet Symposium: Sustainable Use of Water Resources; Maputo; 1-2 November 2000.

ic industrial activity under a specified set of conditions and subtracts the operational costs incurred under those conditions. Expenses include seed, fertilizer, labor, fuel, equipment depreciation, and importantly, the capital and operating costs associated with providing necessary irrigation water to the crop. Including the costs of accessing groundwater is essential because it helps bring the analysis closer to what the water could potentially be worth while still in the ground.

The sum left over is then divided by the volume of water needed to grow the crop under the specified conditions, and the quotient shows the theoretical maximum amount a farmer could pay for the water and still break even.

Consider the following simple hypothetical:

Residual Value Simplified Example

Revenue From Hay Cultivation 50 acres X 10 tons per acre X $100 per ton = $50,000

Costs of Hay Cultivation 50 acres X $500 per acre = $25,000

Net Revenue = $25,000

Water Needed = 100 acre-feet

Net Revenue/Water Needed= Residual water value of $250 per acre-foot

Method 6: Net present value valuation

Net present value (NPV) analysis entails examining the amount of money an investment is expected to make and discounting it based on anticipated risks in order to translate expected investment returns into "today's dollars."[57] As such, NPV analysis offers some advantages to those seeking to value groundwater assets in a place such as Texas, where groundwater is owned as real private property. NPV analysis can help translate specific activities into the common language of financial value anchored along a timeline and providing transparent assumptions of the risks used to determine the requisite discount factors. This makes it a tool for conducting "apples-to-apples" value comparisons between disparate uses of the surface that might affect access to groundwater beneath.

For instance, a 1,000-acre tract of land in the Midland or Pecos area could have valuable groundwater underneath but might also be the subject of competition between various business interests. An oilfield water sales company might want to purchase the surface as a means to access the water beneath, leading it to seek a farmland-level price for the land to minimize the relative price it is paying for the underlying water, so as to maximize its returns on that natural capital asset. In contrast, a pipeline operator seeking to build a tank farm might be willing to pay a surface price far in excess of the implied "farmland value." This is because the pipeline company would be investing many tens of millions of dollars to install infrastructure intended to yield cash flow for decades and would presumably not seek to make a primary business of extracting and selling groundwater from under its tract.

Under this type of circumstance, using a "land value method" valuation approach like that employed in the Layne Christiansen example above could yield a highly distorted view of groundwater value. A bulk water seller might be willing to pay $2,500 per surface acre for the entire tract, but the pipeline operator might be willing to pay five or more times that much for subdivided portions of the tract. NPV analysis can potentially help bridge the valuation gaps by quantifying the economic returns each party expects relative to its anticipated investment outlay for the land.

Similarly, NPV analysis is also useful in environmental and water security contexts because it can provide insights into competing water users' willingness to accept payment to *forego* water use.[58] Such foregone use could take the form of spot market sales, longer-term supply agreements whereby a lower value user (like a cotton farm) fallows fields to supply water to a higher paying user (like oilfield frac'ers), and/or investment in technology that creates a more durable surplus of water available for alternative, higher-value uses. NPV analysis can potentially help backstop insights provided by sporadic local market transactions and potentially guide water owners in making more nuanced long-term allocation and investment decisions.

NPV analysis also has downsides. First, the calculation's mathematical structure is enormously sensitive to input assumptions. Commodity prices matter. For instance, a fracturing water project with an $18 million initial project investment that sells 100 thousand barrels per day (kbd) of water at an average water sales price of $0.35 per barrel (bbl) yields a net present value of approximately $70 per acre-foot of water, assuming a 15-year project life. Changing the water price to $0.40/bbl lifts the 15-year NPV to $121 per acre-foot. In other words, a 14% increase in the water sales price yielded a roughly 70% increase in the underlying groundwater resource's implied value.

Discount rate assumptions also matter. The discount rate for a water project typically consists of a baseline risk-free rate (typically the 10-Year T-Bill rate) and then a discretionary discount factor applied on top of that. In determining this rate, the borrower's company-level situation matters (how good of a credit is it in lenders' eyes?) and the global commodity price situation will also greatly influence the discount rate. Herein

[57]Amy Gallo, "A Refresher on Net Present Value," Harvard Business Review, 19 November 2014, https://hbr.org/2014/11/a-refresher-on-net-present-value.

[58]Qureshi, M. E., Ranjan, R. and Qureshi, S. E. (2010), An empirical assessment of the value of irrigation water: the case study of Murrumbidgee catchment*. Australian Journal of Agricultural and Resource Economics, 54: 99–118. doi:10.1111/j.1467-8489.2009.00476.x.

problems arise because a 10-year time horizon in the oil and gas or farming sectors exposes projects to potentially huge commodity price risks whose timing is very difficult to predict. Furthermore, there are currently no direct hedges a pure-play water seller can use to mitigate its exposure to oil and gas price fluctuations, particularly since energy producers in the Permian Basin generally avoid signing firmly binding take-or-pay contracts for water supplies.

The current NPV approach of making essentially straight-line risk projections will likely need to give way to methodologies that incorporate more probabilistic assessments and better reflect the complex realities of risk in the modern global economy. As two experienced risk assessment practitioners put it in late 2016: "*Valuation methods—not only for infrastructure projects but in general—should start by accepting that cash flows are uncertain and treat them accordingly. That is, relying on a branch of mathematics (probability and statistics) that knows how to deal with uncertainty*."[59] The same reasoning applies to water-oriented investment projects.

Method 7: Conservation Value

In certain instances, water may also have a "conservation value," in essence, an existence or preservation value. Since groundwater is owned as real private property in Texas, a regulatory regime aiming to preserve groundwater in place should compensate property owners for idling their natural capital assets. For surface lands, conservation easement values in Texas often range between 35% and 65% of the tract's market value.[60] Such a range could help anchor the determination of what property owners should be paid for groundwater assets that they forego developing for a certain time period.

CONCLUSION

Groundwater valuation is—and will remain—an exercise requiring analysts to make judgment calls for each specific asset and aquifer location being evaluated. But this is true of markets for many illiquid assets whose combined transaction volume is in the hundreds of billions of dollars per year globally, including other forms of real property such as residential and commercial properties as well as athletic talent, energy commodities, and intangible assets such as financial derivatives.

As long as those appraising water values provide a clear and transparent accounting of their assumptions and analytical inputs, defensible values are eminently achievable. Actionable valuations for water assets can unlock many billions of dollars in currently constrained economic potential, including reserve-backed lending, more sales and leases of water reserves in-situ, and potentially, enabling equity markets to price in the potentially significant water holdings of multiple publicly traded companies with substantial land footprints in Texas.

This analysis is akin to a "beta version software." It seeks to lay the foundation for more groundwater property holders to systematically value their assets, scrutinize the methodologies presented here, and, ideally, find ways to improve upon them. As the process of iterative improvement proceeds, the groundwater value data points developed can guide the creation of economic opportunities and the resolution of disputes alike. The author also hopes that more groundwater valuation data can be made publicly available. The TWDB already does an admirable job of making a substantial—and growing—repository of geospatial and hydrogeological data available to the public. Augmenting this dataset with greater disclosure of groundwater transaction prices and valuations can help property owners, policy-makers, and the voting public more effectively collaborate and craft policy approaches to protect private property and optimally manage our great state's groundwater resource base.

[59]Arturo Cifuentes and David Espinoza, "Infrastructure investing and the peril of discounted cash flow," The Financial Times, 2 November 2016, https://www.ft.com/content/c9257c6c-a0db-11e6-891e-abe238dee8e2.

[60]"FAQ Page: What amount can I expect to receive from a conservation easement?," Texas Agricultural Land Trust," http://www.txaglandtrust.org/faq-page/.