



Utilizing sustainability criteria to evaluate river basin decision-making: the case of the Colorado River Basin

John Berggren¹ 

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Abstract

Increasing demands, climate change and variability, and over-allocation pose tremendous challenges for the sustainable management of water resources. Federal river systems such as the Colorado River Basin provide an opportunity to understand multi-level governance challenges to sustainability as well as opportunities to improve decision-making processes. This paper seeks to understand what components of the decision-making process are important for meeting sustainability criteria. This research uses the Colorado River Basin in a multi-method study designed to understand how those specific components not only highlight challenges to sustainability, but also how they may be utilized to further sustainability objectives. Results suggest that process components such as stakeholder participation, decision-making transparency, and fairness are important considerations in the sustainability of a river basin system. Further, a nuanced analysis of the process suggests that these components provide guidance for how decision-making might be improved. This includes emphasizing problematic hydrological or institutional events, reconciling transparency and decision-making efficiency, and acknowledging that all users in the system will need to undertake shortages. Results also suggest how the state and federal governments have specific roles in implementing and facilitating these processes.

Keywords Sustainability · Water governance · Colorado River Basin · Participation · Transparency

Introduction

Water resources in the twenty-first century face significant supply-and-demand challenges. International river basins are vulnerable as countries attempt to balance the provision of basic human supplies with economic development and healthy ecosystems. Federal rivers—defined as those major rivers that are “within or shared by a federal political system” (Garrick and Stefano 2016 p. 78)—are subject to multiple countries and levels of government, which creates complex horizontal and vertical governance challenges. Unsurprisingly, then, recent research on water governance has focused on barriers to ensuring secure and reliable water supplies, including increasing

demands (Falkenmark and Molden 2008), climate change (Overpeck and Udall 2010), and climate variability (Meko et al. 2007). These barriers may be exacerbated in federal river basins, where additional complexities include the potential mismatch between governing institutions and biophysical systems, as well as the potential breakdown in polycentric systems when multiple, independent authorities face problems stemming from collective action dilemmas (Schlager and Heikkila 2014).

In response to this research on institutional barriers, a growing body of work usefully focuses on broad reforms such as increased flexibility (McCaffrey 2003; Stakhiv 2011), increased adaptive capacity (Pahl-Wostl 2007), integration of science and policy (Reed and Kasprzyk 2009), collaboration (Sabatier et al. 2005; Ananda and Proctor 2013), and a more holistic sustainable approach that meets both the short- and long-term needs of all stakeholders (Kenney 2005; Schlager and Blomquist 2008). Similarly, specific criteria have been developed to holistically evaluate environmental decision-making (Gibson et al. 2005). Gibson et al. (2005) developed essential elements which could be used to identify and assess sustainable governance systems. Specifically, the authors developed eight sustainability criteria: (1) socio-ecological

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✉ John Berggren
john.berggren@colorado.edu

¹ Environmental Studies Program, University of Colorado-Boulder, 397 UCB, Boulder, CO 80309, USA

system integrity, (2) livelihood sufficiency and opportunity, (3) intragenerational equity, (4) intergenerational equity, (5) resource maintenance and efficiency, (6) socio-ecological civility and democratic governance, (7) precaution and adaptation, and (8) immediate and long-term integration. These criteria provide a broad framework for beginning to understand the sustainability of any given system. However, the vertical and horizontal governance dimensions of inter-state and international systems, especially in federal river basins, present significant challenges in meeting these sustainability criteria. Accordingly, a significant gap remains in our understanding of how reforms could be practically implemented to support more sustainable water decision-making (Hedelin 2007; Wiek and Larson 2012).

Significant research has also sought to better understand specific regional challenges by focusing on the institutions governing common-pool resources (CPRs). CPR theory posits that institutions which create and implement specific rules—including allowing resource users to participate in decision-making, developing effective monitoring (both in terms of the resource itself and if users are complying with the rules), and creating enforceable conflict resolution mechanisms—will have improved performance outcomes (Ostrom 1990; Ostrom 2005). Additionally, researchers find that institutions should reflect social norms of fairness, which often includes ensuring users not only benefit by the institutional arrangements, but also be required to bear any burdens should they arise (Ostrom 2005). Drawing on these broader insights, key work by Schlager, Heikkila, and colleagues systematically analyzed institutional design features of interstate water compacts, demonstrating that some of the barriers seen in the literature, such as unanimity rules or the limits of voluntary collaboration, may not be as significant as previously thought (Schlager and Heikkila 2009; Schlager and Heikkila 2011; Schlager et al. 2012). Additionally, their work confirms the importance of implementing effective monitoring systems of interstate rivers and of having capable conflict resolution mechanisms in place before problems emerge (Schlager and Heikkila 2011). Looking forward, it is unclear if these interstate compacts will be sufficient as both supplies and demands continue to change and compact rules may no longer be adequate for the hydrologic conditions (Schlager et al. 2012).

This paper examines the vertical and horizontal governance challenges in meeting sustainability criteria, including the complexities of large-scale institutional arrangements, by evaluating three contemporary Colorado River Basin (“Basin”) decisions and their related decision-making processes: the 2001 Interim Surplus Guidelines, the 2007 Interim Shortage Guidelines, and Minute 319 to the US-Mexico Treaty. While these three decisions do not include all the foundational policies and agreements that have been created over a century of Colorado River governance (e.g., Colorado River Compact of 1922), they do illuminate how

the Basin is currently managed, how this governance system continues to evolve, and how institutions operate in terms of specific process components as they adapt to continually changing social and environmental conditions.¹ The paper also evaluates how a diverse group of Colorado River stakeholders think about these decision-making processes through a survey that examines perceptions and opinions in relation to sustainability criteria. These two research approaches—a decision analysis and decision-making survey—help us understand why specific components of the decision-making process are important and how they provide opportunities for more sustainable outcomes. As such, this paper asks the following research questions: *What components of the decision-making process are important in meeting sustainability criteria? What are the challenges associated with these components? How might a consideration of these components enable or support more sustainable outcomes?*

First, this paper provides a brief introduction and overview of the Basin as its case study for evaluating water governance sustainability. Next, an overview of the decision-making process in the Basin is discussed to provide context for the research approach. Research methods are then provided which include two distinct, but related approaches. The paper then identifies important components of the decision-making process, including specific challenges associated with those components. Following the “Results” section, the paper discusses implications for decision-making in federal river basins and concludes with potential future research directions.

Overview of the Colorado River Basin

The Colorado River and its tributaries emerge out of the Rocky Mountains and drain approximately 244,000 mile² before reaching the Gulf of California in Mexico. Along the way, the river provides water, at least in part, for nearly 40 million people, irrigates 5.5 million acres of land, and has approximately 4200 MW of hydroelectricity capacity (Bureau of Reclamation 2012). Further, the Basin is home to 22 federally recognized Native American tribes, 11 National Parks, 7 National Wildlife Refuges, and 4 National Recreation Areas. Known as the “lifeline” of the American Southwest, the Colorado River provides extensive resources for human and environmental needs.

The Colorado River Compact of 1922 and subsequent legislation, congressional acts, court decisions, decrees, and regulatory decisions collectively comprise what is known today as the “Law of the River.” Briefly, the Colorado River Compact of 1922 apportioned 7.5 million acre-feet annually

¹ The Basin faces some of the prominent challenges that many river basins around the world must confront in the coming decades, most notably over-allocation and reduced flows due to increasing temperatures in the region (Udall and Overpeck 2017).

to both the Upper and Lower Basin for consumptive use. The Boulder Canyon Project Act of 1928 further apportioned the Lower Basin's allocation—4.4 MAF to California, 2.8 MAF to Arizona, and 0.3 MAF to Nevada—and the Upper Colorado River Basin Compact of 1948 further apportioned the Upper Basin's allocation—51.75% to Colorado, 23% to Utah, 11.25% to New Mexico, and 14% to Wyoming.

Both state and federal governments have played prominent roles in Basin development and management since the early twentieth century. While the state and federal governments did come to an agreement on how the interstate waters of the Colorado River would be divided—through the Colorado River Compact of 1922 and subsequent related acts—the states still own the water within their borders. An early twentieth century Supreme Court ruling (*Wyoming v. Colorado*²) held that the legal doctrine of prior appropriation, which established a system of prioritized water rights, applied across state lines. As such, an interstate compact was needed but again the states retained control and ownership of the waters within each state. So, while the states have significant authority to manage intrastate water, the federal government has built and currently operates the large storage projects on the Colorado River, most notably Lakes Powell and Mead.

Additionally, pursuant to the Boulder Canyon Project Act of 1928 and then reaffirmed in the Supreme Court's 1964 decree stemming from the *Arizona v. California*³ case, the federal government—acting through the Secretary of the Interior—has been deemed the “Watermaster” in the Lower Basin. The role of Watermaster includes contracting water allocations within the three Lower Basin states, operating the major reservoirs, and, if specific conditions arise, mandating curtailments or allocating surplus to Lower Basin users. More recently, the Bureau of Reclamation has been heavily involved in facilitating interstate and international negotiations, helping develop and model interstate and international policies, and supporting additional stakeholder involvement in these processes.

Contemporary decision-making processes in the Colorado River Basin

2001 Colorado River Interim Surplus Guidelines⁴

The 2001 Interim Surplus Guidelines established how the Secretary of the Interior would allocate surplus waters in the Lower Basin and also provided California with certainty in reducing its demands down to its original Colorado River

² *Wyoming, State of v. Colorado* 259 U.S. 419, 42 S.Ct. 552, 66 L.Ed. 999 (1922)

³ *Arizona v. California*, 376 U.S. 340, 84 S.Ct. 755, 11 L.Ed.2d 757 (1964)

⁴ U.S. Department of the Interior, Record of Decision—Colorado River Interim Surplus Guidelines (January 16, 2001), available at https://www.usbr.gov/lc/region/g4000/surplus/surplus_rod_final.pdf

apportionment of 4.4 million acre-feet. The seven Basin States, federal government, and key municipal agencies and irrigation districts were the primary negotiators. A significant horizontal governance challenge was for California to negotiate a process for reducing its demand, which became the Quantification Settlement Agreement (QSA). A vertical governance challenge included uncertainty in how surplus waters would be apportioned by the Secretary of the Interior. Specifically, California contended the QSA was contingent on having specific federal surplus criteria in place that it could plan for.

2007 Colorado River Interim Guidelines for Lower Basin shortages and the coordinated operations for Lake Powell and Lake Mead⁵

The 2007 Interim Shortage Guidelines coordinated operations of Lake Powell and Lake Mead and developed shortage-sharing guidelines for the Lower Basin states as Lake Mead elevation levels declined. The seven Basin States, federal government, key municipal agencies and irrigations districts, and some environmental NGOs were the primary negotiators. The Guidelines were in direct response to declining hydrology and loss of storage in key reservoirs, in combination with disagreement among the Basin States regarding various components of the Law of the River (e.g., delivery obligations to Mexico). The Secretary of the Interior at the time, Gale Norton, wrote a letter to the Basin States in 2005 strongly urging the States to reach agreement on shortage guidelines. Secretary Norton threatened a unilaterally imposed solution by Interior under her authority as the Lower Basin “Watermaster” unless the States could agree on the guidelines. This dynamic process again highlights the horizontal and vertical challenges often faced in a federal river basin.

2012 Minute 319: Interim International Cooperative Measures in the Colorado River basin through 2017 and extension of Minute 318 Cooperative Measures to address the continued effects of the April 2010 earthquake in the Mexicali Valley, Baja California⁶

The USA and Mexico signed Minute 319 in 2012 to guide future management of the Colorado River in both countries. The International Boundaries and Water Commission

⁵ U.S. Department of the Interior, Record of Decision—Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead (December 13, 2007), available at <https://www.usbr.gov/lc/region/programs/strategies/RecordofDecision.pdf>

⁶ International Boundary and Water Commission. (2012). Minute 319: Interim International Cooperative Measures in the Colorado River Basin Through 2017 and Extension of Minute 318 Cooperative Measures to Address the Continued Effects of the April 2010 Earthquake in the Mexicali Valley, Baja California. Retrieved from http://ibwc.state.gov/Files/Minutes/Minute_319.pdf

(IBWC), la Comisión Internacional de Límites y Aguas (Mexico's section of the IBWC), the seven US Basin States, the federal government in both countries, and key municipal agencies and irrigation districts, and environmental NGOs—from both countries—were the primary negotiators. The Minute established shortage-sharing procedures, enhanced water infrastructure, coordinated storage operations, and promoted ecological health in the Colorado River Delta. Initially, the State Department represented the USA, as opposed to the seven Basin States as had been the case with other negotiations. This presented a significant vertical governance challenge as the seven Basin States own the water within their state boundaries, whereas in Mexico water ownership is centralized at the federal government.

It is important to note that these three policies did not share the same rulemaking procedures. The 2001 Surplus Guidelines and the 2007 Shortage Guidelines were developed through the National Environmental Policy Act (NEPA) process, whereas Minute 319 was developed in the context of an international treaty. Accordingly, both the Surplus and Shortage Guidelines involved public comment periods, stakeholder consultation, and explicit guidelines for how the process occurred. Minute 319 had fewer explicit guidelines and did not involve designated public comment periods or stakeholder consultation, although a similar collaborative process seemed to emerge (King et al. 2014). Therefore, both processes provide a similar decision-making context for negotiating and implementing decisions that add to the Law of the River.

Clearly, these processes are not apolitical and there is important historical context for each outcome. For example, despite objections, Mexico was excluded from the 2007 Interim Shortage Guidelines negotiations, leading to mistrust and skepticism in the initial Minute 319 discussions. Mexico contended that any agreement which specifies surpluses or shortages in the USA ultimately impacts downstream interests, and therefore that process should include Mexican input. This highlights the importance of considering who is included or excluded in the process, and the subsequent implications for future decision-making.

Research methods

To address the research questions, qualitative and quantitative methods were utilized through two efforts: (1) a decision analysis of three recent policies governing the Colorado River to understand how decisions are made, what is included in those decisions, and who was involved in creating them; and (2) a survey of Basin stakeholders and decision-makers to understand perceptions of those decisions and the related decision-making processes. The decision analysis allowed for a direct comparison of the three policies to identify specific components of the decision-making process that are important in

considering the sustainability criteria. The survey was then used to better understand stakeholder's perceptions of those components and how they fit within the decision-making process. These two approaches allow for a more complete evaluation of the decision-making process by analyzing not only how decisions are made and what they specifically include, but also what a broad group of stakeholders think of those processes and their outcomes. Accordingly, this analysis bridges a systematic evaluation of sustainability criteria with specific components of the decision-making process that water managers could utilize to further sustainability outcomes.

Decision analysis

The decision analysis utilized the methods and codebook as developed by Schlager and Heikkila (2009) and then incorporated the sustainability criteria developed by Gibson et al. (2005) discussed above to create a new protocol by which the three decisions could be qualitatively coded and analyzed. Specifically, questions were developed relating to each of the sustainability criteria, in addition to the questions in Schlager and Heikkila's protocol. This included the decision rules for each policy, specific allocations, decision-making processes, and inclusion of specific elements of the sustainability criteria. The protocol ultimately included 117 primary questions with 122 secondary questions for a total of 239 questions.⁷ In addition to using the primary decision documents themselves, secondary documents were also used to give context and clarity to specific components of the decision. Secondary documents were particularly useful for understanding who was involved in the decision-making process, and included books, law review articles, court documents, meeting minutes, and various reports. This open-ended codebook protocol and coding methods were established in line with other similar research (Miles and Huberman 1984; Crow 2010).

Colorado River Basin decision-making survey

The second part of this study employed a survey of a significant variety of Basin stakeholders and decision-makers. The survey was developed based upon the literature review and decision analysis discussed in the previous section, and included questions pertaining to opinions on decision-making processes, changes to the Law of the River, and the importance of various stakeholder groups. The survey was administered to the members of the Colorado River Water Users Association (CRWUA). CRWUA has a diverse and dynamic membership of approximately 1000 Basin stakeholders, which includes a variety of water managers, government officials (from multiple levels of government), NGO

⁷ The complete protocol, including instructions for the coding process, can be found in Online Resource 1 or be made available by contacting the author.

representatives, Tribal leaders, academics, and concerned citizens. The membership directory for each year is publically available in CRWUA's annual reports. The survey was administered online to 997 unique email addresses in late October of 2016. In an effort to obtain a higher response rate, two follow-up reminder emails were sent in early- and mid-November (Dillman et al. 2009). Two hundred twelve surveys were completed for a 21.3% response rate.⁸ Location within the Basin and occupation were the only two demographic questions asked of each respondent, the results of which are detailed in Table 1. Because the CRWUA membership changes yearly, it is difficult to say if the survey respondents were representative of the overall membership.

The survey results were then quantitatively analyzed to explore the research questions discussed above. Several regression analyses were conducted to explore relationships between specific variables (discussed in more detail below) and a variety of other answers given regarding respondents' perceptions and opinions on the decision-making process. Most of the questions had Likert-like scale options for the respondents to answer. For some of the statistical analysis, the variables from these answers were left as continuous variables. In other cases, initial analyses found it was necessary to convert these continuous variables to binary variables. For example, several of the questions asked respondents their opinion of when certain significant institutional events may occur (e.g., a compact call between the Upper and Lower Basins by certain years). The scale of responses included very likely (at least 90%), probable (at least 70%), possible (50/50 probability), unlikely (less than 30%), and very unlikely (less than 10%). Multiple models were explored to determine the appropriate point at which to collapse the responses into a binary scale. Based on these initial model runs, these probability variables were collapsed into two groups: more probable ("probable" and "very likely") and less probable ("possible," "unlikely," and "very unlikely").

Results

What components of the decision-making process are important in meeting sustainability criteria? What are the challenges associated with these components?

Results from the first two research questions illuminate parts of the decision-making process that are important in consideration of the sustainability criteria, including specific challenges. Table 2 helps identify these components of each

respective process by comparing the three decisions across the eight sustainability criteria. Several components of the decision-making process were recurring themes in this comparison. These components—stakeholder participation, transparency, and fairness—were not only important considerations in the process, but also highlighted specific challenges that need to be overcome in achieving more sustainable outcomes in the Basin.

Stakeholder participation is one factor frequently cited by the water policy and CPR literature as being essential to sustainability (e.g., Ostrom 2005; Mostert 2006). However, the decision analysis revealed that the ultimate success of any decision may be limited by the difficulty in finding a balance between, on the one hand, inclusivity, and on the other, timeliness, and effectiveness. For example, as shown in the socio-ecological system integrity criterion in Table 2, Minute 319 included a broader consideration of ecological systems compared to the previous two decisions. This broader consideration reflected greater participation by the environmental NGO community. Similarly, in the intragenerational equity criterion, the 2001 Surplus Guidelines and 2007 Shortage Guidelines explicitly excluded certain stakeholder groups. Comparatively, however, while Minute 319 was more inclusive, it still was not comprehensive and some stakeholders felt excluded (e.g., Native American Tribes). Comparing across the socio-ecological civility and democratic governance criterion reveals why groups who did participate may have been more successful in meeting those broader ecological goals, namely, environmental NGO participants from both countries were included earlier in the process. Also in this criterion, negotiations for the previous two decisions were in the context of an EIS process (requiring public comment periods), whereas Minute 319 did not require any public comment periods and the negotiations were more private. With the 2001 Surplus Guidelines and 2007 Shortage Guidelines, decision-makers made efforts toward inclusivity (i.e., public comment periods), but the inclusivity occurred after the decision had largely been settled, and those outside stakeholder groups' inputs were not necessarily included and thus came to little effect. Similarly, efforts to include more diverse stakeholder groups earlier on in the process may be limited by the number of participants that can ultimately be included (as was the case with Minute 319). As such, this balance of inclusivity, timeliness, and effectiveness presents a challenge in decision-making.

The decision analysis also revealed that flexibility in what was deemed "participation" by stakeholders seemed to make for a more effective process overall. That is to say, when at certain points negotiations reached an impasse, informal discussions outside of the formal negotiating framework made the process more effective with a diverse suite of stakeholders. For example, in both the 2007 Shortage Guidelines and Minute 319, it was reported that some level of informal agreements among decision-makers was necessary to overcome barriers

⁸ Due to funding constraints, other forms of incentives were unavailable (e.g., cash or mailed surveys). Lower response rates can be expected for single-mode web only surveys without other incentives for participation (Millar and Dillman 2011; Bethlehem 2014).

Table 1 Distribution of survey respondents, by location and occupation

	Occupation/affiliation					Totals
	Water manager/government	Water professional	Water user	Citizen/other or unknown	Non-governmental organization	
Location						
Arizona	44% (22)	40% (20)	6% (3)	4% (2)	6% (3)	23.6% (50)
California	35.71% (10)	39.29% (11)	14.29 (4)	7.14% (2)	3.57% (1)	13.2% (28)
Nevada	80% (12)	6.67% (1)	6.67% (1)	6.67% (1)	0% (0)	7.1% (15)
Colorado	45.1% (23)	27.45% (14)	5.88% (3)	5.88% (3)	15.69% (8)	24.1% (51)
New Mexico	33.33% (4)	33.33% (4)	8.33% (1)	0% (0)	25% (3)	5.7% (12)
Utah	58.33% (14)	33.33% (8)	0% (0)	0% (0)	8.33% (2)	11.3% (24)
Wyoming	40% (2)	40% (2)	20% (1)	0% (0)	0% (0)	2.4% (5)
Mexico	0% (0)	33.33% (1)	0% (0)	0% (0)	66.67% (2)	1.4% (3)
Other/unknown	50% (12)	20.83% (5)	8.33% (2)	4.17% (1)	16.67% (4)	11.3% (24)
Totals	46.7% (99)	31.13% (66)	7.08% (15)	4.25% (9)	10.85% (23)	100% (212)
Lower Basin	47.3% (44)	34.4% (32)	8.6% (8)	5.4% (5)	4.3% (4)	43.9% (93)
Upper Basin	46.7% (43)	30.4% (28)	5.4% (5)	3.3% (3)	14.1% (13)	43.4% (92)

The Lower Basin totals consist of Arizona, California, and Nevada, while the Upper Basin totals consist of Colorado, New Mexico, Utah, and Wyoming

in the process (McClurg 2013). In some cases, this manifested as trust-building activities between prominent stakeholders. In other cases, it was private, off-the-record discussions among key negotiators. In both circumstances, giving stakeholders the flexibility to engage in off-the-record discussions ultimately supported the success of the overall decision.

Another component of the process that also emerged was the often-recurring call for transparency. Like stakeholder participation, transparency is often discussed in the literature as essential for water decision-making (e.g., Whiteley et al. 2008). Indeed, one of the primary goals of the federal NEPA process is for the process to be transparent and publically driven. This decision analysis revealed, however, that there may be some utility in limiting the transparency of some of the negotiations and decision-making. For example, comparing the three decisions across the socio-ecological civility and democratic governance and intragenerational equity criteria demonstrates that Minute 319 was less transparent than the previous two decisions, despite it being more inclusive as discussed above. Accordingly, the ability for decision-makers to agree on the final decision was contingent, at least in part, on being able to have frank discussions behind closed doors. This demonstrates one of the vertical governance challenges in a federal river basin: when the states, who prefer more closed-door discussions, are the primary water rights owners, their processes may have contradictory requirements to those of the federal government. In each of the decisions studied, there were apparent tensions between allowing the Basin states the room to come to agreement privately, while also including other interested stakeholders in ongoing discussions.

Another component commonly identified in the decision analysis was fairness. While a broad concept, fairness is often described in the literature by notions of balanced representation, adequate debate, recognition of diverse values, or an overall more just process (Renner et al. 2013; Wilder and Ingram 2016). Regarding CPR institutions, Ostrom 2005 suggests that institutions are perceived as fairer if they proportionally distribute the benefits and burdens of any decision. Accordingly, the decision analysis reveals that Minute 319 included a fairer process in most of the sustainability criteria. Minute 319 explicitly included comprehensive monitoring (socio-ecological system integrity), specific funding mechanisms (intragenerational equity), a framework for future negotiations (intergenerational equity), and emphasized collaborative endeavors (socio-ecological civility and democratic governance). An example from the decision analysis wherein achieving fairness proved challenging for all three decisions, however, involved figuring out how to acknowledge and explicitly handle trade-offs between stakeholder groups and decision objectives (immediate and long-term integration) and specific sectors (livelihood sufficiency and opportunity).

Some of these trade-offs exemplify horizontal governance challenges, including the Basin states' needing to determine which states would take surpluses or shortages, and in what quantity. For example, the 2001 Surplus Guidelines acknowledged that California could continue to use surplus water, but gave the other Basin states certainty that this continued use was temporary. Other trade-offs exemplify vertical governance challenges, such as with the geographic scope of the policy. For example, again with the 2001 Surplus Guidelines, there was debate about whether to include environmental

Table 2 Summary themes from evaluation of the eight criteria categories for the three Colorado River Basin policies

	2001 Surplus Guidelines	2007 Shortage Guidelines	Minute 319
Socio-ecological system integrity	Includes specific ecological systems, primarily main-stem endangered species; specifically excludes mitigation of impacts in Mexico; some monitoring for impacts to endangered species and water quality; negligible impacts expected from decision.	Includes specific ecological systems, primarily main-stem endangered species; some monitoring and conservation measures included; negligible impacts expected from decision.	Includes broader ecological systems (i.e., the Colorado River Delta), however human uses still priority; includes comprehensive monitoring; specifically acknowledges previous ecological degradation; primary water quality concern is salinity.
Livelihood sufficiency and opportunity	Primary purposes are agriculture and M&I; does not define priorities for human uses; does not include marginalized groups or non-consumptive uses; does not acknowledge economic impacts; does acknowledge negative impacts in Mexico.	Primary purpose is storage; does not define priorities for human uses; did not include marginalized groups in the process; some mention of non-consumptive uses; includes specific time period for implementation.	Primary purpose is agriculture, M&I, storage, and the environment; does not define priorities for human uses; does include non-consumptive uses (i.e., the Delta); does not acknowledge economic impacts; includes specific time period for implementation.
Intragenerational equity	Excluded some stakeholders from the process (e.g., Mexico); the decision is not permanent; quantified allocation scheme used; included public commenting period; does not include specific funding mechanisms.	Excluded some stakeholder groups from the process (e.g., Mexico); the decision is not permanent; quantified allocation scheme used; included public commenting period; does not include specific funding mechanisms.	More inclusive process, although not comprehensive; decision is not permanent (shortest period of the three with a 5-year implementation period); quantified allocation scheme used; many negotiations were not public; includes specific funding mechanisms.
Intergenerational equity	Limited mention of future generations, although decision can be modified or terminated in future; considers different future hydrological scenarios; acknowledges uncertainty in future hydrology; some monitoring, but limited changes in decision implementation.	Limited mention of future generations, although decision can be modified or terminated in future; considers different future hydrological, climate, social, and environmental scenarios, although not all explicitly used in decision; acknowledges uncertainty in future hydrology.	Limited mention of future generations, although decision specifically mentions a framework for future negotiations; decision can be modified or terminated; considers different future hydrological, climate, and environmental scenarios; specific inclusion of flexibility.
Resource maintenance and efficiency	Does not discuss the value or efficient use of water; limited transferability of water; specifically acknowledges hydrologic variability; limited discussion on certainty of allocations (i.e. surpluses); multiple government agencies involved, with formal coordination; some discussion of demand management.	Does not discuss the value of water; includes some transferability of water (e.g., Intentionally Created Surplus); acknowledges hydrological, climatological, and historical variabilities; some future allocations are contingent on system conditions; multiple government agencies involved, with formal coordination.	Does not discuss the value of water; does discuss efficient use and transfer of water; includes transferability of water (e.g., Intentionally Created Mexican Allocation), but contingent on future system conditions; some demand management, primarily efficiency upgrades.
Socio-ecological civility and democratic governance	Multiple stakeholder groups involved, primarily the US Basin states, federal government, and primary water agencies; other stakeholder groups (e.g., NGOs) participated in public comment period; negotiations primarily in context of EIS process; Bureau of Reclamation facilitated formal negotiations and provided modeling capabilities.	Multiple stakeholder groups involved, primarily the US Basin states, federal government, and primary water agencies; some NGOs were included earlier in the process; other groups were consulted (e.g., Mexico, Tribes); negotiations primarily in context of EIS process; Bureau of Reclamation facilitated formal negotiations and provided modeling capabilities.	Multiple stakeholder groups involved, although fewer than previous decisions; US and Mexico NGOs involved early on in process; US and Mexico federal governments held informal networking and negotiations early on in process; specifically emphasizes collaborative endeavors; less transparent; both the US and Mexico federal governments provided modeling capabilities.
Precaution and adaptation	Acknowledged uncertainty in the decision, included some flexibility in implementation; does not specific how new information could address uncertainties; hydrologic models and historical/projected streamflow records used; includes trigger points for automatic changes in decision.	Acknowledged uncertainty throughout decision, included flexibility in implementation; limited discussion of penalties for violations; includes trigger points for automatic changes in decision.	Acknowledged uncertainty throughout decision, included flexibility in implementation; no mention of penalties for violations; 5-year implementation period due to uncertainties; includes trigger points for automatic changes in decision.
Immediate and long-term integration	Acknowledged tradeoffs between stakeholder groups; acknowledged tradeoffs between objectives; does not establish a river basin organization or educational outreach.	Acknowledged tradeoffs between stakeholder groups; acknowledged tradeoffs between objectives; does not establish a river basin organization or educational outreach.	Established some priorities for allocations; limited acknowledgement of tradeoffs between stakeholder groups; established a trust to oversee Delta impacts; does not require outreach.

impacts in Mexico in the EIS process (most notably the Colorado River Delta). Ultimately the federal government decided not to include those impacts, much to the dismay of some environmental NGO stakeholders, which led to negative outcomes in that excluded geographic area (Glennon and Culp 2002). Despite Minute 319 being more successful in creating a fair process, each decision still had some challenges in the achievement of fairness throughout the decision-making process, and the necessity of such achievement proved to be an obstacle to moving toward more sustainable outcomes.

How might a consideration of these components enable or support more sustainable outcomes?

Stakeholder participation

The decision analysis identified that balancing stakeholder inclusivity with timeliness and effectiveness is a significant challenge to meeting sustainable criteria. Building upon this, the survey included several questions in regard to participation and the results of which reveal how a consideration of this balance of stakeholder participation might enable or support more sustainable outcomes. Some of the survey questions queried the respondent's personal involvement in the process while other questions queried respondent's opinions on the general importance of specific stakeholder groups being involved in the process. Utilizing this latter set of questions, an index variable was created to test relationships between support for increased stakeholder participation and a variety of other variables (see Online Resource 2 for a detailed description of the index variable, along with some basic statistics).

As noted above, interstate water compact vulnerability and the risk of significant shortages have been called into question, especially in consideration of increasing demands and climate change (Schlager et al. 2012). Interestingly, several regression models identified a significant relationship between survey respondents who think that overall the Basin system is vulnerable, and those who are more likely to support increased stakeholder participation. For example, survey respondents who agreed that *all* users will be required to undertake shortages also supported increased levels of stakeholder participation ($b = 3.603, p < 0.01$). Similarly, those who thought a compact call between the Lower and Upper Basin by 2026 is probable also supported increased levels of stakeholder participation ($b = 1.458, p < 0.1$). This suggests that stakeholders who believe more drastic steps are necessary to fix any problems (i.e., all users need to undertake shortages), or that a significant legal event may soon occur (i.e., compact call), may see increased levels of stakeholder participation as part of the solution. In other words, highlighting the risk of potential future shortages and/or potential for litigation may support decision-makers in creating a more participatory process.

Also discussed in the introduction, CPR theory notes the importance of decision-making scale and that higher scales of decision-making (i.e., collective-choice or constitutional) present additional challenges for rule modification. Indeed, while there have been significant additions to decision-making rules in the Colorado River Basin (see the “[Overview of the Colorado River Basin](#)” section), many have argued that the fundamental Law of the River does not need to be modified or transformed (e.g., Gold 2008). Two survey questions asked respondents how much of a change to the Law of the River were two previous decisions—the 2007 Shortage Guidelines and Minute 319—with possible responses ranging from a fundamental change to no change at all. A fundamental change to the Law of the River would represent a collective-choice or constitutional modification and would therefore be difficult and time-consuming. Using the results of these questions as independent variables, regression models examining the relationship with the stakeholder participation index variable revealed interesting implications for the Law of the River and participation. The more that respondents thought Minute 319 was a change to the Law of the River, the more likely they were to support increased stakeholder participation ($b = 1.898, p < 0.05$). This suggests that if more difficult rule modifications at higher decision-making scales are desired, decision-makers might benefit from having a more participatory process. It is important to note, however, that no such relationship was evident with the 2007 Shortage Guidelines.

Fairness

Similar to stakeholder participation, an index variable was created to test relationships between fairness and other variables. The survey included a variety of questions relating to fairness as identified in the decision analysis and literature, including topics such as adequate representation, trust, positive impacts, and requiring all users to bear any burdens (see Online resource 2 for the complete list of questions). Overall, the more that survey respondents think the system is sustainable and equitable, the more likely they were to think overall decision-making in the Basin is fair ($b = .539, p < 0.1$ and $b = .922, p < 0.01$, respectively); this suggests that a focus on outcomes considered to be fairer may produce a decision-making environment that is perceived as more sustainable. In returning to the decision analysis, one such opportunity found is the need to focus on not only how shortages and curtailments should be shared among users, but also how potential benefits and surpluses should be shared. Minute 319 specifically allocates how future surpluses—based on specific system conditions—are to benefit users in both the USA and Mexico.

Another opportunity to create a fairer process was a consideration of both which users will be required to undertake

curtailments or shortages, and whether these curtailments should be temporary or permanent. In regard to the latter, only 38.4% of the survey respondents agreed or strongly agreed that *permanent* curtailments are necessary. This compares with 69.2% of respondents who agreed or strongly agreed that *temporary* curtailments are necessary. Interestingly, however, those respondents who think that only “some users” will need to undertake shortages—as compared with “no users” or “all users” needing to undertake shortages—are less likely to view the overall system as being fair ($b = -3.365$, $p < 0.01$). Even though there was a significant difference in views on temporary versus permanent curtailments, only requiring “some users” to undertake curtailments was strongly associated with a perceived decrease in fairness.

Transparency

One survey question asked respondents their level of agreement with the statement that decision-making in the Basin is transparent. Table 3 presents the results of multiple logistic regression analyses using the survey respondents’ views on transparency as a dependent variable (collapsed into binary outcomes), along with three different groups of independent variables. These groups of independent variables were selected from the survey questions as they relate directly to the specific research questions. It is important to note that the

participation questions used here are different from the index variable analyzed above in that they relate to respondent’s individual involvement in the decision-making process.

In terms of “barriers,” for example, those respondents who see the necessity of “changes the Law of the River” as a barrier to reaching a decision were less likely to think the overall process was transparent. Similarly, those that view a “lack of trust” as a barrier were also less likely to view the process as transparent. The analysis also revealed that those respondents who describe themselves as having a seat at the negotiating table are less likely to think that the overall process is transparent, compared with those who do not identify themselves as having a seat at the table. Further, those respondents who agreed that Basin negotiators are, “concerned about their own interests,” and agreed that those negotiators have, “adequate power” to protect those individual interests, are more likely to think the process is transparent. In other words, those stakeholders not actually at the negotiating table believe the process is more transparent, compared to those who are at the table, who believe the process is less transparent. This seems counter-intuitive because one might expect that those at the table to believe, or at least report, that their decision-making is transparent. This suggests that those who are actually at the table recognize that certain groups are being excluded or kept in the dark, while those not at the table might not be fully aware of the discussions behind closed doors.

Table 3 Logistic regression results of decision-making transparency. Each model tests the role of a specific set of survey questions (barriers, participation, and representation) in survey respondent’s perception of decision-making transparency (the dependent variable). A positive coefficient suggests perception of a transparent process, whereas a negative coefficient suggests perception of a lack of transparency

	Model 1	Model 2	Model 3
Independent variables			
Barriers			
Changes to the law	-0.260*	(0.128)	
Local/regional politics	0.213	(0.166)	
Lack of trust	-0.726**	(0.217)	
Need to compromise	0.060	(0.152)	
Risk of litigation	0.066	(0.147)	
Participation			
Seat at the table		-0.625**	(0.207)
Representative at the table		-0.331	(0.206)
Consulted after draft		-0.010	(0.156)
No involvement		0.106	(0.169)
Representation			
Negotiators concerned			0.419* (0.172)
Negotiators have power			0.446* (0.187)
Any changes are positive			0.038 (0.137)
Location (ref = Lower Basin)			
Upper Basin	0.042	(0.315)	-0.005 (0.388) 0.248 (0.328)
Location other	-0.179	(0.575)	-0.345 (0.807) 0.199 (0.651)
Probability > $\chi^2 =$	0.000	0.000	0.000
Standard errors in parentheses			

** $p < .01$, * $p < .05$

Discussion

Previous work examining these various concepts in water decision-making have acknowledged the difficulty in prescribing specific criteria that water managers could follow (Rogers and Hall 2003; Wilder and Ingram 2016). Rogers and Hall effectively argue that water governance should work to be more open and transparent, inclusive and communicative, coherent and integrative, and equitable and ethical (Rogers and Hall 2003). Recognizing the importance of principles, however, does not change the fact that operationalization remains context dependent for each system (ibid). As Wilder and Ingram (2016) note, the principles they propose are effective in *examining* equity, but are less effective at *prescribing* specific governance mechanisms and policy tools. Following along these lines, the findings from this research in the Colorado River Basin suggest that parts of the decision-making process—participation, transparency, and fairness—are important considerations, but they require a context-specific and nuanced understanding for how they could be utilized to support more sustainable outcomes.

For example, much of the discourse around water policy in recent years has focused on increasing stakeholder participation and enlarging the negotiating table to create a more inclusionary process. Indeed, the current era (1990s to present) of federalism and US water policy has been classified as an era of “restoration and collaboration” (Gerlak 2014). Although less common, there has also been some work suggesting a limitation to participation, especially as it relates to the public (Mostert 2006). This research differs from some of the former literature in that it supports the notion that a myopic focus on a more inclusionary and collaborative process might not be entirely effective, especially in a federalist system, as it does not necessarily lead to better outcomes. Instead, focusing on the process itself—namely when and how to incorporate a broader suite of stakeholder inputs—might ultimately support a more sustainable approach. This focus partially aligns with one of Roger and Hall’s (Rogers and Hall 2003) principles that affected stakeholders should be included “throughout the policy chain,” but differs in that “wide participation” is always appropriate (p. 28). For example, as was the case with Minute 319, the early involvement of a select group of stakeholders may support overcoming vertical governance challenges, such as the scope of the decision, to reduce future negative impacts. In the context of the Colorado River Basin, including stakeholders as end unto itself may not necessarily be the most appropriate route to achieving sustainability.

This research also found that highlighting the likelihood of shortages and/or litigation may lead to decision-makers supporting a more satisfactory inclusive process. Given the significant challenge of effective stakeholder participation discussed above, this suggests that overcoming multi-level coordination challenges may require identifying and

highlighting such likelihoods, rather than conducting a top-down or bottom-up push for greater participation in and of itself. Further, when stakeholders are included in the negotiations, allowing them the freedom and flexibility to have discussions outside of the formal negotiating table may lead to more successful results. The challenge of different regulatory processes and responsibilities at different levels of government may require this level of informality.

In consideration of the fairness component, this research found a decrease in perceived fairness when decisions only required some users to undertake curtailments. Therefore, simply acknowledging that all users may have to undertake some level of shortage may lead to greater support for a specific decision. As discussed above, each of the three decisions struggled with inter-state trade-offs regarding who would undertake shortages or surpluses. What this research suggests is that one way to overcome those challenges is to begin by acknowledging that all users might be required to undertake shortages, even if they are temporary. Once it has been established that all users will be required to undertake shortages—something not required by the existing Law of the River—decision-makers may be able to propose and implement more sustainable outcomes. This finding is supported in the literature that suggests distributing costs and benefits across all users in a given institutional arrangement results in greater support (Schlager and Heikkila 2011). Similarly, this aligns with one of Wilder and Ingram’s (Wilder and Ingram 2016) directional principles toward equity in water governance: sharing both the benefits and *burdens* associated with coming water governance challenges.

This research has also demonstrated the necessity of reconciling the call for transparency with the need for safe, behind-closed-door discussions and negotiations. As with increased stakeholder participation, decision-making transparency is something that ostensibly should be a focal point of decision-making and is often discussed in the literature as important. Indeed, transparency can support the legitimacy of any new decision or outcome (Whiteley et al. 2008). Less often discussed, however, is that there may be limits to transparency and finding the appropriate balance between privacy and effective decision-making is no trivial task (Tortajada 2010). This research supports the latter in that there appears to be some nuance to the issue of transparency. Instead of focusing only on how to make the decision-making process more transparent, perhaps some institutions that allow for private discussions would facilitate more successful and sustainable policies in the future. As a negotiator heavily involved in these basin-scale decisions noted, “...it requires some brainstorming in the safe places without the pressure or all of the sunlight at times” (McClurg 2013 p. 28).

One possibility for managing the need for both closed-door discussions and transparent decision-making may be to lay the responsibility for overseeing negotiations on an independent government agency with different decision-making authority

than the Basin States. Clearly defined roles at each level of government has been identified as important for federal rivers (Garrick and Stefano 2016), and this research provides an empirical example of this importance. Because the Basin States are sovereigns, private negotiations could, and should, still occur among those state principals. But again because of the States' status as sovereign holders of water rights, it may be in the interest of all involved to have the process at least monitored by a disinterested body or agency. The federal government, for example, could help ensure that discussions do not systematically exclude or disadvantage specific stakeholders, including individual Basin States. The unique authority of the federal government, especially in the Lower Basin, could provide an opportunity for overcoming challenges of transparency and decision-making.

Conclusion

This research has built upon previous interstate water compact work by incorporating the eight broad sustainability criteria developed by Gibson et al. (2005). This analysis revealed the importance of several process components—stakeholder participation, transparency, and fairness—when considering decision-making sustainability in the Colorado River Basin. Further, it has drawn on that examination to identify how a focus on those components might support decision-makers in meeting more sustainable outcomes. The results of this research suggest that though previous literature has focused on the need for transparency and stakeholder participation, too much of a focus on either might actually impede sustainable decision-making. Focusing on the process—when specific stakeholder groups should be brought into the process or the potential role of the federal government in reconciling the need for transparency and effective decision-making—might allow decision-makers to better identify and implement more effective outcomes.

Future research could further explore this balance of transparency, stakeholder participation, and decision-making. For example, this research found a somewhat counter-intuitive result in that those stakeholders who were not at the actual negotiating table were more likely to think the process is transparent compared to those at the table. Exploring why this might be the case and seeing how these perceptions compare to other river basins would help further understand transparency and decision-making. Similarly, additional research is needed on how informal negotiations influence these decision-making processes. This research seems to suggest that some level of informality is important, if not necessary, but additional research could focus on balancing the formal with the informal. Another area of future research could focus on additional mechanisms for monitoring these private or informal negotiations. This could include designing and implementing specific boundaries

around those negotiations—both in terms of timing and authority—to allow those decision-makers flexibility and privacy, while also institutionalizing some level of accountability. Finally, while these future research areas should include additional case studies of other river basins, the large data set collected for this project could also be further analyzed to explore these additional research questions.

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