WATER AUCTIONS: DESIGN, IMPLEMENTATION, AND EVALUATION

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INTRODUCTION

This guidebook was developed to assist those seeking improved ways to acquire water for specific needs, such as a tribal water settlement, an endangered species instream flow program or to firm up urban drought supplies. Potential users include tribal, state, and federal agencies, cities, irrigation districts, non-profit organizations, and private firms needing to design and implement water acquisition programs. Water auctions can be a valuable tool when water is available to move from its current type of use (and users) to new locations and types of use. The role, potential advantages and disadvantages, implementation and evaluation of water auctions are discussed in depth in this publication.

This guidebook begins with a brief discussion of the role of auctions in regional water management, advantages and disadvantages of auction mechanisms and an overview of steps needed to create an effective water auction, as well as a concise menu of decision and evaluation criteria. Later this publication examines implementation factors, and the potential shortcomings of differing auction designs. Water auctions have been used for centuries, yet each auction program

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has a unique context and purpose, and auction design needs to reflect the underlying goals of the water acquisition program.

Why Consider Water Auctions?

Impetus for water to shift across types of uses and locations arises from climatic, economic, and policy changes that affect water availability and water demand. Such changes include drying of regional streams and soils, policies that dedicate water to improve habitat or water quality, and from a changing mix of water using enterprises in regional economies. Flexibility in water use over time is an important component of adapting to change.

Modern governments have formal procedures for evaluating and permitting proposed changes in water use. These procedures vary, but can be complex in recognition of economic, environmental, and cultural spillover effects (externalities) that may accompany changes in how, where, when, and by whom water is being used. Governing regulations may constrain movement of water across jurisdictional boundaries or transfers away from specific types of use. Engineering and hydrologic studies may be required to assess effects of a proposed transfer on surface water flows and recharge to groundwater, given potential effects on other water users and water-dependent habitat. Financial costs of acquiring water and obtaining approval to change its use may overwhelm benefits to those initially interested in trading water (Hartwell 2007; Lachman 2016; Garrick 2008).

This guidebook focuses on the water auction process itself, with auctions representing just one piece of a larger process of transferring water. Readers with a stake in water transfers are encouraged to educate themselves thoroughly on current legal, political, and economic considerations for moving water from one place or type of use to another in their region. It is essential to search out the perspectives of experts in law, engineering, hydrology, regulatory compliance, and political negotiations for your region. Water transfers across uses and locations not only can affect personal finances and business prospects, but also affect regional economies, environmental quality, and community well-being.

Development of a water auction can be valuable at a specific stage in the process of facilitating change in water use. Identifying specific water entitlements that can be moved to new locations and types of use is essential, and often complex, work that must be completed prior to offering water through an auction. An auction can be used to determine which interested parties receive what quantities of available water and how much they pay for it. In situations where there are multiple parties wanting to sell or lease water to a single acquirer, auctions also can be used to identify the successful sellers and the prices they receive.

Potential Advantages and Disadvantages of Auctions

Water auctions offer a custom-designed process for establishing water price and quantity and selecting successful bidders. Auctions may be preferable to party-by-party negotiations when they are perceived as fairer and more transparent than ad hoc negotiations. While designing and implementing a successful auction requires careful up-front planning, this upfront cost may be lower overall than costs of conducting and consummating multiple individual transactions. Once an auction process becomes established in a region, the auction design can be used over multiple occasions and become a familiar way of establishing prices and quantities.

A potential disadvantage of auctions includes lack of participation due to unfamiliarity and discomfort with the process. There also is potential for collusion among participants that affects prices and selection of successful bidders. The upfront costs for establishing an effective auction design may make an auction impractical for small amounts of moderately valuable water being transferred once. The greater the value of the water assets involved and more frequently an auction can be conducted in a region, the more likely the investment in designing an auction will be "worthwhile."

Water auctions have been used in various parts of the world for many centuries. For example, parts of Spain have used auctions to allocate river water to farmers for more than 700 years, from the thirteenth century on (Donna and Espín-Sánchez, 2018a&b). In modern times, auctions occur most commonly in the western U.S. and Australia, Chile. A listing of water auctions referred to in this report is provided at the end of this document.

INTRODUCING WATER STAKEHOLDERS TO AUCTION PROCESS

In regions for which water auctions are unfamiliar, careful consideration needs to be given to building trust in the credibility and fairness of the process. Providing upfront information is part of that consideration. Potential participants need to be approached in ways that build trust in the auction process. Other water stakeholders need to be considered as well, so that auction is accepted as a fair and legitimate way to determine who obtains water and how much they pay.

Building Trust in Auction Process

Participant trust is an important aspect of a successful water auction. Providing information to participants may be a means of acquiring that trust, as was concluded in the Yakima River water auction (Rux 2008). In that instance, there was virtually no participation (only one bid received) and no water obtained by the auctioneer. A focus group was conducted to determine why the auction failed. The most common response was that eligible participants did not bid because they did not trust the auction process, nor did they trust the auctioneer. It is unclear exactly what information could have been provided to the potential bidders to remedy the lack of trust in this instance. One addition that may have helped to increase trust is to let participants know the procedural workings of the auction and how winning bids and prices paid are identified. If participants believe that the auction procedures and goals fairly represent their concerns and interests, they are more likely to take part (Kendy 2018).

The Jicarilla Apache Nation in New Mexico represents the first western U.S. Native American Nation to implement a water auction (Colorado River Governance Initiative 2013). In 2011, the Nation auctioned off 6,000 acre-feet per annum (AFA), with auction design assistance provided by California Institute of Technology faculty (Oat and Paskus 2013). In order to build trust in the process and provide privacy, updates on bidding activity were released to participants but individual bidders remained anonymous (Oat and Paskus 2013). Due to uncertainty over how the process would work, only three private parties bid in the first auction and the average sale price was below what was viewed as a "true market value" at $75 per AFA (Becker 2012). Participants included the Bureau of Reclamation and Las Campinas, a suburban country club (Becker 2012). After completion of the first auction, the multiple winners had the option to extend the one-year leases they procured in the auction (Oat and Paskus 2013; Becker 2012). In September 2012, the Jicarilla Apache implemented a second auction for one-time delivery of water in 2013. A higher price of $82 per AFA was received for the 6,500 AFA auctioned, and the number of bidders increased (Becker 2012). The Nation's water settlement explicitly authorizes off-reservation leasing of tribal water and the Nation manages an active leasing program. The two auctions were temporary measures, in the context of the Nation's larger ongoing water leasing program.

Pincus (2008) proposes a mechanism where potential sellers submit a secret minimum acceptable price, and they only actually sell their water if their price is met. The goal is to reduce the risk of participating, as those offering to sell do not have to accept low prices. Similarly, Zetland (2013) proposes an "all-in-auction" where participation is mandatory, but because bids are ranked and chosen from lowest to highest, irrigators who do not want to lose any water can bid very high prices that will not be accepted. Other theories have proposed similar mandatory auctions that force participation but seek to keep trust by assuring no bidders will have to accept unreasonably low prices (Sibly 2008).

Providing Upfront Information to Potential Participants

Timing in transmitting information is important. Farmers need to plan participation based upon crop planting cycles (Jenkins 2007; Cummings 2003; Hartwell 2007; Lachman 2016). Robust participation is an intermediate goal of any auction, and the auction must be conducted to minimize uncertainties created by the auction by being scheduled early enough in the crop planting cycle so that the participants can plan farming operations and water leasing portfolios simultaneously.

Another important consideration is what kind of information to provide to prospective bidders (Hailu 2007; Lachman 2016). Information disclosure should be designed to build participant confidence in the process and maximize participation, and simultaneously minimize the likelihood that participants overstate their bids (Hartwell 2007; Cummings 2003; Garrick 2008). In sealed-bid auctions, information provided to the participants includes whether a reserve price[2] exists; if so, the level of the reserve price, and whether a budget cap (or procurement quota) exists and the level of the cap or quota. If an iterative approach is utilized, the participants may be notified between rounds which bids are provisionally accepted and/or the price for which bids are provisionally accepted (Cummings, 2003). Participants should be informed in advance of how tie breaking operates, to build perception of the auction as fair.

[2] In a water auction the reserve price is the maximum amount of money that the auctioneer (or buyers) is/are willing to spend per given volume of water. A list of definitions is included at the end of this guidebook.

Determining the optimal amount of information to provide is a balancing act. On the one hand, providing more information creates a sense of participant trust in the auction process leading to greater participation. On the other hand, more information may enhance ability to submit collusive bids (such as all submitting the same price).

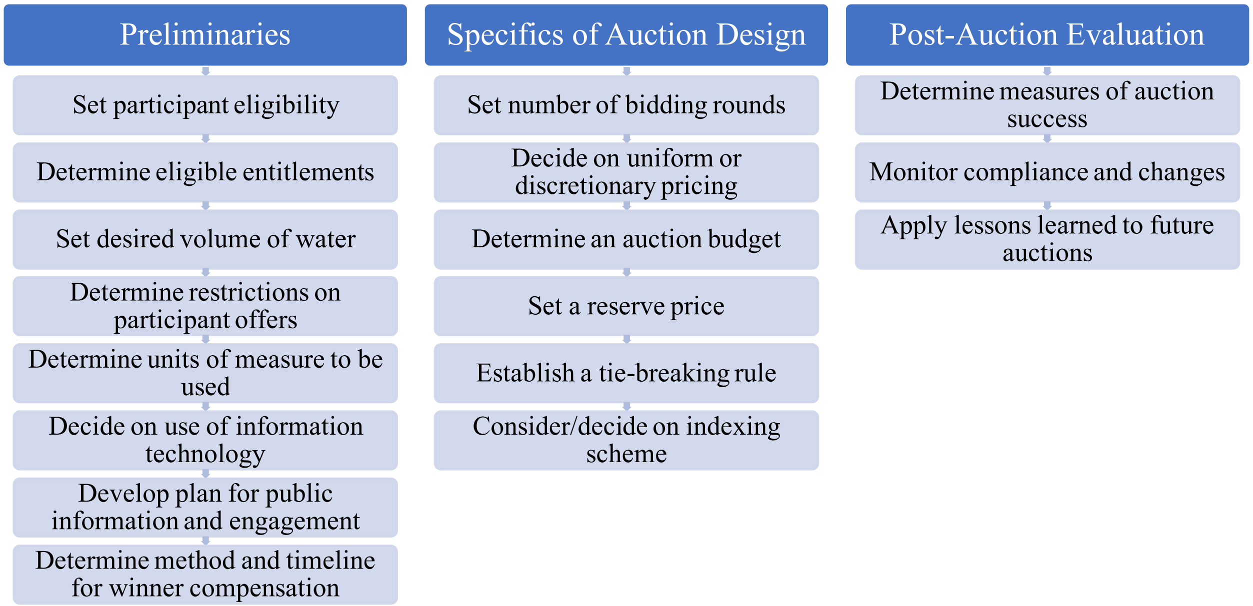
In the case of the Deschutes River auctions, the auctioneer instructed the participants that a reserve price existed, but they were not provided the amount of the reserve price (Hartwell 2007). In the subsequent year's auction, the participants were told that a new reserve price existed, and they were informed as to the level of the prior year's reserve price. Hartwell (2007) concluded that the participants acted strategically based upon this disclosure of information in the second year. Many of the submitted bids in the second year were near to the disclosed first year's reserve (Hartwell 2007).

In a rural Japanese collective-action setting, Takeda et al. (2015) analyze auctions for conservation contracts with farmers where some districts provided more information than others. When all participants were given full information, creating a sense of "procedural fairness" (meaning the auction information was disseminated in a universally fair manner), competition was higher, transaction costs were high, and farmers overall received lower prices. When only select community leaders were given information, this led to "distributive fairness" (meaning the distribution of prices was more uniform and did not create big winners or losers) and price coordination, resulting in better prices on average for farmers. The authors do not conclude that either method is better than another, but a balance should be sought. While in principle, both types of fairness could be achieved, realistically the costs of implementing an auction to achieve both types of fairness are very high.

WATER AUCTIONS: DESIGN CHOICES

This section provides a high level of detail related to auction design and implementation. Design choices are discussed roughly in the order in which they appear in auction process.
Water auctions can be of several different types and the design choices discussed apply to both procurement and conventional auctions. In a procurement auction, several bidders compete to sell a particular item to one purchaser (the organization seeking to acquire water) (Lachman 2016). The bidders are attempting to sell their item (or service) at the highest possible price. In a conventional auction, there is one seller, and the bidders are comprised of many potential buyers. The bidders are attempting to buy the item (or service) at the lowest possible cost. The building blocks of designing a water auction are described below and summarized in Figure 1.

Figure 1: Overview Water Auction Design, Implementation and Evaluation



Who Is Eligible to Participate?

First, it is important to determine who is eligible to participate in the auction. The auctioneer must determine whether geographical restrictions are necessary (Garrick 2008; Hartwell 2007; Lachman 2016). For instance, it may not be appropriate to allow out-of-state water entitlements[3] to be included in an auction. Further, it may also be advantageous to refine the geographic restrictions to those entitlements that can serve the goals of the particular auction, for example, if the entitlements are from within particular river basin(s) or regions. On the other hand, having a variety of participants is important, especially when groups like environmental NGOs are becoming an influential part of water transactions (Richter 2019).

What Types of Water Entitlements are Included?

Second, it is necessary to determine which entitlements, and what type of entitlements, will be included in the auction. For example, it may be advisable to only allow entitlement holders that actively use their water allotment and have a minimum entitlement amount to participate in an auction (Hartwell 2007). This requirement serves at least two purposes. First, if the entitlement holder is not actively utilizing her entitlement but the water is still auctioned, and potentially transferred out of the area, return flow patterns will be disrupted which may impact other downstream water entitlements and downstream ecosystems. The issue of common pool resources with unidirectional flow, like water in a stream, has been explored in laboratory experiments, though the solutions have yet to be analyzed fully in the real world (Holt 2012).[4] Second, by only

[3] For the purposes of this guidebook, the term “water entitlement” is a generic term referring to any type of legally recognized water entitlement; including water rights defined by state law, contractual rights to water from a federal project, etc.

[4] If the purpose of the auction is to acquire wet water, it may be necessary to ensure that the auction is restricted to the most senior or “drought proof” types of entitlements in a region and to entitlements which have been regularly exercised.

allowing volumes of water that are above a minimum threshold level, costs of administering the auction are contained.[5] Georgia's Flint River Basin procurement auctions provide an example of when restricting types of entitlements may have been counterproductive. In that case, allowing the sale of only surface water permits did not lead to desirable results, due to high hydrologic connectivity between surface and groundwater (Mullen 2019).

Quantities of Water Offered?

After a threshold quantity of water is set, auction rules need to specify how much of their entitlement bidders can offer for auction (Lachman 2016). In some auctions, participants are required to place their entire entitlement amount (or consumptive use volume) in the auction (Cummings 2003), while in other auctions participants are able to auction a portion of their entitlement amount (Hartwell 2007). An advantage of the full entitlement requirement is that it simplifies post-auction monitoring (Cummings 2003). This advantage is counterbalanced in cases for which auction participants own more than one entitlement and auctioning one (or more) entitlement would not greatly diminish their agricultural activities. If post-auction monitoring is not problematic, then allowing participants to auction portions of their entitlement may lead to preferable results.[6]

Water Accounting: Quantifying Water to be Transferred

A related consideration is whether auction volumes are based upon a permitted (or diversion) volume, or consumptive use amounts (Garrick 2007). This will hinge upon the type of entitlement being transferred. Idiosyncratic water entitlement issues need to be considered on a case-by-case basis. This is particularly important in states that practice the doctrine of beneficial use because while the entitlement holder has ownership over the volume that she beneficially uses, in many cases she may only transfer a volume of water that she consumptively uses (see for instance, Arizona Revised Statutes (A.R.S. 45-141(b)).[7,8] These policies are in place because downstream users benefit from return flow, portions of a diversion entitlement not consumed by upstream users, and can claim legal injury if the return flow volumes that they have come to expect and beneficially use are not available (A.R.S 45-141). It can be difficult and controversial to determine consumptive use volumes, and so it may be necessary to instead use a proxy in order to estimate the volume.[9] For

[5] If the auction is designed to occur in several subsequent years, it may be necessary to require rotation of eligible participants to broaden overall participation. In addition, it may be useful to rotate the specific tracts of land on which irrigation is being foregone in order to minimize possible environmental impacts from continuously fallowing the same fields (IID 2007).

[6] This is based mainly on the assumption that individuals will be more likely to participate in an auction if they can determine what portion of their entitlement (or consumptive volume) they are willing to auction, rather than being required to auction an entire entitlement amount. As a result, a larger volume of water at a lower price per unit may be obtained.

[7] Although the doctrine of beneficial use is a well know water law concept and codified in statute, it can become complex as implemented across various jurisdictions. For an interesting discussion, see Neuman 1998.

[8] For instance, Section 1725 of the California Water Code reads in part: "A permittee or licensee may temporarily change the point of diversion, place of use, or purpose of use due to a transfer or exchange of water or water rights if the transfer would only involve the amount of water that would have been consumptively used or stored by the permittee…"

[9] It may be necessary to consult local laws and consider precedent in other water transfers to determine how the consumptive volume is determined. This is for two main reasons. First, in order for a valid transfer to occur, both parties

example, Chapman (2018) uses high-resolution spatial data to create a water balance-based model for mean annual runoff. Innovative methods like these are making data-based decisions more possible for various water users and decision makers. Regardless of the method chosen, the auction procedures must be clear to all participants, and an up-to-date understanding of regional hydrology involved is key (Kendy 2018).

An additional consideration is specifying the units of volume use in conducting the auction. Hartwell (2007),Cummings (2003), and Hill (2011) provide examples of auctions conducted on the basis of price per acre of land removed from production.[10] However, auctions can be conducted on a basis of acre-foot (Lachman 2016; Alevy 2010)[11] or any other standard volumetric unit. In Spain, some auctions were conducted to auction off time periods to irrigate as that is the manner in which irrigation entitlements are specified (Isselhorst 2017; Donna and Espin-Sanchez, 2018a&b). The quantity measure adopted needs to be easy to calculate, well understood by participants and consistent with applicable law.

Online Auctions

Incorporating online technology into auction design is another important consideration. Online auction design can streamline many facets of the auction process including bid submission and data collection, and it facilitates communications between bidders and auctioneers. Cummings (2003) provides an early example of submitting bids online, allowing bids to be quickly compared. Hartwell (2007) explains how the Deschutes River Conservancy used old technology (fax machines and telephone calls to collect bids from participants who lacked internet access) and then posted bids online so that bidders had up to date information to revise and resubmit bids.[12] Bjornlund (2003) discusses early examples of how the internet was used in South Australian spot water markets. Rather than occurring once a year, however, the South Australian online auctions are conducted weekly. Oczkowski (2008) describes and analyzes Watermove, an online trading system implemented in 2002 to facilitate water trading in Australia's Greater Golburn trading zone, one of the most active in the country. The system is more accurately an example of a weekly "clearinghouse" auction and is only used for temporary water entitlements.

Australia has been a leader in online water trading, occurring there since 2002. Online water trading is practiced in Australia through multiple outlets, either through local government like the Victorian Water Register or brokers, exchanges, and clearinghouses like Waterfind and

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must agree, and be clear, on the volume to be transferred. Second, there are often state and federal laws that restrict the volume that may be transferred. If these laws are violated, the agreement may be invalidated.

[10] Conducting auctions in terms of acres of land removed from production may only be practicably employed when the duty of all of the participants' water rights are nearly the same per acre of irrigated land. For instance, in the Deschutes River auction, the duty of all of the participants' water rights was 4 acre feet of water per acre of land. This allowed the participants to submit a bid based upon the amount of acreage they wished to take out of production rather than being required to submit a bid based upon acre-feet. See, Hartwell 2007.

[11] An acre-foot of water is defined as a volume of water that would cover one acre to a depth of one foot. http://www.merriam-webster.com/dictionary/acre-foot.

[12] Because bidders may be able to more effectively collude or bid shade with multiple rounds, care must be taken when using this type of iterated approach. Nevertheless, despite the risks, this type of auction design can bring about desired results (Cummings 2003; Bjornlund 2003).

WaterExchange. The Water Exchange is the largest water trading mechanism in Australia, with trades are tracked through an online portal that matches buyer and sellers (Water Exchange n.d.).

Some water auctions have been impacted by the COVID-19 pandemic, adapting to continue operations online. The 8th Annual Wilks Water Auction in New South Wales moved to an online format for the first time in 2020 for health and safety reasons (Water Exchange, n.d.; Water Exchange Australia n.d.). This presented challenges for both the auction organizers and for participants unaccustomed to an online trading format. However, the 2020 auction was successful with forty-six registered bidders engaged competing for 23,400 megaliters (ML) (1 ML is equal to 0.81 AF) (Wilks Water n.d.). Both permanent and temporary rights were sold during the 10-day auction period.

In California, water managers are experimenting with online water trading for greater efficiency (The Nature Conservancy, 2020). One of the most prominent of these platforms in California is Waterfind, based on water trading systems that are used in Australia. Currently, this platform is seeing about 3,000 trades per year with 370,000 acre-feet in volume traded (Waterfind USA n.d.). WestWater Research has also created online platforms for agricultural users primarily. In 2020, in the Rosedale-Rio Bravo Water Storage District in Kern County, WestWater, along with the Environmental Defense Fund and Sitka Technology Group, set up an online system to give growers and farmers convenient ways to trade their water and to help meet the District's goals for the state's Sustainable Groundwater Management Act (Babbitt 2020). Despite successful uses of online technology in facilitating the auction process, web-based systems are not universally used. Potential participants may be discouraged from participation due to poor internet access and lack of experience with online technology (Hartwell 2007). Historically, water auctions took place in person at recognized locations in agricultural areas and served as community networking events. Many regions still prefer to utilize in-person auctions to conduct water transactions on a local scale (Alevy 2010).

Single or Multiple Rounds of Bidding?

Another important consideration is whether to conduct a single round auction or a multiple round (iterative) auction. In single round auctions, each bidder submits a single bid and bids are either accepted or rejected at the conclusion of one round. In an iterative auction, bids are collected and provisionally accepted or rejected. The bidders, even the bidders whose bids were provisionally accepted in the previous round, are then allowed to submit another round of bids and those new bids are again either provisionally accepted or rejected. This process continues for either a predetermined number of rounds, or until bidders are satisfied with the results and no longer wish to submit new bids (Cummings 2003; Lachman 2016).[13]

One benefit to single round auctions is simplicity for both auctioneer and participants (Hartwell 2007). However, the advantage of conducting an iterative auction is that in theory it will

[13] If an iterative approach is used, an important consideration is how much and what type of information to provide to the participants between rounds. This consideration is discussed infra.

maximize participation and minimize procurement costs. In Georgia's Flint River Basin auctions, the state experimented with both single and multiple round designs. The first auction had eight rounds, but the state ended up paying more (up to 50%) by the final rounds because collusion between farmer bidders allowed them to raise their bids. The second auction, among other changes, was a single round, and resulted in lower average prices believed to be closer to true farmer valuations (Lachman 2016). Recent articles on multiple round auctions can be found in Hill (2011) and Iftekhar (2013), and analysis of single round auctions in Alevy (2010) and Takeda (2015).

Payment Arrangements

At the conclusion of the auction, it is necessary to determine how and when winning bidders will be compensated. A simple method of compensation is to pay a lump sum amount to the winning bidders by a specified date.

Another, more complex, method is to pay the winning bidders in installments. For instance, in one water transaction, participants were paid in three installments: the first installment was paid within sixty days of entering into the agreement, the second installment was paid within six months of entering into the agreement but only after bidder compliance had been verified, and the third installment was paid once it had been determined that all of the provisions of the agreement had been met, and no later than sixty days from the contract termination date (IID 2004b). Various payment schedules and methods may be devised. These should be explicitly described in auction program information for potential participants. In the 2007 Prescott Valley water rights auction, largely considered one of the most successful of its kind, the town initially received few bids, until they gave bidders an option to make payments along with completion of successive requirements (Lachman 2016).

Revenue Equivalence in Auction Design?[14]

Economic theory indicates revenue equivalence among auction designs (Vickrey 1961; Milgrom 1989) However, when economists have tested these theoretical results experimentally in the context of a hypothetical water auction, revenue equivalence has not been achieved (Tisdell, 2004). In such experiments, uniform price auctions outperform discriminatory price auctions because bidders tend not to overstate their value for the resource as dramatically (Hailu, 2007).[15] Additionally, uniform price formats are found (experimentally) to promote more competition, result in higher revenue for sellers, and be more effective in water rights allocation (Zhang 2012).

Despite these experimental and theoretical findings, both the Deschutes River Conservancy in Oregon and the Environmental Protection Division in Georgia utilized a sealed bid multi-unit

[14] It is generally assumed in the theoretical literature on auctions that revenue equivalence exists across auction designs (Vickrey 1967; Milgrom 1989). Revenue equivalence implies that regardless of the specific auction design chosen, the dollar value of the winning bid is expected to be the same. However, to achieve revenue equivalence, several assumptions ust be satisfied. These are: independence of bidders' values, bidder risk neutrality, lack of bidder budget constraints and that all bidder values are drawn from the same distribution (Krishna 2002). These assumptions often are not satisfied in practice. Consequently, revenues likely do vary with auction design.

[15] In computer simulations of markets with little participation, discriminatory auctions lead to extreme overbidding, whereas uniform pricing produces relatively more consistent and predictable results (Hailu 2005).

procurement discriminatory auction to acquire water from appropriators. In both instances, the discriminatory method was chosen out of political concern; the water agencies believed that appropriators would be less likely to participate in an auction where every bid that was accepted was paid the same per unit amount rather than each bidder's own bid (Hartwell 2007; Cummings 2003). Discriminatory pricing has also been used in Canada (Hill 2011). Examples of uniform pricing for water and environmental auctions can be found in Japan (Takeda 2015) and in theory (Nemes 2016; Zetland 2013).

Criteria for Selecting Winning Bids

In addition to choosing price structure and number of bidding rounds, a decision rule must be specified to separate winners from losers. In a procurement auction, there are several ways to accomplish this. The first way is to set a cap on the price per unit that will be accepted (Hartwell 2007). This cap is referred to as the reserve price. Any bid that is below the reserve price is accepted and any bid above the reserve price is rejected. There are also methods that create a guaranteed minimum reserve price for the bidders which can increase the total number of participants, a desirable characteristic for efficient auction outcomes (Pincus 2008). A potential problem is that the auctioneer is required to accept all bids regardless of the volume of water required or the budget for the program. This happened in the 1991 California Drought Bank when the auction design obligated the State of California to purchase for more water than actually was needed for drought mitigation purposes (Howitt 1994; Israel and Lund 1995).

Alternatively, winners can be selected using is a fixed maximum budget (Hartwell 2007; Lachman 2016). Bids are ranked and accepted from lowest to highest until the budget cap is reached, or a maximum target amount of water may be fixed, and bids accepted from lowest to highest until the target is reached. In practice, both a reserve price and a budget cap can be used to minimize the per-unit cost paid for water (Hartwell 2007; Cummings 2003). Mullen (2019) and Lachman (2016) discuss the use of budget caps in Georgia Flint River Basin auctions, and Hill (2011) analyzes a reverse auction in Canada with a fixed budget. Using both a reserve price and a budget cap is generally preferable to using either method alone. This strategy minimizes the likelihood of overpayment per unit and also ensures that the overall budget is not exceeded.

Tie-Breaking Rules

It is important to consider the possibility of ties and specify the applicable rules (Cummings 2003). To motivate this concern, consider a situation in which reserve price is set and a budget cap is set. Suppose that there are two equal bids which are below the reserve price, but the acceptance of both bids would place the auctioneer above the budget cap. The auctioneer needs a rule that governs this situation. In the Georgia water auctions, in the event of a tie, the winners were randomly selected up until the point at which the budget cap is exceeded. Choosing the winner randomly reduces the likelihood that participants will view the tie-breaking process as unfair.

Tie breaking rules are important to choose the winners, and they also reduce the likelihood that the participants collude in an effort to subvert the auction. If the participants know that the tied winners will be chosen at random when the budget cap is exceeded the incentive to collude will be minimized and competitive bidding is more likely to occur (Cummings 2003).

Ranking Bids Based on Multiple Criteria

Another possibility is to rank bids based upon a predetermined indexing scheme (Lachman 2016). Bryan (2005) explains that the index may take one of several forms including: the Environmental Benefits Index (EBI), Habitat Hectares Approach (HHA), a risk analysis method, or some other variation. The United States Department of Agriculture (USDA) has used the EBI and enumerates criteria for ranking bids (Bryan 2005; USDA 1999). Under the EBI approach, an indexed value is calculated based upon six environmental factors and one cost factor.[16] Bids are then ranked and compared. Though there is a specific EBI outlined by the USDA, EBI has become a more general term that encompasses the use of any kind of indexing scheme to rank bids. Hill (2011) uses an EBI where wetland restoration and number of potential waterfowl nests are the main factors, and Nemes (2016), focusing on urban stormwater, bases an EBI off of runoff frequency, nitrogen load, and amount of potable water saved.

In an HHA, characteristics of existing vegetation are compared against benchmark communities of mature stands in their natural undisturbed state (Bryan 2005; USDA 1999). In particular, aspects of vegetation in an area are scored and summed and are multiplied by the area of the site in order to calculate a magnitude of actions (Bryan 2005; Oliver 2003).[17] An index then may be created, as was the case of Australia's Victorian Bush Tender trials, by multiplying the previously obtained score by a Biodiversity Significance Score. The Biodiversity Significance Score is a measure of the rarity of the ecological vegetation class. The result is then divided by the bid price to create a Biodiversity Benefits Index (Bryan 2005; USDA 1999).

Under a risk analysis framework, as was used in Australia's Catchment Care Auction, a numeric value is obtained by calculating the environmental value of an area and determining the potential threat to that area (Bryan 2005). The risk of each site is calculated as the threat score multiplied by the respective environmental value score and summed over all threats (Bryan 2005).[18] Sites with the greatest environmental value and subject to the most serious threats are at highest risk. Participants then submit bids that outline a proposed method for reducing their respective environmental threat scores as well as a price for undertaking the action (Bryan 2005). Bids can then be indexed by using the following formula: benefit to be obtained multiplied by environmental value divided by the cost of the bid (Bryan 2005). This allows for a direct comparison of the bids in

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[16] To calculate the EBI, the following formula is used: EBI=N1+N2+N3+N4+N5+N6-N7 where the N's are equal to (with the following maximum number of points available): N1 is the wildlife factor (100 points), N2 is the water quality factor (100 points), N3 is the erosion factor (100 points), N4 is the enduring benefits factor (50 points), N5 is air quality benefits from reduced erosion (50 points), N6 is state or national conservation areas (25 points), N7 is cost factor. For a complete breakdown of how the points are awarded within each sub-category, see USDA (1999).

[17] "…[v]egetation features assessed include physiognomy (e.g. presence of large trees, understorey), viability (i.e. presence of weeds, regeneration, litter, logs), and landscape context (e.g. area, shape, connectivity)." (Bryan 2005).

[18] "[The] environmental value of a site is derived from the site's Geomorphology, Hydrology and Remnant Vegetation characteristics. Sites may also be subject to specific threats. Threats are processes that degrade the biophysical environment including Bed Instability, Bank Instability, Dams and Offtakes, Patch Size, Invasive Weed Presence, Weed % Cover, and Grazing Pressure." (Bryan 2005).

terms of an environmental benefit/cost ratio. The auctioneer can choose the bids that maximize this ratio.

A simplified comparison approach was utilized in the Edwards Aquifer region of Texas. In that example, irrigators were asked to submit bids based upon acres of land they were willing to fallow (Colby and Pittenger 2006). Bids were evaluated based upon several criteria, including crop types, irrigation system, commitment to dry land farming[19], and the bid price per acre. The Edwards Aquifer Authority favored fallowing lower valued crops to minimize local impacts and revenue losses to irrigators. In this example, bids were compared but no strict method of indexing was developed.

Mullen (2019) proposes another type of indexing system, called the Flow-Impact Offer (FIO) to rank bids for buyback of groundwater pumping permits. It uses a hydrological model with variables like withdrawal location, connectivity of the area, and the duration and amount of pumping to create a groundwater flux-to-withdrawal ratio from which the FIO is calculated and used to rank bids. This metric was applied in simulation to Georgia's Flint River Basin auctions to reduce groundwater withdrawal, though similar hydrology-based systems could be used where the proper data is available. By now, it is better known how groundwater withdrawals effect flows (Flores 2020; Ruybal 2019), and similar methods for assessing the effects of groundwater pumping have also been developed (Huggins 2018), though they are often in the context of water management support in general, and may not be specific to the auction transaction types discussed here.

Although the above indexing methods apply mainly to auctions designed to improve environmental characteristics, they could be modified and used for other water auction purposes, such as supply reliability or reduced economic impacts from crop fallowing. In the case of supply reliability, bids could be indexed by reliability characteristics of water sources. In the case of concern over local economic impacts, bids could be indexed based on crops grown or projected job and revenue losses.

Political and socioeconomic factors have been used as variables for creating a comprehensive index. Lezzaik (2018) includes data on variables like country governance and food security in creating a groundwater risk index in the Middle East. Along with climatological and hydrological data, they create a unitless metric that can be compared across different places to rank groundwater risk. This ranking could possibly be applied to bids, giving more weight to places with high risk of groundwater vulnerability.

The purpose for using indices is to satisfy auction objectives while minimizing acquisition costs. While indices provide an opportunity to tailor an auction to specific objectives, the cost and difficulty of a complex indexing approach may be high. Specific criteria for the auction must be

[19] Clearly, this component of the index is only applicable to locations where non-irrigated farming is viable.

carefully designed and communicated in advance. This includes identifying goals to be achieved, as well as creating a scoring algorithm. Land and water characteristics must be surveyed, risks calculated, and an analysis of those results undertaken. The implementing organization must have adequate expertise to review water entitlements and conduct a quantitative assessment. Once the index is developed, all of the bids must be ranked from most cost-effective to least cost-effective.

Another drawback is that indexing processes may not be viewed as fair and impartial. Despite publicized algorithms being used to calculate scores, potential water sellers/lessors may not feel comfortable with this arrangement, and they may object to intrusion on their land for surveying and indexing processes.

OTHER EXAMPLES OF WATER AUCTIONS

This section provides additional examples of water auctions to supplement the other examples of water auctions discussed elsewhere in the paper. A list of all water auctions described in this report is provided at the end of the document.

Snoqualmie Valley, Washington, U.S.

A 2017 leasing auction in the Snoqualmie Valley of Washington offered irrigators the opportunity to bid for the right to draw water from the river for irrigation (Ladwig 2017). Hosted by the Snoqualmie Valley Watershed Improvement District (SVWID), this auction aimed to increase participation and engagement within the District. Sellers included water rights holders seeking to sell or lease their rights to a water bank managed by the SVWID, to then be sold to farmers wanting access to water for irrigation (Ladwig 2017). Before the auction began, the SVWID ensured that at least two sellers were willing to participate to provide the target water volume. Sealed bids were submitted the process of identifying a market clearing price consisted of matching locations, then matching bid and offer prices in descending order. The final market price of $125/AF was set as the midpoint between the lowest bid and offer matched (Ladwig 2017).

Limari River Basin, Chile

The informal nature of the developing water auction market in Chile means that detailed information is not always recorded or released to the public. Nevertheless, auction transactions are described as quite active (Alevy et al. 2010). The Chilean Water Code, approved in 1981 and later modified in 2005, grants water right holders the ability to trade (Alevy et al. 2010). Chilean water auctions are not heavily regulated and typically only require that transactions be reported to the appropriate water utility authority (Hadjigeorgalis 2009; Alevy et al. 2010). Most of the current auction activity occurs in the Limari River Basin in the Coquimbo region where both permanent and temporary trades occur (Hadjigeorgalis 2009).

Flint River Basin, Georgia, U.S.

The Flint River Drought Protection Act of 2001 authorized the State of Georgia to hold an auction during drought to pay farmers for reductions in irrigated agricultural acreage (Georgia Water Science Center 2016). This auction has been referenced several times previously in this report. The reductions in water use for irrigation occur during severe droughts declared by the Georgia Department of Natural Resources by March 1 each year based groundwater levels, streamflows, and precipitation (Haire 2001; Georgia Water Science Center 2016). Cutting back irrigated acres helps ensure adequate water flows within the Flint River Basin especially for municipal users (Haire, 2001). The announcement of a severe drought can trigger a voluntary water auction, as was the case in 2001 and 2002 (Georgia Water Science Center 2016). Funds for compensation totaled $10M and were provided by state tobacco settlement money (Hollis 2001). Only surface water irrigators were eligible to submit offers to fallow irrigated land. More stringent restrictions were imposed in the second year to ensure that compensation was paid only for acreage that had been irrigated in the previous three years and would have been irrigated again under normal circumstances (Mullen 2019; Hollis 2002).

The 2001 auction was composed of five rounds in which farmers could submit bids to receive payment to refrain from irrigating an acre of land. The Director of Environmental Protection Division (EPD) accepted or rejected offers based on the total cost of all bids presented (Mullen 2019). Farmers could resubmit bids if their previous ones were rejected (Mullen 2019). The average price for compensation was $135 per acre, with bids ranging from $75 per acre to $800 per acre. In total $4.5M was spent to temporarily remove 33,000 acres from irrigation (Mullen 2019). A bid cap of $150 per acre was implemented for the 2002 auction, with a new acceptance rule for any bid below this cap until the desired goal for acreage taken out of irrigation was reached (Mullen 2019). The 2002 auction was also restricted to a single round with bids varying from $74 per acre to $145 per acre. The average acre went for $128. The second auction removed more than 41,000 acres from irrigation, for payments totaling $5.3M (Mullen 2019).

Farm and Ranch Auctions, Colorado, U.S.

Sometimes water auctions occur as part of auctions of ranch or farmland. Water is transferred through an auction mechanism alongside other assets such as land and farm equipment. These types of Farm and Ranch auctions are prominent in Colorado, with a few recent examples. The family-owned Reynold Farm located near Mead, Colorado hosted an auction for their land and the attached water and ditch rights in 2016 (Worthington 2016). In total, 13 bidders, including the City of Broomfield and the County of Broomfield, spent $12.6M. Two hundred and seventy-six Colorado Big Thompson (C-BT) water units were sold at this auction, selling for $7.6M (an average of $27,357 per unit or $20,244 per AF[20]) (Worthington 2016). The sale of 15.75 Highland Ditch water shares went for an average of $148,000 each ($3,808 per AF[21]), totaling $2.3M (Worthington 2016). More recently, a farm and ranch auction in Loveland, Colorado set records prices in 2019. The total spent at auction was $15.5M with $13M spent on water (Hall and Hall 2019). 250 people attended the auction, 96 placed bids, and 21 became buyers. Of the 176 C-BT units sold, the most

[20] The Northern Water Board of Directors sets a percentage quota for C-BT units each year that dictates the amount of water delivered. A unit is 1/310,000 of the total 310,000 AF allocated to the project. The average quota for a C-BT unit is 74% meaning that one unit yields 0.74 AF (Northern Water n.d.).
Price per acre foot is calculated as: price per C-BT unit multiplied by average C-BT quota (0.74).
[21] The average annual delivery per Highland Ditch share is 38.87 AF (Little Thompson Water District 2019).
Price per acre foot = price per share/acre feet per share (38.87 AF)

expensive was $65,867 ($48,742 per AF) at closing while the average was $55,867 ($41,342 per AF) (Hall and Hall 2019). Highland Ditch shares were also auctioned off for an average of $268,667 ($6,912 per AF), with a high price of $304,000 ($7,821 per AF) (Hall and Hall 2019).

TYPES OF PROCUREMENT AUCTIONS

Procurement auctions focus on obtaining water from competing sellers and are of three different types: ascending auctions, descending bid auctions, and sealed bid auctions (Hartwell 2007; Lachman 2016). In an ascending auction, the price starts at a relatively low level and begins to rise. The winner is the participant that is the first to stop the rising price of the item. This ensures that the bidder who wishes to sell the item at the lowest possible price is victorious.[22] In contrast, in a descending bid auction, the bid price starts at a relatively high level and begins to fall. In this scheme, bidders compete to bid the price downwards until no participant wishes to challenge the preceding bid. The bidder with the lowest bid is the winner. In a sealed bid auction, the participants submit confidential bids, the bids are collected, and the auctioneer chooses the lowest bid.

Sealed bid auctions offer a further complication because the auction can be structured for winner to receive one of two prices (Hartwell, 2007). The first, and most obvious, price is the amount that the winner submitted in their winning bid. The second option is the winner receives the Vickrey price (Vickrey, 1961); the price that was submitted by the second-place bidder.

The use of the Vickrey price is reputed to induce more "truthful" bids by reducing bidders' incentive to misstate their value for the resource. A Vickrey auction is designed to minimize the possibility of bid shading by the participants.[23] Despite this reputed advantage, Vickrey auctions are rare in practice (Rothkopf 1990). There has been research using models and simulations that support use of a Vickrey (second-price) mechanism in water and other auctions, but real-world use is still limited (Chan 2003; Ausubel 2004; Hailu 2007; Hurley 2003). Among the reasons for its lack of practical use are the added complexity, chances of low or even zero revenues for sellers, vulnerability to collusion by a group of bidders, and the chance for single bidder to use multiple identities to take advantage of the second-place price format (Ausubel 2006).

Sealed Bid Multiple-Unit Procurement Water Auctions

The auction types above may be applied to a wide variety of auction designs. Modifications to these generic types can be made based on the goal of the auction. In the case of a water auction, a typical goal is to acquire the target volume of water at a minimum cost. With only one purchaser of water, bids are accepted from several prospective sellers/lessors. So, water auctions generally take the form of sealed-bid multiple-unit procurement auctions (Hartwell 2007).

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[22] Using the language of economics, this ensures that the participant that places the lowest value on the resource is selected and is able to sell the item at the lowest possible price.

[23] In a procurement auction, "bid shading" occurs when bidders (proposing to sell or lease water) submit bids that are higher than their own actual value for the water.

In a multi-unit auction, more than one unit of a resource is auctioned (Hartwell 2007; Rux 2008; Cummings 2003). In many water auctions, participants submit bids that contain different volumes of water and different prices per unit of water. The item that is proposed to be traded could also be acres of land a farmer agrees to fallow (Colby and Pittenger 2006), irrigation permits per acre (Mullen 2019), time for irrigation (Isselhorst 2018), or conservation contracts (Takeda 2015). The process is further complicated because water entitlements are not necessarily homogeneous in water quality, reliability during drought and other features (Lachman 2016). As a result, the auction must provide a means to bid for a heterogeneous resource.[24] This difficulty may be alleviated through two main practices: a) requiring that the water entitlements offered for auction be relatively homogenous,[25] and b) by using a sealed bid technique to conduct the auction.[26] Any other method/practice becomes unwieldy because of difficulties in comparing bids on a per unit basis.

The need to accommodate heterogeneity in characteristics of water entitlements should not be confused with the need for a diverse range of values (heterogeneity in valuation) among auction participants. For a trading program to be workable, there must be a range of higher and lower willingness to sell or lease a unit of water. An inclusive auction with a wide range of economic values among participants gives way to more trades that are more efficient in allocating water to its highest-valued use. Essentially, a good auction design will probably limit the types of water rights included, making them similar enough to be comparable and keeping the auction somewhat simple, but it will not want to limit it so much that there is little variety in rights for sale and demands of participants, because then there will be little to trade for at all.

Sealed bid multi-unit procurement auctions, like any auction type, have unique complications. The first consideration is whether to create an auction that has a discriminatory price structure or a uniform price structure. With discriminatory price structure, each winner receives the respective amount of their own submitted/accepted bid. In a uniform price structure, each winner receives the same price, regardless of their submitted bid: the auctioneer sets a maximum threshold for bid acceptability and each participant whose bid is less than this threshold is paid the maximum threshold price (Hartwell 2007, Lachman 2016).

Other Variations in Water Auction Design

Most water auctions described in the literature have been sealed bid procurement auctions. However, variations in auction design have been developed to address specific considerations. Two such variations are discussed below along with their potential strengths and weaknesses, submitting

[24] Variability may exist due to different priority dates, location in a particular basin affecting conveyance costs, water quality, etc.

[25] For instance, in the Deschutes River Auction, the participants all had the same duty of water per acre and a relatively non-variable supply. Nevertheless, the auctioneer assumed the risk that water allotment may diverge from expectations (Hartwell 2007). Another practice that may be utilized is to only allow right- holders that own rights that were granted prior to a particular priority date to participate. Other methods for ensuring water homogeneity may be utilized.

[26] This facilitates a multi-unit auction because the auctioneer can more easily compare disparate bids by calculating a price per unit of resource acquired. Due to time constraints and impracticability, other auction methods are not amenable to this type of calculation.

complete supply schedules and indexing schemes (discussed in an earlier section as a method to rank bids based on multiple criteria).

Requesting potential sellers/lessor to provide a bid schedule has advantages obtaining different quantities of water through an auction process (Hartwell 2007; Hailu 2007). In this method, bidders who have water to lease or sell do not submit one bid with one price; rather, each bidder submits a bid that containing different acceptable prices for providing various quantities of water through the auction process. At low prices, the volume of water offered is expected to be low. As prices increase, the volume of water offered by is expected to increase –like a standard economic supply curve. This auction approach takes into consideration different marginal values for water held by those selling and those seeking to acquire water. The range of bids linked to quantity facilitates alignment of marginal values. In theory, this method would provide optimal results.

As a practical matter, however, this is a complex process to undertake and about which to communicate. Participants must understand how the auction operates to ensure they are comfortable with the auction design. Because this is a radically different from a typical auction it may be difficult to obtain the requisite trust.

Logistical considerations also make this method complicated. It is necessary to compare complete supply curves to determine which bidders will be selling/leasing, rather than simply comparing single bids. The auctioneer is able to accept portions of bids, rather than having to accept or reject entire bids. If there is a budget cap for acquiring water, the auctioneer needs to determine which portions of bids to accept so that the budget cap is not exceeded while also acquiring the maximum feasible amount of water.[27] While economic theory indicates that results from this type of auction lead to cost effective water acquisition results, its complexities may overwhelm the theoretical appeal. The authors did not identify an actual example of this type of auction being implemented.

Double Auctions and Water Trading Markets

The use of the word "auction" is broad; sometimes in practice referring generally to systems by which goods are bought and sold. Double auctions have multiple buyers and sellers, all of whom can submit bids. A sealed-bid version of a double auction is often called a clearinghouse (Friedman 1993). Double auctions have been used in water trading in various locations around the world. Some ideas generated by double auctions may be applicable to water procurement auctions (Du 2017; Oczkowski 2008; Tisdell 2011; Xu 2018). However, double auctions actually are general water trading mechanisms, not auctions in the sense discussed in this publication. Consequently, double auctions are not discussed further here.

[27] There are methods to address this scenario: single increment spread, market-maker liquidity, large spread and iterative bidding (Hartwell 2007, 39- 44).

POST AUCTION COMPLIANCE AND EVALUATION

Monitoring and enforcement are essential to ensure that winning bidders comply with the terms of the auction, specifying what organization is responsible for monitoring compliance and how compliance is determined. Typically, monitoring involves ensuring that participants cease (or reduce) irrigation on the lands their winning bid obligates them to refrain from irrigating for the time period agreed upon in the auction program. Monitoring and enforcement of irrigation for specific land parcels can be costly, and it is important to utilize tools appropriate for the given situation.

Tools for monitoring and enforcement can be based on current practices in the region for monitoring water use as compliant with water entitlements and with cropland fallowing programs. For instance, locking irrigation gates may be appropriate (IID 2004). Remote sensing is commonly employed in many regions to ensure that specific tracts of land are not being irrigated. A common enforcement mechanism is drive by enforcement staff inspection of specific parcels that are no longer supposed to be irrigated.

Although water procurement auctions are being used more frequently, they are not commonplace. Consequently, it is important to evaluate auction performance so that design and implementation can be improved (see, Hartwell 2007; Cummings 2003; Garrick 2008; Bryan 2005; Rux 2008; Alevy 2010; Hill 2011; Takeda 2015). Auction goals need to be specified, both for effective auctions design and to provide criteria against which success of the auction can be assessed.

Success of an auction program can be determined in a variety of ways. For instance, in the Georgia Flint River auctions, the desired volume of water was acquired and so the auction was declared successful. Nevertheless, when the results of the auction were analyzed, Cummings (2003) determined that the same volume of water could have been acquired in a more cost-effective manner. Indexing schemes (Mullen 2019) can be used for evaluation purposes, as well as for choosing among bids. Minimizing overall procurement cost is a common criterion (Hailu 2007). This simple criterion, however, may not capture the true goal of a water auction to maximize the benefits produced while minimizing procurement cost (Garrick 2008; Bryan 2005). It is advisable to create several measurable criteria that reflect different aspects of auction success. Table 1, below, provides a general list of criteria that may be used individually or in combination to evaluate auction success. Table 1 also suggests appropriate metrics and metric calculation procedures.

SUMMARY

Auctions can be a valuable tool when water is available to move from its current type of use (and users) to new locations and types of use. Auctions can allocate available supplies, generate revenues and engage stakeholders in an interactive regional decision process. The role, potential advantages and disadvantages, implementation and evaluation of water auctions have been discussed in some depth in this publication. A series of decision and implementation steps are needed to create effective water auctions and to balance the advantages and potential shortcomings of differing auction designs. Water auctions occur around the world and share common characteristics, yet each auction program reflects its unique context and the guiding purpose of the auction program and its sponsors.

Table 1: Water Auction Evaluation Criteria

Type of Criteria	Explanation of the Metric
Total volume of water obtained	A goal in a water auction may be to maximize the volume of water obtained within a budget constraint. To calculate the total volume obtained, sum the volume of each accepted bid and compare against a predetermined target volume of water. Success may be judged by how close the acquired volume is to the target volume.
Total amount of money spent to procure water (inclusive of auction administration costs)	Generally, a goal in any procurement auction is to minimize the money outlay to acquire the resource; or alternatively, to stay within a specified budget. The total amount of money spent may be determined by summing the money spent on each accepted bid. Success may be determined by not exceeding a predetermined budget. However, in order to achieve other auction goals, it is necessary to spend at least a minimum amount of money; therefore, it may be appropriate to set a budget range to judge success.
Average price paid per unit of water, to sellers and/or lessees	This metric focuses on the price paid per unit of water to sellers and/or lessees. To calculate, sum the payments for water to sellers and lessees, and divide by the volume of water obtained. The average price paid per unit of water can be compared against a predetermined target or against indicators of water's value. It is often compared with measures of water's economic value in regional agriculture. Success may be determined by whether the price paid is "high" compared with other measures of value, or high compared to a target.
Effectiveness index	The effectiveness of an auction depends on the specifics of its context and goals. It might be most reasonable, if an indexing system were used to rank and weight bid importance, that a totaling of that index is used for determining whether the goals were met. For example, if protecting wetland species was the primary auction goal, then the total EBI from all accepted bids may be used to gauge effectiveness. Most often, this would be compared against a goal that is set prior to the auction. Along with environmental, these could also represent agricultural economics, municipal, industrial, or multi-sector indicators (Kendy 2018).
Cost of administering the auction	The goal of a procurement auction is to acquire a resource at the lowest possible cost; however, this does not necessarily consider the cost to design and implement the auction. Therefore, in order to determine auction success, the cost element could include auction administration costs. In order to determine whether the auction itself was conducted in a successful manner, with respect to auction administration costs, sum the administration costs and compare the actual costs against a predetermined target.
Post-auction costs	The costs of a successful water procurement auction often do not stop with the auction itself. There will likely be long-term costs associated with post-auction compliance and evaluation. These costs can vary greatly; there can be a few or many sites to monitor, and agreements can be for a season or in perpetuity. It is possible that failure to enforce post-auction compliance can lead to eventual failures of other goals.

Level of participation	In order for any auction to be successful, participation is crucial. The total number of participants may be compared against a target level of participation, or as a proportion of those eligible to participate. Success may be determined by how closely the actual participation compares to the target. Of course, as discussed before, some auction designs require full participation, in which case this criterion is not applicable.
Diversity of participants	Though it may make sense for an auction to limit participants so that water rights types or homogeneous, this is usually not the case with participants' valuations of their water. For bid ranking in a procurement auction to work, there need to be participants with low and high unit values. If they all have the same or similar price that they are willing to accept, then there is no way to choose which bids to accept as the buyer. This may not be able to be measured directly, but the effects can be seen or calculated post-auction.
Absence of participant collusion	To achieve optimal results in an auction, collusion must be minimized. Although there is no direct method for calculating collusion a direct analysis of the bids may be used to determine whether it is likely that collusion has occurred.
Participant trust	In order to achieve other auction goals, participants must trust the auction process. Although the number of participants serves as a proxy for this, trust can be more directly assessed through the use of survey techniques. Participants may be asked, post-auction, whether they believed that the auction process was fair and whether they trusted the auction process. Non-participants may be asked what factors prevented their participation.

WATER AUCTION DESIGN AND IMPLEMENTATION CHECKLIST

This checklist is provided as a set of reminders intended to assist with the water auction design and implementation process.

Upfront Auction Design

- ☐ **Establish consensus about goals auction is intended to accomplish; allocate specific quantity of water, maximize revenues earned by sellers, attract broad participation, etc.**
- ☐ **Determine eligibility to participate.**
- ☐ **Determine types of water entitlements to include.**
  - Should there be constraints on the location of eligible water entitlements?
- ☐ **Determine volume of water (or other goal) that is desired.**
- ☐ **Determine the volume that each person may offer.**
  - May individuals auction their entire entitlement amount? Their historical diversion amount? Their consumptive use amount?
- ☐ **Determine the units of volume to conduct the auction in.**
  - Should the auction be conducted in terms of acre-feet, standardized water per

acre amount or a different metric?

- ☐ **Set the auction date and implementation timeline.**
  - Are there seasonality or planting cycles to consider?
  - Start of publicity, outreach and informational meetings.
- ☐ **Set the number of rounds of bidding.**
  - Should only one round be used? Should multiple rounds be used, but the number be predetermined? Should there be multiple rounds but the number not be predetermined?
    - Should the number or rounds be divulged? Should information be divulged between rounds? If so, how much and what type of information should be disclosed?
- ☐ **Determine the type of information technology to use.**
  - Can any part of the auction be conducted over the telephone, fax, or internet? Is any other information technology consideration important?
- ☐ **Develop a public information and participant engagement plan and timetable.**
- ☐ **Determine payment arrangements.**
  - How and when will winning bidders be compensated?
- ☐ **Determine what price the winning bidders will be paid.**
  - Should a uniform price bid selection be used or a discriminatory price bid selection?
    - Should the existence of the uniform or discretionary auction be divulged?
- ☐ **Determine an auction budget.**
  - Should a budget cap or a quantity quota be set? If so, should any or all of this information be divulged to the bidders?
- ☐ **Set a reserve price.**
  - Should the existence, or the level, of the reserve price be divulged?
- ☐ **Establish a tie-breaking rule.**
  - Should the existence, or the operation, of the tie breaking rule be divulged?
- ☐ **Consider using an indexing scheme**
  - Does the use of an index (EBI, HHA, etc.) make sense to help rank bids? Which index should be used? Can it be implemented correctly and understood by all participants?

Post Auction Compliance and Evaluation

- ☐ **Determine the evaluation methods to be used for auction success.**
  - What type of metrics will be used to assess auction success? Should success be based upon obtaining a desired volume of water? Upon minimizing procurement costs? Upon minimizing auction costs? Based upon a calculation of benefit per dollar spent? Through the use of focus groups or surveys? Or some other method?
  - Develop a plan to collect data needed for evaluation.
- ☐ **Monitor actual change in water use to assure compliance.**
- ☐ **Determine whether improvements can be made to the auction process for the future.**
  - Were the goals achieved? If not, what can be done to improve the outcome?

WATER AUCTIONS DESCRIBED IN THIS REPORT (grouped by nation)

United States

- Yakima River Water Auction, Washington, U.S. (p. 4)
  - Example of poor participation and need to build trust
- Snoqualmie Valley, Washington, U.S. (p.17)
  - 2017
  - Examples of water auction
- Deschutes River Auctions, Oregon, U.S. (p. 5, 9, 12, 21)
  - Reserve price
  - Technology for auction
  - Sealed bid
- California Drought Bank, U.S. (p. 13)
  - 1991
  - Criteria for bid selection
- Prescott Valley Water Rights Auction, Arizona, U.S. (p. 12)
  - 2007
  - Payment schedule
- Jicarilla Apache Nation, New Mexico, U.S. (p. 4-5)
  - 2011-2013
  - Example of water auction
- Farm and Ranch Auctions, Colorado, U.S. (p. 19-20)
  - 2016-Present
  - Example of water auction
- Edwards Aquifer Authority, Texas, U.S. (p. 15)
  - 1997
  - Comparison approach to bid selection

- Flint River Basin Procurement Auctions, Georgia, U.S. (p. 7, 11, 13, 15, 18, 24)
    - 2001-2002
        - No other years of severe drought
    - Restricting entitlement type
    - Single versus multiple rounds
    - Discussion of budget caps
    - Tie-breaking rules
    - Indexing system and groundwater measurement
    - Sealed bid
    - Goals
    - Example of water auction
        - Funds supplied by Tobacco Settlement

Australia

- Spot Water Markets, South Australia, Australia (p. 9-10)
    - Online auctions have occurred since 2002
    - Weekly internet auctions
    - Watermove online trading system
    - Greater Golburn trading zone
- Catchment Care Auction, South Australia, Australia (p. 15)
    - Risk analysis framework
- Wilks Water Auction, New South Wales, Australia (p. 11)
    - 2013-Present
        - Annual Auction
    - Example of water auction moving from in-person to online due to pandemic

Other Nations
Canada (p. 12-13)

- Reverse auction with a fixed budget

Chile (p. 10)

- Low-tech methods of trading
- Limari River Basin, Chile (p. 18)
    - Trading permitted since 1981
    - Example of water auction

Spain (p. 3)

- Auctions to allocate river water to farmers since 13th century

Rural Japan (p. 6)

- Collective-action setting
- Information released

GLOSSARY

Acre-foot – A volumetric unit of measure used for large amounts of water, approximately 325,850 gallons. It is more accurately a volume of water that would cover one acre to a depth of one foot. One acre-foot is equal to 1.233 megaliters.

Ascending Bid Auction - In an ascending bid procurement auction, the price starts at a relatively low level and begins to rise temporally. The winner is the bidder that first stops the ascending price and accepts that price in payment for the resource. In this way, the bidder that is willing to accept the smallest price for the resource is chosen as the winner.

Bid Shading - A process by which bidders attempt to conceal their true value of the resource. In a procurement auction, bidders attempt to shade their bids in such a manner that the auctioneer believes that they value the resource more highly than they really do in an effort to obtain a premium for the resource.

Budget Cap - In a water auction, a budget cap is the maximum total amount of money that the auctioneer is willing to spend to acquire the entire volume of water.

Consumptive Use - The actual amount of water used. In crop production, it is actual water consumed by the crop, plus transpiration and evaporation, but does not include the runoff and/or recharge from the total amount of water applied (in areas that use irrigation).

Descending Bid Auction - In a descending bid procurement auction, bidders bid down the price that they will accept sequentially until no bidder wishes to bid the price down any further. The bidder that will accept the lowest price is the winner.

Double Auction - Also known as a "clearinghouse." An auction system that has multiple buyers and sellers, allowing multiple transaction to happen simultaneously. It functions more like a small-scale water market than what most people think of an auction.

Discriminatory - An auction pricing structure where each winner receives the actual amount that was submitted/accepted. Used in contrast to uniform pricing.

Fallow – An agricultural practice in which crop production is stopped on areas that were historically cropped. Also known as crop idling or forbearance.

Index - A method of ranking bids based upon predetermined set of criteria.

Iterative Auction - An auction that consists of more than one round of bidding where bidders are allowed to revise bids between rounds.

Megaliter - A unit of measurement in the metric system equal to one million liters. It is used as the units for Australian water auctions. The conversion to acre-feet is 1 megaliter = 0.81 acre-feet.

Multiple Unit Auction - An auction where more than one unit is placed for auction. In the case of a multiple unit water auction, participants submit bids consisting of various volumes of water.

Permitted (Diversion) Volume - A maximum amount of water that a water user is legally allowed to take or divert directly from a water source.

Procurement Auction - An auction where the auctioneer's goal is to obtain (rather than sell) a particular item or resource.

Reserve Price - In a water auction the reserve price is the maximum amount of money that the auctioneer (or buyers) is/are is willing to spend per given volume of water.

Revenue Equivalence - The theory that regardless of what auction design is used (ascending, descending or sealed bid), the chosen bid price is expected to be the same.

Sealed Bid Auction - An auction where bidders submit confidential bids. In a procurement auction, the auctioneer obtains the confidential bids and selects the lowest bidder as the winner.

Sealed Bid Multi-Unit Procurement Auction - An auction design particularly suited for water auctions because it permits the submission of bids that may vary in quantity.

Uniform - An auction pricing structure where each winner receives the same price, regardless of what their actual bid amount was. Used in contrast to discriminatory pricing.

Vickrey Auction - In a procurement Vickrey auction, the winning bidder is paid the amount that the second-place bidder submits. Under economic theory, this method minimized the threat of bid shading.

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