People and Their River Story

By Tinamarie Haskell

Old Dominion University

Executive Summary

The Colorado River Basin (Basin) is experiencing climate change effects and overconsumption which is rapidly decreasing water levels. While concern is growing, it is Indigenous communities who are jumping into action to facilitate change for the Colorado River (River) despite their inability to fully use their water. Indigenous communities face many barriers to their water use regardless of whether they have federally recognized water rights. This case study focuses on the Colorado River Indian Tribes (CRIT) who were the first tribes in Arizona to have their water rights spelled out (Krol, 2022). They were allocated rights to 662,000 acre-feet of the river's flow on the Arizona side and 56,800 acre-feet, plus some, on the California side after their reservation was established in 1865 (Krol, 2022). Since then, they have maintained centuries-long farming traditions while overcoming infrastructural, financial, and legal barriers to using their allocation (Krol, 2022).

This case study began with the decision space where important stakeholders and rules relevant to the Colorado River and the Colorado River Indian Tribes' experience on the River were mapped. The maps produced reflected realistic parameters for decision-making within the Colorado River system. The main stakeholders to note are the government, including Congress, the Department of Interior (DOI), and the Bureau of Reclamation, Indigenous communities, especially CRIT, and the Colorado River Water Users Association (CRWUA). Since the Colorado River is so heavily managed by multiple authorities there are some important rules to consider such as the Winters Doctrine, Arizona v California, the Drought Contingency Plan, and the CRIT Water Resiliency Act. The goal statement was formed after considering each stakeholder and rule; A future where water needs are met while the purpose of the Colorado River and Indigenous Water Rights are respected, protected and well managed.

The wicked problem and the system were understood with a conceptual model. The wicked problem is unique to the Colorado River and the CRIT experience. It is a social planning problem with no true solution, only a range of better or worse solutions. The challenges in the system are the changing climate, overconsumption of water resources and infrastructural, funding, and legal barriers to Indigenous water rights. The conceptual model highlights how governance, climate change, water use, Indigenous communities, and the challenges are connected through feedback loops.

After a thorough understanding of the system, fragilities were easily identified. The main fragilities of the system are the threshold for evaporation, dependence on snowmelt, dependence on water, dependence on water rights, dependence on infrastructure, dependence on skilled personnel, dependence on funding, and dependence on marketing opportunities. The exogenic hazard of climate change and five endogenic hazards were identified from the fragilities including consumption, ignored water rights, lack of proper infrastructure, limited funding, and decreased health. These five endogenic

hazard scenarios were then used to develop a spectrum of possible futures. The spectrum for each scenario includes four futures: collapse, continue, discipline, and transformation. The collapsed future for each hazard would be the worst-case scenario and result in a degraded environment and people, both Indigenous and non-Indigenous, being unable to meet their needs. The transformative future would be a future where the hazards were monitored and mitigated for a reality most closely resembling the goal statement.

Using the spectrum of possible futures, interventions were then carefully developed with the goal statement in mind while also focusing on gathering around the story. The interventions were split into three categories; gathering around the story, decreasing consumption, and government collaboration. Each category had a few interventions to address the various hazards that would make moves toward the goal statement. Table 3 shows each intervention discussed and its pros and cons.

After the pros and cons of each intervention were analyzed and led to the final recommendations which were recommended to several stakeholders including CRIT, governing authorities, and CRWUA. Recognizing that:

- Climate change is causing decreased snow melt and increased evaporation and is largely contributing to low water levels
- CRIT and Indigenous communities must overcome many barriers to their water despite recognized water rights
- Overconsumption is the main threat to the Colorado River Basin
- Gathering around stories will provide increased participation and productivity in reaching a desirable future

Acknowledging that:

- The Colorado River Basin is heavily managed by multiple stakeholders
- Addressing Colorado River water use and allocations will not be easy to accomplish
- The government and other organizations like CRWUA are giving voices to Indigenous communities
- CRIT is in a position that may pave the way for other Indigenous communities

The following interventions are recommended to Congress, CRIT, and CRWUA for implementation:

- hosting a Colorado River Indian Tribes Gathering to use stories as a tool for decision making
- including story exercises in CRWUA meetings
- non-Indigenous migration out of the Basin is encouraged by federal, state, and local governments
- introducing limitations on water use for agriculture and supporting less consumptive farming practices
- quickly resolving Indigenous water rights
- passing the Colorado River Indian Tribes Water Resiliency Act of 2021

Table 3: Interventions addressing the hazards and possible future scenarios and its main pros and cons.

Intervention	Pros	Cons
Colorado River Indian Tribes Gathering	increased participation, perspectives, productivity, understanding, and advocation	costly event, time commitment
CRWUA	increased participation, productivity, and advocation	awkward approach
Raising Tribal Voices	increased participation, productivity, and advocation	awkward approach, time commitment
Outsource	water for Basin, decreased demand	costly, demand on other sources
Migration	decreased consumption, do not displace Indigenous communities	uproot non-Indigneous people, government will need to provide support
Agriculture	decreased consumption, water saving practices to maintain production	affect livelihoods, decrease economy, decrease local food availablity
Municipal Water	decrease consumption	costly, minimal decrease
Resolving Water Rights	all Indigneous communities have rights and access to water	difficult to divert water in current River conditions
Passing S.3308	increase CRIT's revenue and financial freedom	water users will have to pay for CRIT's water
Providing Aid for Infrastructure	upgrade infrastructure, increase access to water	costly

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1 Introduction

1.1 Study Area

The Colorado River Basin (Basin) takes up 246,000 square miles in seven states, including Wyoming, Colorado, Utah, New Mexico, Arizona, Nevada, and California, and Mexico (Figure 1) (Stern et al., 2022). The 1,450-mile-long river (American Rivers, 2022) supplies water to nearly 40 million people

(Stern et al., 2022) and brings in $1.4 trillion in annual economy (American Rivers, 2022). However, it is widely known that the Colorado River (River) water uses exceeds the River's natural flows (Stern et al., 2022).

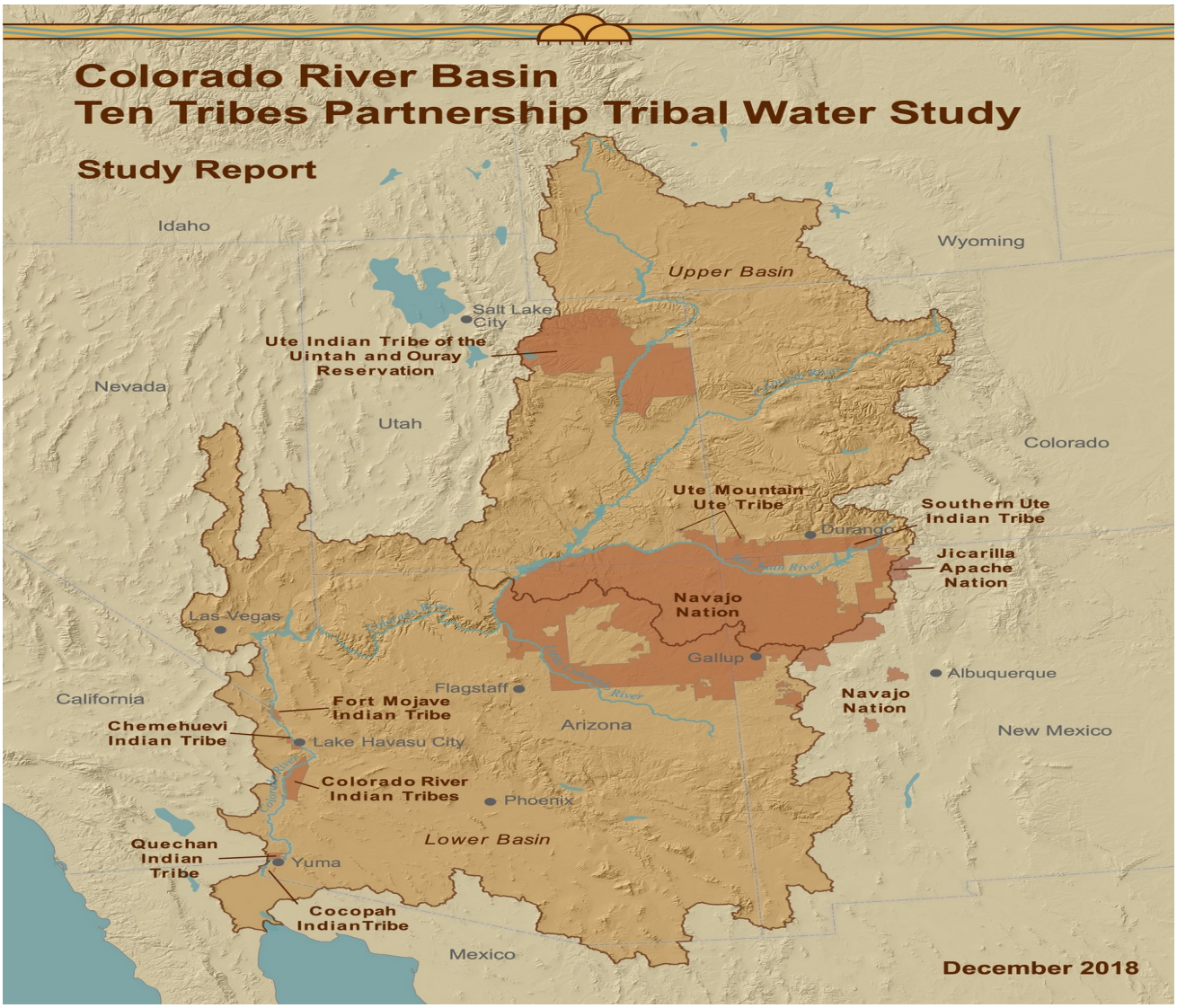

Figure 1: Map of Colorado River Basin (USBR, 2018).

There are many Indigenous communities along the Colorado River and many more within the Basin that would benefit from its tributaries and prosperity. Tribes in the Colorado River Basin have quantified rights to about 20% of the annual average water supply (Colorado River Research Group, 2016). However, many tribes still have outstanding claims while many who do have claims are not fully using the water allocated to them (Colorado River Research Group, 2016). Unfortunately, tribes of the Colorado River Basin know all too well the consequences of empty taps on economies, communities, and life (Krol, 2022). As a result, tribes are prepared to be a part of the solution to decreased water sources caused by drought and climate change (Krol, 2022).

Over 150 miles west of Phoenix, Arizona, lies the Colorado River Indian Reservation (Reservation) (Figure 2) (USBR, 2018). The land, originally inhabited by the Mohave and the Chemehuevi, was established as a reservation in 1865 by the federal government (USBR, 2018). Later, in the 1940s and 1950s, the Hopi and Navajo tribes were relocated to the Reservation (USBR, 2018). The Reservation includes 353 square miles in Arizona and 66.7 square miles in California (USBR, 2018). The Reservation also has over 113 miles of shoreline along the River – which serves as life-sustaining cultural and economic focal points for the Colorado River Indian Tribes (CRIT) (USBR, 2018). CRIT water rights were quantified with the Arizona vs California decision (Armao, 2021). Since then, CRIT has secured diversion rights to more than 700,000-acre feet of water (Armao, 2021).

Figure 2: Map of the Colorado River Indian Reservation (CRIT, 2009).

This case study focuses on the Colorado River and its users facing a historic drought and climate change effects. Currently, the government, non-Indigenous communities, CRIT, and other Colorado River stakeholders are navigating water rights, water needs, and the potential future of the River on the Colorado River Indian Reservation. Gathering around this story can be the turning point for Indigenous communities, water needs, River protection, and Basin prosperity. This case study aims to convince CRIT, the government, and the CRWUA to follow through with the recommendations presented to reach a transformative future.

1.2 Case Study Template

The Mitigation and Adaptation Research Institute (MARI) Case Study Template (Plag, 2021) was used to carry out this case study. This template was developed for the Conservation Leadership program at Old Dominion University, where students learn to address wicked problems while integrating natural, physical, and social sciences.

Following the template, research of the background information and answering questions on who and what was being studied happened first. Then the decision space was mapped, where the stakeholder map, rules map, and understanding of our wicked problem were developed. Next, fragilities and hazards that can affect the system were identified. Foresight was then developed once the potential hazards and their impact on the future were understood. Possible futures were then explored, both desirable and undesirable. Using transformation knowledge, interventions that could lead the systems toward a more desirable future were developed. Finally, after weighing the pros and cons of the interventions, recommendations were formulated to help the stakeholders meet the goal statement.

2 Societal Context and Decision Making

2.1 Societal Context

The Basin has been in a long-term drought since 2000 and it has been estimated that 2000 to 2018 has been the driest period in the last 100 years of records (Stern et al., 2022). Flows in the Colorado River Basin have decreased significantly during this time. Natural flows used to average about 14.7 million acre-feet annually but from 2000 to 2020 have only averaged 12.5 million acre-feet annually (Stern et al., 2022). The Bureau of Reclamation declared the first level one shortage condition for the lower basin in August 2021 and in August 2022 they announced the first level two shortage condition. This condition declaration led to water supply delivery cutbacks (Stern et al., 2022).

There are about 4,277 members of CRIT with the primary community in Parker, Arizona (USBR, 2018). Although they have many water uses, most of their allocation still goes unused and becomes water for central Arizona farmers (Armao, 2021). The Colorado River Indian Tribes attempt to generate revenue with their water rights but still sacrifice their water to conserve 150,000-acre feet of water for Lake Mead and minimize cutbacks for lower priority users (Armao, 2021). For their help, they are receiving $38 million mostly from the state of Arizona but still hit legal limitations for using their water and still suffer from a lack of infrastructure (Armao, 2021). As a result, the Colorado River Indian Tribes have begun advocating for themselves and the River. In 2021, S.3308 – Colorado River Indian Tribes Water Resiliency Act of 2021 was introduced to congress and the CRIT Chairwoman, Amelia Flores, submitted a testimony to the House Subcommittee on Water, Oceans, and Wildlife to fight for their right to decide how to best use their water.

Table 1: Main stakeholder groups and their level of interest and influence. Interest and decision-making authority (influence) is briefly explained for each stakeholder.

Stakeholder	Level of Interest	Interest	Level of Influlence	Decision Making Authority
Congress	Mid	social and economic value	High	oversees Basin operations, regulates River
Bureau of Reclamation	Mid	social and economic value	High	Basin management, enforces regulations
CRWUA	High	direct users of the River	High	gathers stakeholders for decision making
CRIT	High	cultural, direct users of the River, water rights	Mid	resources to fight for change
Indigenous Communities	High	cultural, direct users of the River, water rights	Low	provide support to those fighting for relevant change
Non-Indigenous Communities	Low	direct users of the River, consumptive culture	Mid	provide support to those fighting for relevant change
Colorado River	High	fulfil its purpose	Low	changes to resource accessibility

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To fully understand the social dynamics around the river, Table 1 explains the main stakeholders and their role in the system. Congress and the Bureau of Reclamation are mainly interested in protecting the social and economic value of the River. They have the highest authority over the River's usage. The Colorado River Water Users Association (CRWUA) often gathers stakeholders to discuss decisions and care about the River as direct users. CRIT and other Indigenous communities are interested in building back their culture around the River and gaining full rights over their water. CRIT is in a more advantageous position to create change for themselves and other Indigenous communities because of their history and allocation rights. Other Indigenous communities still have the power to support those that are fighting for change relevant to their values. Non-Indigenous communities, although direct users of the River, don't experience the same connection to the River as Indigenous communities. Non-Indigenous people often participate in consumptive culture, but they still have the power to rally behind those who fight for changes relevant to their values. The Colorado River's purpose is to be a river. Although the River cannot present an argument, the River can continue to respond to overconsumption and climate change in negative ways, hopefully sending signals to the benefiting from it.

2.2 Decision Space

The decision space is where the stakeholders are mapped in detail based on their interest, influence, and understanding of the roles of the stakeholders. The rules and regulations that govern the stakeholder's decisions are considered, understood, and mapped. This is important to maintain the realistic parameters that the stakeholders make decisions within and to identify the stakeholders to whom recommendations should be made. Mapping the decision space takes a participatory modeling

approach, meaning system dynamics and context are considered while including all interested parties in the decision-making processes (Plag, 2021). Essentially, the decision space develops parameters, agreed upon by all stakeholders, for the decision makers to work in and make informed recommendations.

2.2.1 Stakeholder Map

There are many stakeholders involved in the Colorado River Story. Figure 3 maps all relevant stakeholders. The Bureau of Reclamation, part of the Department of Interior, has an important role in the basin's management (Stern et al., 2022). The Bureau of Reclamation is funded and overseen by Congress for facility operations and programs to protect and restore endangered species (Stern et al., 2022). The Bureau of Reclamation is also the water master of the Lower Basin which gives the federal government a principal role in the Lower Basin management (Stern et al, 2022). The Lower Colorado River Basin Region has a Native American Affairs Program and manager within the Bureau of Reclamation (USBR, 2020). This program is meant to provide financial and technical assistance to Indian Tribes within the region to develop and maintain reliable and sustainable water supplies (USBR, 2020).

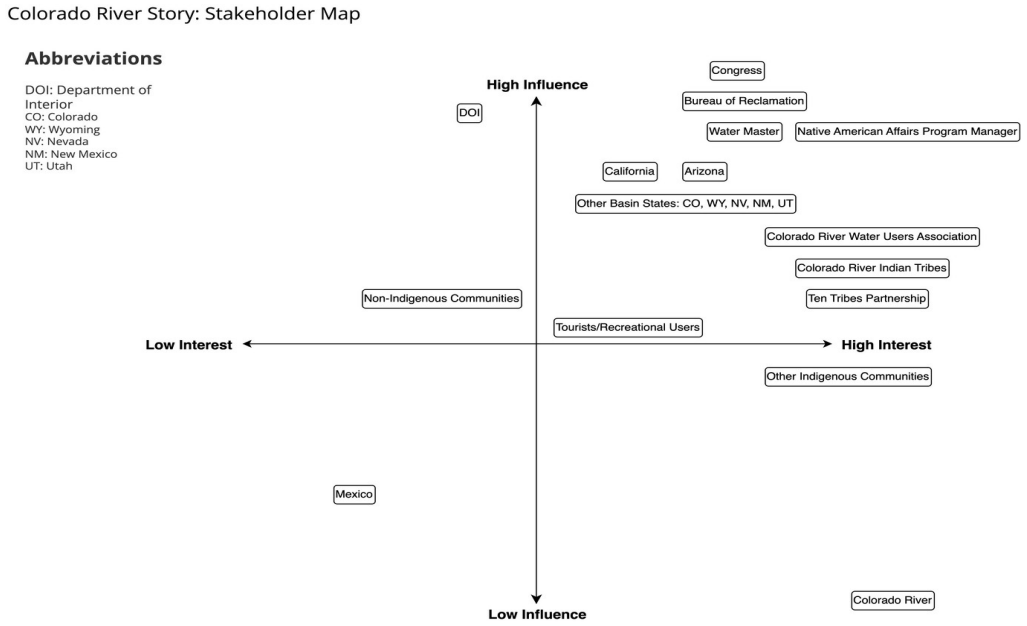

Figure 3: Stakeholder map indicating the interest and influence of all stakeholders. The vertical axis represents the amount of influence each stakeholder has in the Colorado River Story and the horizontal axis represents the amount of interest the stakeholder has in the Colorado River Story.

After more than 100 years of tribes' water rights claims being dismissed, there is now willingness from the federal government to work with tribal governments as equal partners in stewarding water from the Colorado River (Krol, 2022). Indigenous communities along the River have a stake in the Colorado River story which can be seen in the critical role that was played by many tribes in implementing the Drought Contingency Plan (Krol, 2022). The Colorado River Indian Tribes are also willing to work with stakeholders as they have left part of their allocations in Lake Mead to help keep water levels from

dropping which can be attributed to the first shortage declaration delay (Krol, 2022). However, the Colorado River Indian Tribes have their own stake and seek to share their water with other state users through leases (Krol, 2022).

Although the Colorado River Indian Tribes occupy a 300,000-acre reservation along the Colorado River that extends into both Arizona and California (Krol, 2022), other Basin states and Mexico also have a stake in the Colorado River story. Non-Indigenous communities, tourists, and recreational users all rely on the Colorado River for different uses as well.

The Colorado River Water Users Association (CRWUA) is a nonprofit, nonpartisan organization that gathers Colorado River Stakeholders to exchange ideas and perspectives on the River's use and management with the intention to advocate for common objectives and face the prolonged droughts and hotter, drier future while protecting the Colorado River (CRWUA, 2020). The CRWUA has included three tribal representatives on the board of trustees for a few decades and has made significant strides to improve its relationship and communication with the Tribes (CRWUA, 2020). Much of the tribal recognition and progress within the CRWUA can be attributed to the Ten Tribes Partnership (CRWUA, 2020). The Ten Tribes Partnership was formed by ten federally recognized Tribes, including CRIT, with federally reserved water rights in the Basin (USBR, 2018). The Ten Tribes Partnership was formed to strengthen tribal influence within in the Basin States over the management and use of the Colorado River and its resources (USBR, 2018). The Ten Tribes Partnership ship also supports their Tribes' efforts to develop and protect tribal resources as well as address legal, economic, and infrastructure barriers related to their water rights (USBR, 2018).

Most importantly, the Colorado River itself has a stake in the story. "The purpose of a system is what it does," (Beer, 2002). Therefore, the Colorado River system has a right to be a river and serve the purpose of a river.

2.2.2 Rules Map

The Colorado River is heavily managed and operated under numerous compacts, federal laws, court decisions and decrees, contracts, and regulatory guidelines – together known as the "Law of the River" (USBR, 2015). These rules and regulations apportion the water and manage the use of the River among the basin states and Mexico (USBR, 2015). Below, Figure 4 maps relevant Laws of the River and other rules and regulations. The most important rules and regulations are then discussed in chronological order.

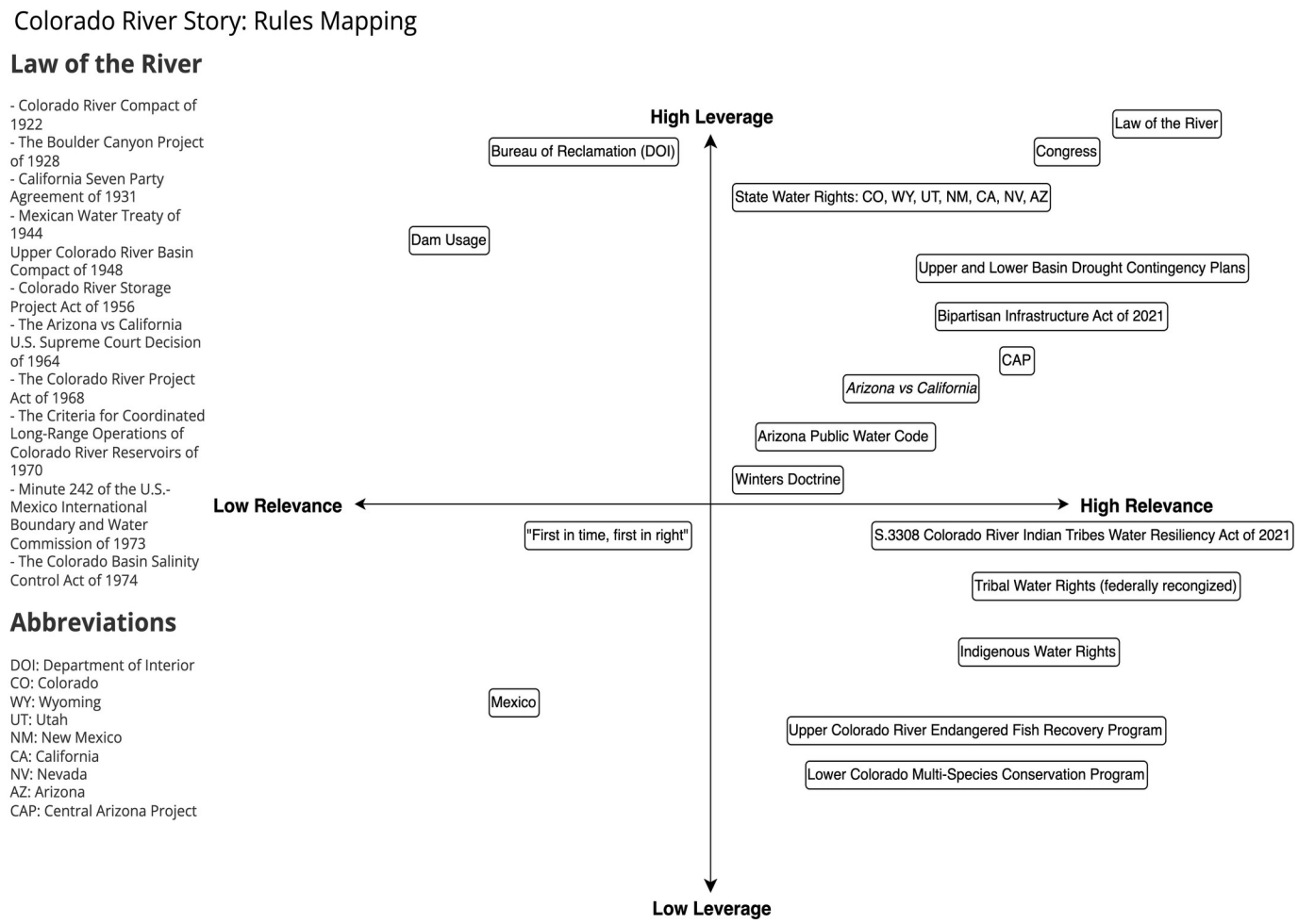

Figure 4: Rules map indicating the leverage and relevance of regulations and norms applicable to the Colorado River Story. The vertical axis represents the amount of leverage and the horizontal axis represents the amount of relevance.

Before the Law of the River, “first in time, first in right” was the foundation of water use in the west – if you claim the water first you can use it first (Krol, 2022).

In 1908, tribal reserved water rights were recognized by the U.S. Supreme Court for the first time under Winters v. United States (Colorado River Research Group, 2016). This allowed for water rights to exist at the formation of the reservation because water is necessary to establish a permanent homeland and are not affected or lost by use and nonuse (Colorado River Research Group, 2016).

In 1919, the Arizona Public Water Code was established requiring that a person must apply for and obtain a permit and certificate to appropriate (use) surface water and that beneficial uses (domestic, municipal, irrigation, stock watering, waterpower, recreation, wildlife, nonrecoverable water storage, mining) shall be the basis, measure, and limit to the use of water within the state (ADWR, 2022).

The Colorado River Compact of 1922 established the upper and lower basin, dividing line at Lee Ferry,

Az (Stern et al., 2022). Each basin state was allowed 7.5 million acre-feet annually and the upper basin could not deplete more than 75 million acre-feet over any 10-year period (Stern et al., 2022). Tribes were mostly left out except for a small reference to federal reserved water rights (Krol, 2022).

In 1928 the Boulder Canyon Project Act modified the Colorado River Compact by authorizing the construction of the Hoover Dam and other facilities to bring water to Southern California (Stern et al., 2022). 7.5 million acre-feet were allocated to the three lower states and the Secretary of Interior was directed to be the sole contracting authority for the lower basin (Stern et al., 2022). Subsequently, Lake Mead was created for flood control, water storage, and the generation of electricity (Krol, 2022).

In 1944, the US-Mexico Water Treaty was signed. This treaty discerned the water allocations for the two countries and would be governed by the International Boundary and Water Commission (Stern et al., 2022). The Treaty stipulated that the US would provide Mexico with 1.5 million acre-feet annually plus additional when a surplus is declared (Stern et al., 2022). However, during drought delivery may be reduced proportionally to US reduction (Stern et al., 2022).

The Upper Colorado River Basin Compact of 1948 determined water allocation to the upper basin states (Stern at al., 2022). It established the Upper Colorado River Commission to administer the provisions and Colorado was established as the largest entitlement holder in the upper basin (Stern et al., 2022).

The Colorado River Storage Project (CRSP) Act of 1956 authorized storage reservoirs and dams as well as the Upper Colorado River Basin Fund for project costs and the Lower Colorado River Basin Development Fund (Stern et al., 2022).

In 1963, Arizona v. California finally settled and split the water surplus between Arizona and California (Stern et al., 2022). During this decision, the Secretary of Interior designated a water master for the lower basin (Stern et al., 2022). Native American reservations were finally entitled to priority as recognized tribal reserved water rights under the Winters Doctrine were to be present perfected rights (Krol, 2022). Arizona v. California was the first time tribal water rights were quantified and included in the reservation’s state’s allocation to water (Colorado River Research Group, 2016). Additionally, the Central Arizona Project (CAP) was authorized to be built for water distribution and now delivers water to more than 80% of the state’s population (CAP, 2022). However, to win California’s support, California’s water allocation has priority over CAP (Stern et al., 2022).

In 2019, the Drought Contingency Plan outlined strategies to address the historic drought in which Tribes played a significant role in developing (Krol, 2022).

The Bipartisan Infrastructure Act 2021 provided $2.5 billion to settle water rights claims including $224 million for tribes in Arizona (Krol, 2022).

The Colorado River Indian Tribes Water Resiliency Act of 2021 is currently in congress. The act is

written to authorize the Colorado River Indian Tribes to enter into lease or exchange agreements and storage agreements relating to water of the Colorado River allocated to the Colorado River Indian Tribes, and for other purposes.

2.3 Goal Statement

Each stakeholder should have their perspective towards a future they would like to reach considered when developing a goal statement. Common objectives between stakeholders were used to develop an individual statement that considered all stakeholders' influence and interests. The final goal statement formed was agreed upon by all with minimal sacrifice and reasonable compromise.

Iteration 1: *Indigenous and non-Indigenous communities come together with local and federal governments to manage and protect the purpose of the Colorado River*.

Iteration 1 focused more on a process rather than a future that did not meet all the stakeholder's interests.

Iteration 2: *A future where the purpose of the Colorado River and Indigenous Water Rights are respected, protected, and well-managed*.

Iteration 2 lacked focus on meeting water needs which was an important aspect of the Colorado River system and to the stakeholders.

Iteration 3: *A future where water needs are met while the purpose of the Colorado River and Indigenous Water Rights are respected, protected, and well managed*.

Iteration 3 considered all stakeholders and their interests and was the agreed upon goal statement.

3 Wicked Problem and Conceptual Model

3.1 Wicked Problem

This case study aims to build a story around the Colorado River Indian Tribes and their fight for water rights while protecting the purpose of the Colorado River. However, many other stakeholders are involved and must be considered, especially the water needs of non-Indigenous communities. Social planning problems such as this are considered "wicked problems" as defined by Rittel et al. (1973). It is important to note that, for a wicked problem, there is no set of solutions to pick from. Every wicked problem is unique to itself, and no two wicked problems are the same – accordingly, their solutions will always be tailored to the specific situation. Possible solutions to these problems are not true-or-false, but better or worse (Rittel et al., 1973). Furthermore, different stakeholders have their own perspectives on the problem and the framing of the problem shapes the possible solutions.

Colorado River water starts as snowpack in the southern Rockies (Armao, M., 2021). Snowmelt then

flows into tributaries in Utah, Wyoming, and Colorado (upper basin) providing water for the Basin (Armao, M., 2021). However, the Colorado River Water Compact of 1922 was based on one of the wettest 10-year periods and essentially established a permanent deficit thereafter (American Rivers, 2022). On top of the usage deficit, climate change has been shrinking the Colorado River for many years (Milly et al., 2020). Both snow loss and evaporation have increased with warming temperatures (Milly et al., 2020).

The Basin's water is used for agricultural irrigation, municipal and industrial uses, as well as hydropower, fish and wildlife, and recreational uses, but 70% of all usage is for the irrigation of 5.5 million acres of land (Stern et al., 2022). Recently, the Colorado Research Group acknowledged that existing uses of the water exceed supplies and that other water users are concerned about including tribal water rights in future uses of the basin water (Colorado River Research Group, 2016). Consequently, there is a lot of tension between the Indigenous fight for water rights and the need for less water consumption (Armao, M., 2021). Yet, Tribal claims to water were mostly ignored until the 1960s, and even with resolved rights, there are many barriers to their water use such as a lack of infrastructure, funding, and legal options (Armao, M., 2021). When tribes do not use their allocated water (because they cannot) it doesn't go unused, it is taken to cities and agricultural fields with no compensation to the tribes (Armao, M., 2021). Many Tribes lack the political power to advocate for their water and policymakers allocated water to non-Indigenous farmers, miners, and city builders without considering the Indigenous need for or right to water (Krol, 2022). Now, Tribes that have settled their water claims have to hold agencies accountable and many of these Tribes have yet to see any water because the government has not provided money to build infrastructure (Krol, 2022).

The Colorado River enters the Colorado River Indian Reservation at the northern boundary and flows to the south (Figure 2) (USBR, 2018). The Colorado River Indian Tribes' water is regulated by three dams and levees constructed and maintained by the Bureau of Reclamation (USBR, 2018). The Reservation only sees about five inches of rain annually which means CRIT depends heavily on the River for their floodplain and irrigated agriculture (USBR, 2018). The Colorado River Indian Tribes was the first tribe in Arizona to have their water rights spelled out (Krol, 2022). While they still face many challenges, they have since been able to develop their land for agriculture and leasing agreements which brings in revenue for CRIT (USBR, 2018). Most of CRIT's water goes towards irrigated agriculture and livestock diversion and only about half of their diversion rights are consumptive use (USBR, 2018). Much of their diversions are still left unused (USBR, 2018). Because of the water they do use, they incorporate a sense of balance in their use so people, plants, and animals all have enough to live well, for generations to come (USBR, 2018). To maintain caring for their land, CRIT has addressed conservation efforts by setting aside land and developing preserves as well as participating in conservation programs outside the Reservation (USBR, 2018).

3.2 Conceptual Model

To achieve the desired future, the system must first be understood. Conceptual models enable a full understanding of a system and its main feedback loops. In Figure 5, the Colorado River system is outlined and highlights governance, climate change, water use, and Indigenous communities to better

understand the connections within the system relevant to the Colorado River Story. Figure 5 also highlights the stakeholders who will need to unify around the story so significant changes can be made to reach the goal statement.

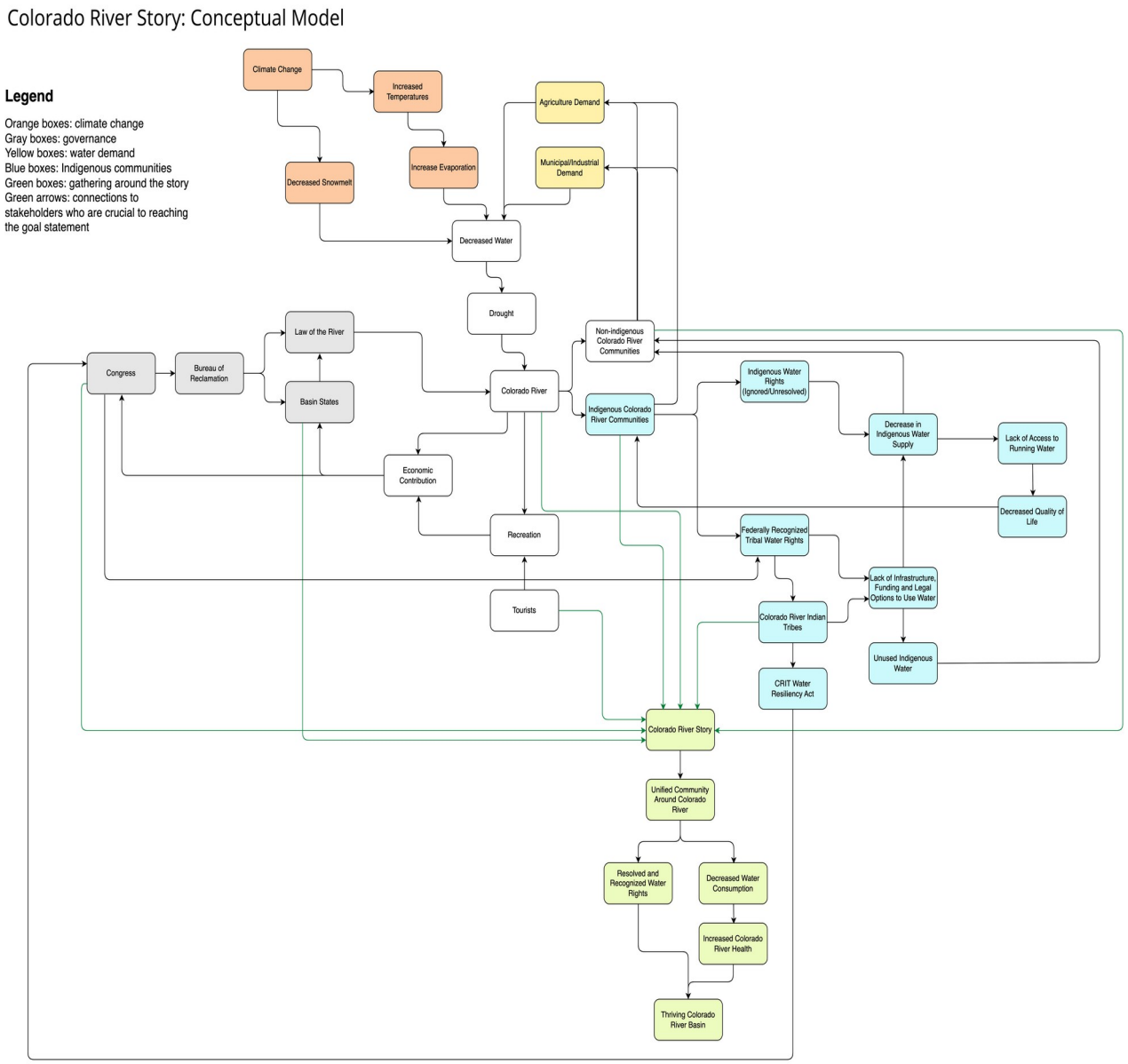

Figure 5: The conceptual model representing the Colorado River system. Gray boxes indicate governing bodies. Orange boxes indicated climate change. Yellow boxes indicate water demand. Blue boxes indicate the Indigenous communities system. Green arrows indicate the stakeholders connected to the Colorado River Story who are crucial to reaching the goal statement and green boxes indicate how gathering around the story can reach a desirable future.

The model, Figure 5, begins with a brief breakdown of the governance system (gray). Congress regulates the River and the Bureau of Reclamation enforces the Law of the River as well as manages the River usage for the Basin states. Climate change (orange) is affecting both snowmelt, which is decreasing, and temperature, which is increasing and causing increased evaporation. Both of these are contributing significantly to the drought the River is facing. Overconsumption also significantly contributes to the drought and water demand (yellow) is mostly from agriculture, municipalities, and industries. Indigenous communities (blue) either have federally recognized water rights or Indigenous water rights which are currently being ignored. Regardless, they both face access issues to their water which allows their water to be used by non-Indigenous communities without compensation. However, CRIT is currently fighting for full use of their water with the CRIT Water Resiliency Act that is active in congress. Finally, the goal statement (green) could be reached if the stakeholders (green arrows) gathered around the story to make transformative changes.

4 System Fragilities

This section describes the fragilities relevant to the Colorado River systems and the Colorado River Indian Reservation. Fragilities are parts of a system that are capable of being harmed; they are inherent to the system and exist independently of time or outside forces. If time were to stop, the risk is diminished, and any hazards would disappear.

Threshold for evaporation

The decline of water levels in the Colorado River can be attributed to evaporation (American Rivers, 2022). Due to water's properties, it has the ability to evaporate, and evaporation will increase with increased temperature.

Dependence on snowmelt

The level and conditions of the water in the Colorado River are largely dependent on snowmelt from the northern areas of the basin (Stern et al., 2022).

Dependence on water (and water levels)

All life is dependent on the availability of water. Both biota and humans need water to survive – specifically, humans need clean freshwater sources to maintain health. Water levels in the Colorado River are crucial to the 40 million people within the Basin who rely on the River as their water source (Stern et al., 2022).

Dependence on water rights

Indigenous communities, as humans, need freshwater sources to support life. Access to clean fresh water for these communities is largely dependent on whether their water rights are recognized federally.

Dependence on infrastructure

Access to water is highly dependent on the infrastructure available. Infrastructure allows water to be delivered to various communities, but efficiency and loss are dependent on the quality of the

infrastructure (USBR, 2018).

Dependence on funding
High-quality infrastructure is dependent on the availability of funding to repair, replace, or build infrastructure (USBR, 2018).

Dependence on marketing opportunities
Funding is dependent on the ability to bring in revenue through opportunities to market goods and services (USBR, 2018).

Dependence on skilled personnel
Operation, maintenance, and management of infrastructure are dependent on the availability of trained individuals with unique skills (USBR, 2018).

5 Hazards and Threats

A hazard is an event or entity that can act upon a system's fragilities and disrupt or degrade the system. There are two types of hazards, exogenic and endogenic. Exogenic hazards originate outside of a system and act upon it. Endogenic hazards originate within a system, usually from an exogenic hazard acting upon a fragility and creating another hazard. Table 2 shows the hazards and the fragilities they can exploit.

Table 2: Fragilities related to their relevant hazards. Decreased health is shown as a consequence because if all fragilities are exploited by the hazards, then the consequence is decreased health. For the purpose of this case study, decreased health is also considered a hazard because of the consequences it has on the environment and its communities.

Fragilities	Hazards	Consequence
threshold for evaporation	climate change	Decreased Health
dependence on snowmelt		
dependence water (and water levels)	consumption	
dependence on water rights	ignored water rights	
dependence on infrastructure	lack of proper infrastructure	
dependence on skilled personnel		
dependence on funding	limited funding opportunities	
dependence on marketing opportunities		

5.1 The Exogenic Hazard: Climate Change

The exogenic hazard in the Colorado River system is climate change. As climate change increases temperatures in the Basin, water will continue to evaporate from the River at a higher rate (Milly et al., 2020). Snowmelt has decreased with increased temperatures and even with predicted changes in precipitation patterns, it will not be enough to maintain flow in the River with the rate of evaporation (Milly et al., 2020). It is expected that climate change will reduce River flow 10% to 30 % by 2050 (American Rivers, 2022).

5.2 The Endogenic Hazards

The following hazards occur from within the system.

5.2.1 Consumption

As populations have increased since the 1922 Colorado River Compact, which already regulated use in a deficit, water needs, and usage has only increased. Despite the recognition that water use outweighs flow, dams and diversions continue to be planned even though 50% of headwater flows in the upper basin is already diverted (American Rivers, 2022). Currently, the lower basin is in a 1-million-acre-foot deficit and in danger of running dry (American Rivers, 2022).

5.2.2 Ignored Water Rights

Federal water laws and regulations should have guaranteed that the first water users of the Colorado River would continue to have their share of water, but this hasn’t been the case (Krol, 2022). Ignored water rights will continue to lead to decreased water access in Indigenous communities and adversely affect their quality of life.

5.2.3 Lack of Proper Infrastructure

It is extremely difficult to access water without proper infrastructure. Older infrastructure suffers from both design limitations and aging problems which causes decreased efficiency and increased loss (USBR, 2018). Without proper infrastructure, operation, and maintenance, CRIT’s and other Tribes’ ability to realize the full potential value of their water is limited (USBR, 2018).

5.2.4 Limited Funding Opportunities

Repairing, replacing, and building infrastructure is expensive (USBR, 2018). CRIT and other Tribes are burdened with identifying inefficiencies and determining the most cost effective solution but are then still limited by their inability to market their goods and services when it comes to their water allocation (USBR, 2018). Even though CRIT has federally recognized water rights and fairly well-developed water usage, they are unable to market their unused water (which is used outside of the Reservation by non-Indigenous communities) for revenue because it was not addressed by the courts (USBR, 2018).

5.2.5 Decreased Health

Water is necessary to maintain human health in a variety of ways. Most importantly, there is the need to consume water to avoid dehydration and dehydration-related illness. However, water access is

important for hygiene. For example, when COVID-19 began to spread, Indigenous communities were more vulnerable to the virus because of their decreased access to water (Krol, 2022). Because there was not enough water for frequent handwashing, there was limited virus prevention and protection (Krol, 2022). Water is also necessary to support the River and its ecosystem's health. A healthy ecosystem is what provides the environmental services, such as clean water, that life depends on.

6 Foresight and Possible Futures

Each hazard comes with a spectrum of possible futures. Possible futures can range anywhere from plausible to implausible and desirable to undesirable. The four archetypal futures are used to explore each hazard. These four futures are collapse, continue, discipline, and transformation.

Since climate change is an exogenic hazard to this system, each of the endogenic hazard futures will need to consider the effects of climate change. For the purpose of this case study, the possible futures of climate change will not be explicitly discussed.

The following outlined possible futures provide realistic foresight for each hazard.

6.1 Consumption

Collapse: Consumption increases without regard for the River water levels and the inability of the River to naturally replenish its water. With climate change and overuse, the Colorado River dries up quickly and can no longer support inhabitants and agriculture within the Basin. River health is diminished.
Continue: Consumption needs increase with increasing population, but water levels are closely monitored. When water levels decrease to predetermined thresholds, the Drought Contingency Plan is enacted accordingly, and cutbacks are enforced. Cutbacks negatively affect Indigenous communities first since they already have limited access to their water. Prolonged drought continues to occur because of need and climate change. River health is poor. Authorities begin searching for water resources elsewhere.
Discipline: Mass consumption cutbacks occur for all water users to maintain water levels in the River to combat climate change effects. Indigenous communities are considered in cutbacks and access to water is provided based on need. River health is stable.
Transformation: Colorado River water use is decreased to below the River's threshold and the River can replenish its water naturally. It is determined the Basin is unable to maintain the needs of all inhabitants and non-Indigenous migration out of the Basin is encouraged. Indigenous communities no longer suffer from a lack of water. River health is thriving.

6.2 Water Rights

Collapse: The government determines Indigenous water rights are not necessary and appeals all previous court rulings. Indigenous communities no longer have rights to water and all previous allocations are diverted for non-Indigenous water needs and uses.
Continue: Indigenous water rights are slowly being rectified by the government but additional help to

ensure water allocations are obtained is not being provided.
Discipline: All Indigenous water rights are recognized federally and additional help to ensure water allocations obtained is there but limited.
Transformation: Indigenous communities are supported by the government until Tribes are satisfied with their access and ability to use their water.

6.3 Infrastructure

Collapse: Indigenous infrastructure is left untouched and begins to fail due to age and lack of maintenance. Indigenous communities are left without infrastructure.
Continue: Indigenous water infrastructure is monitored, and deficiencies are acknowledged by authorities. Tribes remain unable to fix or build their infrastructure.
Discipline: Indigenous communities receive help to fix or build infrastructure, however, they remain unable to maintain the infrastructure for the future.
Transformation: Indigenous communities are able to fix and build infrastructure as needed. They have access to the personnel needed to operate, manage, and maintain their infrastructure.

6.4 Funding

Collapse: Indigenous need for funding is ignored. Indigenous communities have limited methods to obtain revenue.
Continue: Indigenous need for funding is recognized. The government provides limited compensation for some actions or services. Indigenous communities are still unable to bring in stable revenue.
Discipline: The government allows Indigenous communities to lease unused water allocations for revenue. The government's funding is still limited.
Transformation: Indigenous communities have stable revenue because they are allowed to transfer water for off-reservation use and increase revenue. The government fully supports Indigenous communities until they are financially stable.

6.5 Health

Collapse: Access to clean freshwater is limited and a public health crisis occurs. Indigenous access to water is near non-existent. The River's health is diminished and the Basin can no longer support inhabitants.
Continue: Most non-Indigenous communities have access to more than enough freshwater. Indigenous communities still struggle with access to water and are susceptible to diseases. The River's health is low but can still support inhabitants.
Discipline: Basin inhabitants including Indigenous communities have equal access to too much water. River health is low but can still support inhabitants.
Transformation: Indigenous and non-Indigenous communities have equal access to an appropriate amount of water. River health is high and is supporting its inhabitants and ecosystem.

A collapsed future would be the worst-case scenario because the River's ecosystem would be degraded, likely beyond short-term repair, and Basin communities would likely collapse due to a lack of

accessibility to clean fresh water. A transformative future would be the most desirable future as it would be as close to the goal statement as the future could get. A transformative future would consider the River's purpose and the communities along the River's needs, both Indigenous and non-Indigenous. A disciplined future would aim for the goal statement but still have some major flaws. It would be most beneficial to work towards a transformative future for the benefit of all the Basin communities and the River.

7 Interventions

The Colorado River Indian Tribes are suffering from the lack of proper infrastructure and funding to properly use their allocated water on top of the effects of climate change and overconsumption on the Colorado River. Even with the obstacles to their water, CRIT is in a much more advantageous position compared to many other Tribes in the Basin. The aim of the following interventions is to gather the stakeholders around the CRIT story to make positive changes for their future and the future of other Indigenous communities in the Basin while considering both the needs of the non-Indigenous communities and the Colorado River. Table 3 summarizes the interventions and its main pros and cons.

7.1 Gathering Around the Story

Despite the unappealing nature of using stories to discuss serious issues, they can play a powerful role in energizing engagement and understanding (Smith et al., 2017). With the right approach, stories can draw on a variety of fun, memory, emotion, and connections to places, family, friends, or work to expand public conversations about change (Smith et al., 2017). With stories, people who are rarely drawn into explicit conversations about important topics can be included and contribute valuably (Smith et al., 2017). Stories support better foundations for participation and productivity in complex problem-solving with many other benefits such as a more fluid and interdependent understanding of the past, present, and future (Smith et al., 2017) which would be extremely beneficial for all stakeholders involved in the current Colorado River conditions. The power of stories is not that they drive transformation themselves but have the capacity to invite more constituencies to engage and have the motivation and confidence to participate in change (Smith et al., 2017).

7.1.1 Colorado River Indian Tribes Gathering

On the Colorado River Indian Reservation, a two or three day gathering could be held. Specifically, this gathering could be held on the Reservation to bring perspective to stakeholders who have yet to see the Reservation. This gathering could be supported and have representatives from the Bureau of Reclamation, Arizona and California officials, the CRWUA, and other Colorado River authorities. Invited to the gathering could be Indigenous tribes within the Basin, non-Indigenous residents of both the upper and lower Basin, non-Indigenous Basin residents of Arizona and California, recreational users, River municipality and industrial workers, River infrastructure workers, Basin agricultural workers, Colorado River ecological experts, people (Indigenous and non-Indigenous) who are not residents of the Basin, and any others who can bring perspective. At the gathering, several story prompting exercises can be performed. For example, everyone could draw what their idea of a desirable future for the Colorado River would be and then discuss the drawings among the group.

Table 3: Interventions addressing the hazards and possible future scenarios and its main pros and cons.

Intervention	Pros	Cons
Colorado River Indian Tribes Gathering	increased participation, perspectives, productivity, understanding, and advocation	costly event, time commitment
CRWUA	increased participation, productivity, and advocation	awkward approach
Raising Tribal Voices	increased participation, productivity, and advocation	awkward approach, time commitment
Outsource	water for Basin, decreased demand	costly, demand on other sources
Migration	decreased consumption, do not displace Indigenous communities	uproot non-Indigneous people, government will need to provide support
Agriculture	decreased consumption, water saving practices to maintain production	affect livelihoods, decrease economy, decrease local food availablity
Municipal Water	decrease consumption	costly, minimal decrease
Resolving Water Rights	all Indigneous communities have rights and access to water	difficult to divert water in current River conditions
Passing S.3308	increase CRIT's revenue and financial freedom	water users will have to pay for CRIT's water
Providing Aid for Infrastructure	upgrade infrastructure, increase access to water	costly

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Another exercise could examine the infrastructure problem on the Reservation. Participants could use Legos or other building block types to build their idea of a solution and then discuss. These exercises would include all types of participants, even those who may not have specific knowledge because these exercises are about coming together around the story to share anecdotes and ideas from all angles.

Pros:

- increased participation of different stakeholders in necessary change
- increased perspectives on the problems
- increased productivity on developing resolutions
- increased understanding of problems
- increased advocation for communities not usually heard

Cons:

- time commitment
- will require some funding
- large scale event
- will require people to travel

7.1.2 CRWUA

The Colorado River Water Users Association does a decent job at including different stakeholders on their board of trustees and could benefit from applying some story exercises to their meetings. CRWUA aims to be the “venue of choice for productive Colorado River discussions” (CRWUA, 2020). Bringing stories into their meetings could amplify their efforts.

Pros:

- increased participation from their different stakeholders
- unique perspectives they have previously been missing without this approach
- increased productivity in their Colorado River discussions
- increased advocation for Tribes through a deeper understanding
- gives Tribes an alternative to litigation

Cons:

- may be an unappealing awkward approach at first

7.1.3 Raising Tribal Voices in the Government

The government could work more closely with Tribes such as CRIT and the Ten Tribes Partnership who are able to advocate for Indigenous communities and provide more perspective on the issues surrounding Indigenous communities in the Basin. This could be done through story exercises.

Pros:

- increased participation from stakeholders outside the government
- increased understanding of Tribal hardships
- increased advocation for Tribes
- increased productivity for Tribal resolutions

Cons:

- may be an unappealing awkward approach at first
- time commitment

7.2 Decrease Consumption Needs

Climate change effects on the Basin are inevitable and these effects will continue to decrease the Colorado River’s flow despite consumption changes. Regardless of climate change, the Colorado River has a right to flow from the top of the Upper Basin all the way to through its delta in Mexico and into the Gulf of California. The River currently dries up before it even crosses the US-Mexico border (Armao, M., 2021).

7.2.1 Outsource

The Colorado River Basin can begin to look for potential sources of water outside the Basin, such as water delivery or nearby aquifers.

Pros:

- water can still be provided to Basin inhabitants
- decreased demand on the River, increased River Health

Cons:

- delivering water will be costly for both the authorities and residents
- using nearby aquifers would require new infrastructure which will be costly
- nearby aquifers are likely already in use and increased usage could deplete the aquifer
- there may not be enough water nearby to partially support nearly 40 million people

7.2.2 Migration

The federal government, the Bureau of Reclamation, and Basin states can begin to encourage non-Indigenous migration out of the Basin.

Pros:

- decreased consumption needs on the River, increased River health
- Indigenous communities do not get displaced and can continue living along the River
- non-Indigenous people can relocate to many areas with more stable water conditions

Cons:

- non-Indigenous people will have to move from their established homes
- the government may need to provide support to those willing to leave but do not have the means

7.2.3 Agriculture

The federal government, the Bureau of Reclamation, and Basin states can limit the water available for agricultural use and work with organizations like Future Harvest to decrease water use in agricultural practices.

Pros:

- decreased consumptive needs on the River, increased River health
- water saving farming practices can be implemented to maintain production such as
    - rainfall-use efficiency (Turner, 2004)
    - double/multiple cropping (Myint et al., 2021)
    - water efficient crops (Myint et al., 2021)
    - alternate wetting and drying (Pearson et al., 2018)

Cons:

- both Indigenous and non-Indigenous communities may have their livelihoods effected
- decrease in the economic benefit of agriculture
- decrease in local food availability

7.2.4 Municipal Water Conservation

Expanding municipal water conservation can save water throughout the Basin through improved landscaping, water reuse, and water-saving appliances (American Rivers, 2022).
Pros:

- decreased consumptive needs on the River, increased River health
- maintain use without increasing consumption

Cons:

- infrastructure needed for a water reuse system will be costly
- water saving appliances only provide minimal consumption decreases
- water saving appliances will be costly

7.3 Government Collaboration

Because the Colorado River is so heavily regulated by different government entities, it is crucial that the government is actively involved in positive change.

7.3.1 Resolving Water Rights

It has been acknowledged again and again, even with water rights Indigenous communities face many barriers to using their water. Many claims have yet to be resolved. The federal government could make resolving these water rights a priority.
Pros:

- Indigenous communities without water rights would finally be able to use and develop their water
- increased access to water
- increased hygiene, decreased risk of disease

Cons:

- in current overconsumption conditions it may be hard to find water to divert to Indigenous communities
- resolving water rights may make overconsumption conditions worse

7.3.2 Passing S.3308

The government could pass the Colorado River Indian Tribes Water Resiliency Act of 2021.
Pros:

- authorized lease or exchange and storage agreements for CRIT’s allocation
- allows CRIT to bring in revenue through their unconsumed and unused water
- additional revenue can be used towards upgrading and building better infrastructure
- passing this act could pave the way for other Tribes to be able to do the same with their water and become more economically stable

Cons:

- water users who were benefiting from unused Tribal allocations may now have to pay for water use

7.3.3 Providing Aid for Infrastructure

The government could provide grants or other funding to CRIT and other Indigenous communities to aid in developing better infrastructure.
Pros:

- Tribes can upgrade or build infrastructure that better suits their needs
- better infrastructure can increase efficiency and decrease water loss (decreased consumption)
- increased access to water
- increased hygiene, decreased risk of disease

Cons:

- funding infrastructure would be costly
- funding may be difficult to find

8 Discussion and Conclusions

Reaching the goal statement requires all the stakeholders to come together and develop strategic plans that benefit each other. Here is where everyone needs to begin gathering around the story. As water sources decrease, Tribes of the Colorado River are conveying that everyone is in this together (Krol, 2022). However, the stakeholders need to consider that Indigenous people won't just focus on water as a commodity (Krol, 2022). Tribes will be focusing on their values – the spiritual and cultural aspects to their work on the river (Krol, 2022). It is apparent that Indigenous communities, especially CRIT, have been considering all the stakeholders from the beginning. Recently, CRIT assumed a major role in the Drought Contingency Plan by pledging to fallow farmland so they can contribute 150,000 acre-feet (50,000 acre-feet supports 100,000 households) from 2020 to 2022 to maintain water levels in Lake Mead. So, despite their inability to use their water allocations fully, despite their inability to use their water revenue – CRIT still sacrifices their water for the betterment of the Colorado River Basin, and they are not alone. Tribes within the basin are playing a crucial role in drought management and fortunately, now both the government and non-Indigenous organizations like the CRWUA are bringing Tribal voices to the forefront. This is a pivotal point in time when coming together around the story can make positive changes that will lead to a transformative future for the Colorado River Basin.

9 Recommendations

After mapping the decision space, defining the wicked problem, determining the fragilities and hazards, expanding on possible futures, and developing interventions, recommendations are made as a means to reach a desirable future. The goal of the recommendations is to implement the most effective, feasible, and ethically sound interventions. The goal statement for this case study is *a future where water needs are met while the purpose of the Colorado River and Indigenous Water Rights are respected, protected, and well managed*. These recommendations are made to reach the goal and will benefit not only CRIT and other Indigenous communities, but the entire Colorado River Basin.

Recognizing that:

- Climate change is causing decreased snow melt and increased evaporation and is largely contributing to low water levels
- CRIT and Indigenous communities must overcome many barriers to their water despite recognized water rights
- Overconsumption is the main threat to the Colorado River Basin
- Gathering around stories will provide increased participation and productivity in reaching a desirable future

Acknowledging that:

- The Colorado River Basin is heavily managed by multiple stakeholders
- Addressing Colorado River water use and allocations will not be easy to accomplish
- The government and other organizations like CRWUA are giving voices to Indigenous communities
- CRIT is in a position that may pave the way for other Indigenous communities

The following interventions are recommended to Congress, CRIT, and CRWUA for implementation:

- hosting a Colorado River Indian Tribes Gathering to use stories as a tool for decision making
- including story exercises in CRWUA meetings
- non-Indigenous migration out of the Basin is encouraged by federal, state, and local governments
- introducing limitations on water use for agriculture and supporting less consumptive farming practices
- quickly resolving Indigenous water rights
- passing the Colorado River Indian Tribes Water Resiliency Act of 2021

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